RADIO SERVICING COURSE

A Practical Concise Text On The Use
Of Modern Radio Service Instruments
And The Rapid And Systematic
Attacking of Radio Service
Problems

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Determining the location and cause of trouble in a modern radio receiver by means of a portable radio set analyzer. The development of test equipment of this kind, and logical scientific methods of trouble-shoot-

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PREFACE

The main purpose of this book is to place before the many persons who intend to enter the radio servicing profession, as well as those already engaged in it, a means whereby a clearer insight into the theory, construction, operation and use of the electrical meters and test equipment, used in modern practice can be obtained either by home study, or in connection with school courses.

It is intended to serve as a complete, logically arranged course in radio servicing. It is assumed that the student is already familiar with the elementary principles of electricity and magnetism, and possesses some knowledge of the theory, construction, and operation of radio equipment.

Every attempt has been made to increase its usefulness as a text. The topic sections are captioned and numbered for easy reference. Enough carefully selected review questions for self-examination, or the questioning of entire classes, have been included at the end of each chapter. A large number of illustrations have been worked in with the text, not only to help the student to visualize the actions explained, but also to acquaint him with the actual arrangements and appearance of modern commercial test equipment. The advantages of using systematic methods of attacking radio service problems have been stressed throughout, and the exact proceedures to follow have been explained in detail.

Grateful acknowledgement is due the various electrical and radio manufacturers for the kind spirit of cooperation and helpfulness which they have shown in furnishing the descriptions, circuit data and illustrations of their apparatus. The authors are also indebted to the many friends, both in the teaching and radio servicing professions, who have furnished valuable suggestions and criticism from time to time during the preparation of the text. Mr. Edward Buechner, Jr. has also been of great assistance in the preparation of the drawings.

It is in the hope of increasing the popularity of scientific, systematic methods of radio servicing, and in enabling Service Men to better understand these modern methods and the equipment required to put them into effect, that this work has been undertaken.

New York City, January 5, 1932

A. A. G.
B. M. F.

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Chapter 1.

INTRODUCTION

The servicing of modern radio sets is no longer the simple problem which was presented in the servicing of early broadcast receivers. With the advent of all-electric operation, the now very popular superheterodyne, multi-stage radio frequency and band-pass receivers, it became increasingly important that the Service Man possess more than a mere understanding of a few certain elementary principles of receiver operation and testing.

In the early days of broadcasting, receivers were battery-operated; either dry cells or a storage battery being used as a source of filament current, depending upon the type tube that was utilized, and dry "B" battery blocks furnished the plate voltage supply. The average receiver usually employed five similar tubes in a tuned radio frequency circuit, consisting of two stages of tuned radio frequency, a tuned detector and two stages of audio amplification. Power tubes, dynamic speakers and electrically-operated power units were, as yet, comparatively unknown. The ordinary horn-type magnetic loudspeaker unit and the telephone head-set were the only reproducing instruments in common use.

Few tests were necessary to determine the cause of an inoperative receiver. Generally, the tubes were at fault. Either the filament emission became very low or the tube burned out. The former condition could be ascertained by substituting a tube that was known to be good. Battery voltages could be measured by means of a pocket voltmeter, or where the Service Man was more fortunate, with a more accurate and precision-built low-resistance voltmeter. Simple arrangements, such as a lamp in series with some voltage source, a telephone head-set used with a battery, and sometimes a voltmeter connected in series with a battery, were available for testing circuit continuity and for open circuits. By-pass condensers seldom short-circuited, because, only on rare occasions did the plate voltage batteries exceed ninety volts. Any man who could repair an inoperative receiver or point out a defective tube was considered an expert.

As receiver design became more advanced and complicated with the introduction of power tubes and power voltage supply units, the so-called "expert" found the necessity of learning the theory of the operation of these devices, very important. He could not efficiently localize and remedy troubles unless knowledge of the principles involved was at hand. Also, the need for more versatile and accurate measuring instruments became imperative. It was no longer possible to service receivers properly and rapidly with the pocket voltmeter alone. Meters with several voltage ranges were required for checking the different voltages now employed in receivers due to the adoption of the power tube and the B voltage device, commonly called a "B-eliminator" at that time. The multi-range, low resistance voltmeter became almost universally used. Later, this voltmeter was found to be unsatisfactory for really accurate work and more sensitive instruments were developed and used.

Soon after, the radio public demanded receivers that could be tuned without manipulating numerous dials and knobs. This demand created the single dial receiver. Instead of three or more tuning dials, the variable capacitors were ganged together to one shaft, making possible, single-dial tuning with possibly, one auxiliary control. As it was hardly possible in practice to have the tuned stages, each consisting of one section of the gang condenser and the tuning coil with its wiring, absolutely similar to each other, small adjustable compensating condensers were built on to each section of the gang to keep each tuned stage in the R.F. amplifier tuned to exactly the same frequency for any one setting of the dial.

Manufacturers, at about the same time, abandoned the practice of constructing their receivers with all the components or parts mounted bread-board style and completely exposed. With this arrangement, it was but a simple matter to make voltage and continuity tests, for all coils, condensers and resistors, and every connection was easily accessible. The new receivers were constructed with the tube sockets, resistors and most condensers, mounted beneath the chassis. Coils and transformers were placed in metallic shield cans to prevent interstage coupling. Their connecting lugs were also placed beneath the chassis for the advantage of shorter connecting leads, making possible more complete isolation of all circuits. With this change in commercial receiver design, it became necessary to completely remove the entire receiver from the cabinet for every service job which necessitated the making of voltage or continuity tests. This of course was objectionable since it slowed up the service work. To remedy this condition, means were devised whereby these tests and measurements could be made outside of the receiver, without disturbing the mechanical or electrical constants of the receiver under test. This was accomplished by the development of the *radio set analyzer* idea. These instruments and their development will be discussed in detail later.

Upon the appearance of the first A.C. tube electric-operated receivers in 1927 many new problems confronted the Service Man. Not only were circuits more complex and operating voltages more critical, making precision voltage measurements and adjustments more essential, but further knowledge regarding the testing of the new types of tubes, which made their appearance with the new receivers became vitally necessary.

Notwithstanding these facts, there are still some men, who, without the aid of expensive meters and equipment, are capable of seemingly properly servicing and repairing radio receivers. Unless these men were possessed with a thorough mastery of circuit design and modern receiver operation or an extensive and varied practical experience, repairs could not be efficiently made. With the early sets, this was possible because of the relatively few tests necessary to diagnose trouble as compared with the later model receivers. Using these primitive test methods entails the spending of much time on service jobs, but in radio servicing, time must be paid for by the customer. Given enough time, any man with a little knowledge and common sense, can locate and remedy the troubles in a ratio receiver; but it is the amount of time taken to do this work that determines the value of a Service Man to his customer or his employer.

To become a competent Service Man, it is not only essential that radio principles and theories as well as information regarding the characteristics and operating voltages of all types of receiving tubes be mastered, but this knowledge *must be correctly applied*. Without this technical knowledge, no real results can be achieved in the light of modern standards of radio servicing. A Service Man should be familiar with all sorts of testing equipment, especially with his own set analyzer, whose readings he should be capable of interpreting intelligently and rapidly. The most successful Service Man is the one who keeps abreast with all the new developments in the art. Suppose "X" manufacturer releases a new receiver. Every effort should be made at once to secure every bit of service data possible, for future reference. The schematic diagram should be studied carefully. It is rather interesting to note the amount of information that can be derived from a close examination of such a diagram by a man who is trained in the elementary principles of radio. Does the circuit show any departure from previous designs of the manufacturer' receivers? In what respects does this circuit differ, if any, from the ordinary T.R.F. or superheterodyne receiver? What type detection is used? Inquiries into questions of like nature will prove invaluable when this type of receiver needs to be serviced at some future date. Usually the service call will be of the "hurry up" type with little time allowed the Service Man for hunting up diagrams and data on the receiver.

Even after the technical requisites have been mastered, it takes a certain amount of practical experience to really qualify as a first grade Service Man. Naturally, the more experience an individual possesses, the more capable and confident he is. After all, the diagnosing of a radio receiver is only a process of elimination. Certain troubles may be caused by any one of several defects. Checking each of the questionable circuits or components, in turn, will usually disclose the cause of an inoperative receiver. In commercial receivers, certain makes and models have definite points where the first weakness is most liable to appear; and the Service Man who knows these tendencies can do the quickest and best job. This knowledge is gained through repeated failures of the same unit and calls for servicing the same type of receiver. Knowing beforehand the symptoms or effects of this failure upon the receiver, enables quick analysis and repairs to be made and greatly increases the prestige of the Service Man in the eyes of his customer and employer.

The radio receiver of today with its extremely high sensitivity can in no way be compared with the old broadcast set. Specially designed circuits employing tubes of high amplification factor, and others capable of supplying maximum undistorted power output, make this possible. The wide-spread use of the superheterodyne has made important the problem of aligning many tuned circuits for maximum efficiency. To most effectively accomplish this purpose, oscillators generating pre-determined frequencies must be used. The design of oscillators and their construction and operation are matters that the Service Man will find of endless value in properly aligning and balancing modern radio broadcast receivers.

In presenting this volume, the chief purpose in mind was to place before the Service Man, a means whereby a clearer insight into the construction, operation, and use of modern service instruments, and the more intelligent and systematized attacking of service problems, could be obtained—either by study at home, or in connection with a school course in radio servicing. An attempt has been made to present the subject in as simple language, and in as interesting a manner as possible. The course has been so planned that the reader will advance step by step from a study of the very simple and crude testing equipment and methods, to the more refined apparatus and procedures which have made modern radio servicing a profession fully qualified to rank with the highest of the skilled arts.

CHAPTER 2.

ELECTRICAL MEASURING INSTRUMENTS

ELECTRICAL MEASURING INSTRUMENTS — MAGNETIC FIELD AROUND A CONDUCTOR — THE WESTON MOVEMENT — D.C. AMMETERS AND SHUNTS — EXTENDING RANGES OF D.C. MILLIAMMETERS AND AMMETERS — THE D.C. VOLTMETER — THE HIGH RESISTANCE VOLTMETER — INCREASING D.C. VOLTMETER RANGES — MEASUREMENT OF RESISTANCE — THE OHMMETER — MAKING AN OHMMETER — USE OF THE OHMMETER — MOVABLE IRON TYPE A.C. INSTRUMENTS — RECTIFIER TYPE A.C. INSTRUMENTS — THE OUTPUT METER.

1. Electrical measuring instruments: Since we are unable to see, hear, feel, taste or smell an electric current, we must employ instruments for its detection and measurement. These *electrical measuring instruments* are especially useful in the servicing of radio equipment, since they enable us to test the various circuits and parts in order to quickly obtain all the information needed for locating and correcting the trouble. The two simple instruments used most extensively in radio servicing are the *milliammeter* and *voltmeter*. In order to fully understand the operation and the application of these meters to various tests, it will be necessary to review briefly a few of the fundamental principles of electricity and magnetism upon which their operation depends.

2. Magnetic field around a conductor: The first well known electrical principle is that whenever a current of electricity flows through a conductor, such as a piece of wire, it always produces a magnetic force or field around the conductor, as shown at (B) of Fig. 1. This may be proven by connecting a short piece of wire across the terminals of a storage battery and dipping the wire into some iron filings. The filings will be attracted to the wire as shown at (A), just as long as the current is allowed to flow, showing that a magnetic field is

created around the wire by the flow of current. Furthermore the strength of the field produced is proportional to the strength of the current flowing. This may be proved by send-

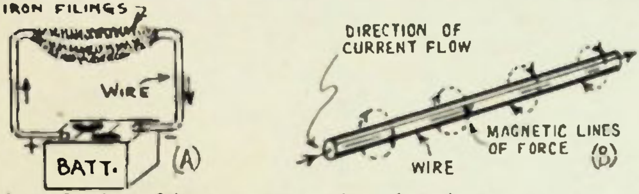


Fig. 1—(A) Iron filings are attracted to the wire by the magnetic field produced around it due to the flow of current through it.
(B) The magnetic field around the current-carrying wire is circular in shape as represented by the dotted circles. These are called "magnetic whirls."

ing currents of various strengths through the wire and noticing how many iron filings are attracted in each case.

If the conductor is formed into a single-turn loop as shown at (A) of Fig. 2, all the circular magnetic lines of force which suround the wire will pass through the center of the loop, as shown. The magnetic field within the loop is more *dense* than on the outside, since all the lines of force are con-

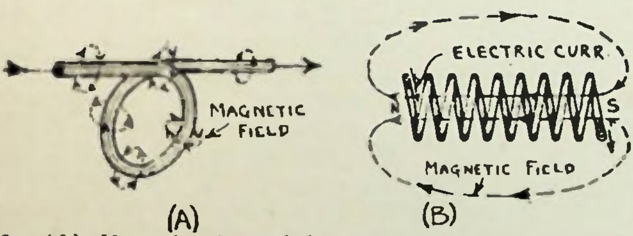


Fig. 2—(A) How the lines of force arrange themselves around a single-turn loop of wire carrying a current.
(B) If the coil is wound with many turns of wire, the magnetic field is strengthened, a magnetic pole is produced at each end, and the lines of force take the paths shown by the dotted lines.

centrated into a smaller area here than on the outside where they spread out. However, the *total number* of lines of force is the same inside of the loop as it is outside.

By winding a number of these loops or turns of wire together as shown at (B), a solenoid or coil is formed, which will have a *north* magnetic pole at one end and a *south* magnetic pole at the other end, as shown at (B). The magnetic fields or forces surrounding the individual turns of wire unite to form a resultant magnetic field or force around the entire coil as shown by the curved dotted lines.

If, such a current-carrying coil is mounted on pivots and placed between the poles of a permanent magnet as shown at

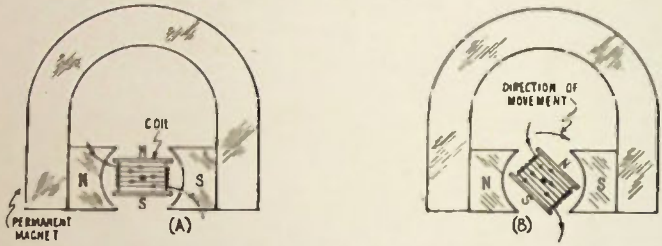


Fig. 3—(A) Arrangement of all of the magnetic poles when a current-carrying-coil of wire is placed between the poles of a permanent horseshoe magnet.
(B) How the coil would tend to rotate due to the mutual attraction and repulsion of the magnetic poles. This is the basic principle upon which most D.C. meters operate.

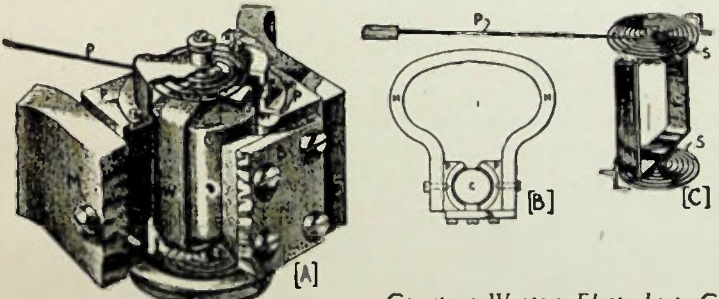
(A) of Fig. 3, the current flowing through it will produce magnetic poles at its two ends, as shown. The N pole of the coil will be attracted by the S pole, and repelled by the N pole, of the permanent magnet. Likewise, the S pole of the coil will be attracted by the N and repelled by the S pole of the permanent magnet. This will cause the coil to rotate or deflect clockwise in the direction of the arrow, taking a position as shown at (B). Furthermore, the deflecting force will be dependent upon the strength of the poles of the coil, which in turn will depend on the strength of the current flowing through the coil. Therefore, an arrangement of this kind, can be used for measuring the strength of electric current. About fifty years ago, the so called *Weston movement* so widely used in direct current measuring instruments today, was developed from this basic principle by Dr. Weston.

3. The Weston movement: The Weston d-c meter movement is constructed essentially along the basic lines represented in Fig. 3, but has many constructional refinements which make it rugged, accurate, and sensitive. An open section of a

meter movement of this type is shown at (A) of Fig. 4, and a description of it follows:

M-M are the poles of a very strong permanent horseshoe magnet with soft iron pole pieces P-P between which is mounted the circular soft iron core C to increase the strength of the magnetic field and make it radial. This is shown at (B). Mounted in the air gap between the core C and pole pieces P-P is the movable coil W consisting of a very light rectangular aluminum form on which are wound many turns of very fine insulated copper wire, through which the electric current (or a definite fraction of the current) to be measured, flows. This current produces magnetic poles which cause a movement of the coil as described in Art. 2, the amount of movement being proportional to the strength of the current flowing through the coil. The coil is provided with steel pivots which rest in jewel bearings, so it may turn freely. The current is conveyed to and from the coil through the light spiral hair-springs which perform the additional function of always returning the coil to a definite *zero position*. A pointer is attached to the moving coil to enable its position to be read accurately from a suitably calibrated scale. The assembly of coil and form L, springs S, and pointer P are shown at (C). The number of milliamperes of current which must be sent through the coil to deflect it across the "full scale" is a measure of the *sensitivity* of the meter movement. A very sensitive meter movement requires only a few milliamperes (1 milliampere = .001 ampere), to do this. A simple d.c. milliammeter employing the Weston movement is shown in Fig. 5.

4. **D.C. Ammeters and shunts:** Since the wire wound on the movable coil must be very fine and light, it is evident



Courtesy Weston Elect. Inst. Corp.

Fig. 4—Assembled Weston D.C. meter movement. A portion of the permanent horseshoe magnet has been cut away at the left to reveal the interior. (See Fig. 5.)
(B) The permanent magnet, core, and pole pieces assembled.
(C) The movable coil, pointer, springs and pivots assembled.

that this coil cannot carry much current without undue heating and consequent burning out of the wire. If the movable element of this form of meter is connected directly in the circuit, it must carry the full circuit current. However, the moving coil is rarely allowed to carry more than about .05 ampere. Thus it may be seen that if the meter is to be connected into circuits carrying more current than this, either the size of the wire on the coil must be increased proportionally to take care of the larger current, or else only a definite fraction of the total current of the circuit must be allowed to go through the coil.

Fig. 5—A modern D.C. galvanometer or milliammeter built in portable form. This employs the Weston movement shown in detail in Fig. 4. This particular instrument is mounted on a type of portable mounting base, which is very convenient in laboratory work.

Courtesy Weston Elect. Inst. Corp.

The former method is impractical, for it would result in a clumsy, heavy coil attendant with numerous construction difficulties. The latter method is the one used to extend the fundamental range of the movement. The current is divided so that only a certain definite part of it flows through the movable coil and the rest is "shunted" around the coil by means of a low resistance or "shunt" connected across it. The action of the meter with the shunt may be explained as follows:

At (A) of Fig. 6, the only path for the current is through the moving coil of the instrument. If the current to be measured is greater than the wire of the moving coil can safely carry, part of the current can be shunted through the parallel shunt resistor R_s as shown at (B). If the resistance R_s is equal to the resistance R_m of the moving coil of the meter, then, just half of the total current will go through the shunt and half through the meter coil. In this case, we simply multiply any reading of the instrument by 2 to determine the total current. If we carry this further and add another similar shunt as at (C) the instrument reading will represent 1/3 of the total current. We might continue this indefinitely, adding any number of equal shunt resistors in parallel and making the current actually flowing through the meter coil less and less. When this type of current measuring instrument is used to measure "milliamperes" the meter is called a *milliammeter*. The milliammeter can be made to read "amperes" by the use of suitable shunts, and is then called an *ammeter*. It must be remembered that a milliammeter or an ammeter must always be connected in SERIES with any circuit, and never *across* the circuit, for since it has a very low resistance, the heavy flow of current which would flow through it would burn it out.

5. Extending ranges of d.c. ammeters and milliammeters: The range of any given d.c. milliammeter, may be increased by connecting an additional shunt resistor across the terminals of the meter. Suppose that the meter on hand has a range of 1 milliampere and that a range of 10 M.A. is needed. Then a shunt must be connected across it. This must be of such value that the moving coil of the meter will carry 1/10 of the total current and the shunt 9/10. This means that the shunt resistance must be 1/9 of the total meter resistance. If the meter resistance is 27 ohms, the shunt resistance required to make a 0-10 milliammeter of it would be $1/9 \times 27 = 3$ ohms.

In this way any milliammeter can be made to serve the function of several meters by using two or three or even four shunt resistors to increase the range of the current capacity. A number of shunts may be connected across the meter and controlled by a contact switch or switches so that any one of

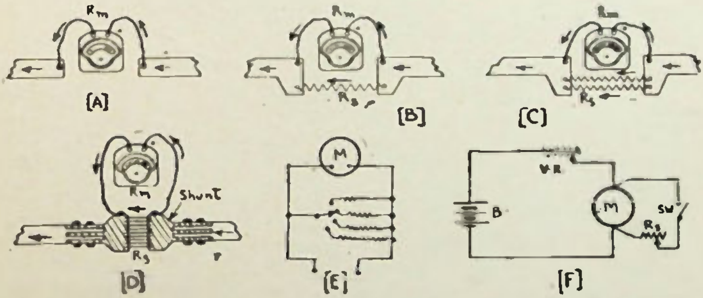


Fig. 6—How shunts are connected in *parallel* with the meter movement to carry a definite fraction of the total current in a circuit, permitting the use of an ordinary milliammeter movement as an ammeter to measure large currents.

them may be put into the circuit at a time. This arrangement is shown at (E) of Fig. 6. The usual procedure when extending the range of a milliammeter is to increase it in multiples of 5 or 10, making selection of the resistances simpler.

It is evident that in order to arrive at the value of the shunt resistance, the exact value of the internal resistance of the meter must be known. Below will be found the approximate resistance values of the model 301 Weston microammeters and milliammeters, and corresponding Jewel meters, used extensively in radio test and service work.

TABLE OF COMMON MILLIAMMETER CHARACTERISTICS

Weston (Model 301) Meters			Corresp. Jewell Meters	
Range Micro-Amp.	Resistance Ohms	Number of Divisions on Scale	Resistance Ohms	Number of Divisions on Scale
200	55	40	140	40
300	—	—	140	60
500	55	50	140	50
Milli-Amp.				
1.	27	50	30	50
1.5	18	75	30	75
2.	18	40	25	40
3.	18	60	20	60
5.	12	50	12	50
10.	8.5	50	7	50
15.	3.2	75	5	75
20.	1.5	40	—	—
25.	1.2	50	3	50
30.	1.2	60	—	—
50.	2.0	50	1.5	50
100.	1.0	50	.75	50
150.	.66	75	.5	75
200.	.5	40	.37	40
250.	.4	50	—	—
300.	.33	60	.25	60
500.	.2	50	.15	50
800.	.125	40		
1000.	.1	50		

However, if the meter resistance is not accurately known, the exact value of the shunt resistance required may be found in another way as shown at (F) of Fig. 6.

Suppose we desire to calibrate a 10 milliampere meter so that it may be used to read currents up to 50 milliamperes. The procedure would be to connect a battery B. in series with the variable resistance V.R. so as to limit the current passing through the meter, (without a shunt), to 10 milliamperes. The resistance should be varied until the meter reads exactly 10 milliamperes and then a rheostat R_s (the shunt) should be switched across the meter and its resistance altered until the meter reads 2 milliamperes. Under such conditions (with the shunt connected)), a reading of 2 milliamperes on the meter would mean that 10 milliamperes were actually flowing through the main circuit. Likewise, full-scale deflection would indicate a 50 milliampere flow, although the needle pointed only to the 10 milliampere division on the scale.

Another method is often used in practice to make an accurate shunt of some odd resistance value not obtainable commercially. Assume we have a 1 milliampere meter whose range we wish to extend to 25 mills. The meter is connected to a single dry cell B (about 1.5 volts) with a variable wire-wound rheostat V.R. in series (about 2000 ohms maximum value in this case) as shown at (F) of Fig. 6. The current is adjusted by means of the rheostat until it is as near 0.95 mills (almost full scale deflection) as possible. The exact reading is noted; let us say it is 0.94 mills. Then a piece of good grade of low-resistance wire R_s which is to be used as the shunt, is connected *directly across* the meter terminals. The proper length of shunt wire must be connected across it to reduce the meter reading to exactly 0.94/25 or 0.037 milliampere. The shunt wire may be filed or scraped carefully to bring the meter reading up to this exact value. This is the proper shunt value then for extending the meter range from 1 M.A. to 25 M.A. (25 times its original value). Readings on the old 1 M.A. scale must be multiplied by 25 to obtain the correct current value when this shunt is used. Additional shunts may be made up in this way to extend the meter range up to any desired values.

When the internal resistance of the meter is known, it is possible to calculate the resistance of the shunt needed to extend the range of the instrument. The formula is $R_s = r/N-1$, where R_s is the unknown resistance of the shunt required; r is the internal resistance of the meter; N is the number indicating the desired new maximum reading.

Resistors used as meter shunts (or as series multipliers for voltmeters) should be of a size capable of carrying the current without undue heating. They must be of a wattage rating sufficient to insure cool operation and must have a very low temperature coefficient, so that the resistance does not change appreciably with change of temperature. They are usually wound with wire such as Manganin, Chromel, or Nichrome, and must be accurate in value. Precision type resistors manufactured especially for this purpose are available.

6. The D.C. voltmeter: A voltmeter is used to measure the *electric pressure* or *voltage* between two points in an electric circuit. It is the *voltage* which makes an electric current flow in a conductor. The measurement of voltage with a voltmeter

is based on the principle that if the resistance of a circuit is *constant*, the amount of current which will flow is proportional to the voltage that is applied to the circuit. If the voltage is doubled, the current is doubled; if the voltage is tripled, the current is also tripled, etc. (This applies strictly to a D.C. circuit only.) Therefore if a *current measuring* instrument is connected *across* a source of voltage, and the resistance of this instrument is of a constant value, then the current sent through it by the voltage will be directly proportional to the voltage across which the instrument is connected, i.e., $I=E/R$. Consequently we can calibrate any given current measuring instrument to read directly the volts applied to its terminals, instead of the *current* flowing through it. This is precisely what is done with a voltmeter.

A voltmeter really consists fundamentally of an ordinary milliammeter movement such as shown in Fig. 4. In order to prevent a heavy current from flowing through it and burning out the delicate low-resistance movable coil when it is connected *across* the voltage to be measured, a high resistance is permanently connected in *series* with the moving coil to limit the current to a safe value. This arrangement is shown at (A) of Fig. 7. Since the resistance of the entire instrument is constant, the current flowing through it—and the deflection of the pointer—will be directly proportional to the voltage applied to its terminals, so the scale of the meter may be calibrated directly to read this voltage. The instrument is then a *voltmeter*. It is evident therefore, that a voltmeter is really an ordinary milliammeter with a resistance of proper value in series with it, and having its scale graduated in volts instead of amperes. The method of calculating the exact resistance which must be connected in series with a D.C. milliammeter of given range to make a D.C. voltmeter of given range from it, may be understood from the following typical example.

Let us assume that we have a milliammeter with a moving coil whose resistance is 30 ohms and full scale deflection is 1 milliampere. It is desired to make a voltmeter having a range of 100 volts, from this. Then enough resistance R must be connected in series with the movable coil, as shown at (A) of Fig. 7, so that when the voltage applied across the terminals of the meter is 100, exactly 1 milliampere will flow through the resistor and coil, and the pointer will be deflected to the end of the scale, now marked in volts, up to 100. By Ohm's law, R=E/I, it is possible to determine the value of the *total* resistance which the meter must have.

In this case R would be 100/.001 or 100,000 ohms. The meter resistance can be disregarded in this case for 30 ohms would make but

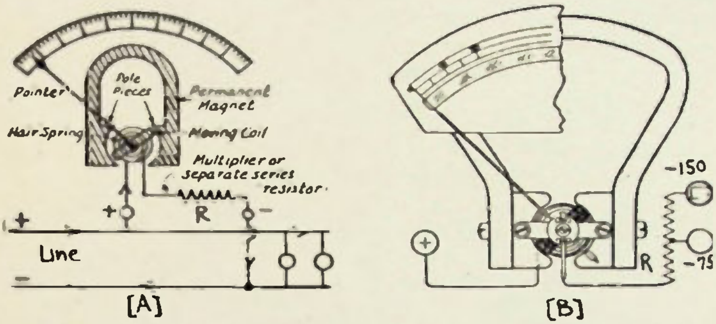


Fig. 7—(A) The general arrangement of a D.C. voltmeter. In addition to the moving coil assembly, there is a resistor connected in series with the coil. This "multiplier resistor" determines the range of the meter.
(B) Here a tapped multiplier resistor is used to make a voltmeter having two ranges—75 volts and 150 volts.

slight difference in the accuracy of the voltage reading. Only in cases where extreme precision is necessary and where the voltage to be measured is small, need the resistance of the moving coil be considered.

Voltmeters are usually rated according to their voltage range and their sensitivity expressed as the "resistance-per-volt." In the 100 volt meter considered above, the meter would be rated at 1,000 ohms per volt, for its total resistance is 100,000 ohms and range is 100 volts. It is common to construct voltmeters with more than one voltage range. This may be done by simply tapping the series resistor at suitable points for the low voltage ranges as shown at (B) of Fig. 7. In this, the series resistor is tapped at its center, providing ranges of 75 and 150 volts. Another way is to provide separate series multiplier resistors for each range, as shown in Fig. 10A.

7. The high resistance voltmeter: Since the function of a voltmeter is to measure the voltage existing across a given circuit, it should not influence in any way the circuit across which

the voltage exists. However, the voltmeter will take some current from the circuit across which it is connected. Thus it can be seen that the amount of current necessary to actuate the meter is important if a true indication of the actual voltage is to be obtained. Some ordinary voltmeters employ for their basic movement, a 10 mil. movement. When such a meter is used

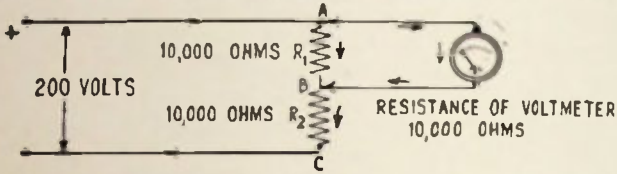


Fig. 8—Effect of connecting a low-resistance voltmeter across a high resistance device in order to measure the voltage. The voltmeter draws so much current from the circuit that it alters the voltage, and so gives a false reading. A high-resistance voltmeter should be used instead.

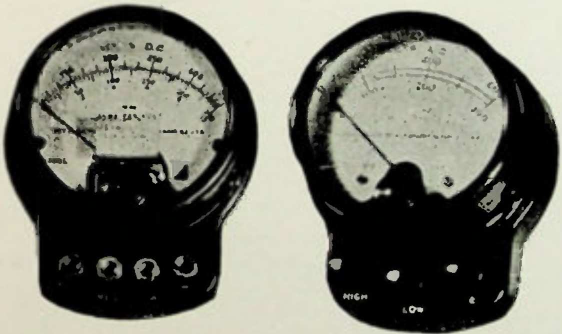
to measure the output voltage across a B battery eliminator or some other such circuit, it is quite evident that the meter will not be reading the true voltage of the circuit, since it is drawing so much current from the circuit that the voltage drops when it is connected.

As shown in Fig. 8, assume we have a potential of 200 volts and resistors R_1 and R_2 are 10,000 ohms. Calculation will show that the voltage across either R_1 or R_2 is 100 volts, when the meter is not connected. An ordinary ten mil meter calibrated to 100 volts will have a resistance of 10,000 ohms. When this voltmeter is connected across R_1 then the combined resistance between points A and B is only 5,000 ohms. The current flowing through the circuit before was 10 mills, but now since the effective resistance across the 200 volt source is 15,000 ohms, the current flow will be 13.3 mills. The voltage drop from A to B will now be $E = I \times R = .0133 \times 56000 = 66.5$ volts. The voltage indicated on the meter will be 66.5 volts, making an error of 33.5 volts in every hundred that is measured. A discrepancy as large as this cannot be tolerated for practical purposes where voltages must be measured accurately.

Since a voltmeter having a high resistance takes very little current from the line, the meter itself must be very sensitive, that is, it must require very little current to move its coil and pointer over full scale deflection. This means that either the permanent magnet must be stronger than in the usual meter or else more turns of wire must be wound on the moving coil to obtain the same ampere-turn effect at a smaller value of amperes. The latter method is usually used in the construction of high resistance voltmeters used in radio work. The moving coil has several layers of exceedingly thin copper wire in order to produce the necessary magnetic field strength. Such meters have a resistance as high as 1000 ohms per volt. The term *ohms-per-volt* may be understood by considering the specific case of a 1000 ohms-per-volt meter having three ranges, 7.5, 150, and 750 volts. Then the resistance in series with the 7.5 volt terminal is 7.5 × 1000 or 7,500 ohms; that in series with the 150 volt terminal is 150 × 1000 = 150,000 ohms; that in series with the 750 volt terminal is 750 × 1000 = 750,000 ohms.

The "ohms-per-volt" value is equal to the total resistance R_t of the meter divided by the *maximum voltage* E_t *marked upon the scale considered*. This is so, regardless of the voltage that will be applied.

Voltmeters so sensitive that they have a resistance of 1,000 ohms per volt are used extensively for voltage measurements in radio receivers and power packs. A 3-scale voltmeter for this purpose is shown at the left of Fig. 9. Voltmeters having an



Courtesy Weston Elect. Inst. Corp.

Fig. 9—*Left*: A popular type of 3-range D.C. high-resistance voltmeter having a resistance of 1000 ohms-per-volt. This is very useful for general radio testing.
Right: A 2-range A.C. voltmeter which is also very useful for general testing work.

ohms-per-volt value as low as 100 are used in ordinary electrical work, since the few milliamperes of current taken by the meter, is not objectionable here. It should be remembered that it is not possible to make a high resistance voltmeter of the same range from an ordinary low resistance voltmeter simply by connecting a resistance in series with it, for this would reduce the current through the meter and reduce the deflection of the needle. The high resistance voltmeter movement must be built especially sensitive for the purpose.

8. Increasing D.C. voltmeter ranges: The range of any voltmeter may be increased to any practical limit by inserting a "multiplier" resistance in series with the voltmeter. The customary method of increasing the range of a D.C. voltmeter is to connect a high resistance in series with it.

Let Rv = the resistance of a voltmeter in ohms, or, if ohms per volt is given, then

Rv = ohms-per-volt × maximum reading, in volts.

V_1 = original maximum reading in volts

V_2 = desired new maximum reading in volts then

then $\frac{V_2}{V_1} = N$, which is the multiplying factor.

R_m = the resistance of the multiplier to be connected in series with the meter, in ohms.

Then $R_m = (N - 1) \times Rv$.

The ratio

$\frac{V_2}{V_1} = N$ "is then the multiplying factor" by which any reading of the low voltmeter scale is to be multiplied in order to determine the true voltage of the circuit.

Problem: Suppose the range of a voltmeter is 150 volts and the resistance is 150,000 ohms. The range is to be increased to 750 volts.

Solution: Then $N = \frac{750}{150} = 5$ which is the multiplying factor.

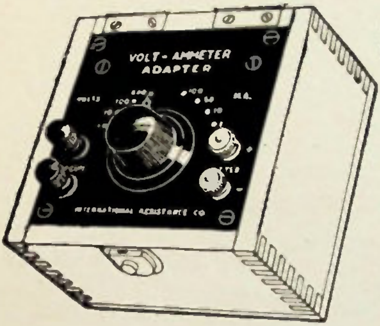
and since $R_m = (N - 1) \times Rv$

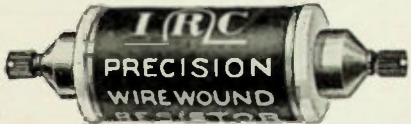
Then R_m $(5 - 1) \times 150{,}000 = 600{,}000$ ohms which is the value of the necessary multiplier.

Each reading taken on the voltmeter according to the old scale, must then be multiplied by 5 to obtain the true voltage reading when the multiplier is used.

It is common to build voltmeters so they have more than one range. This is done in one of two ways. The series resistor may be tapped at suitable points as shown at (B) of Fig. 7, or separate resistors connected to the common terminal of the meter movement may be employed, as shown in Fig. 10A. With the latter arrangement any one can be placed in series with the voltmeter or milliammeter to extend the voltage range, and if one resistor should become open, it will not affect the operation of the meter on the other ranges.

The resistances used as multipliers for a voltmeter, or to convert a milliammeter into a voltmeter should be of the precision type and permanent in value. A type of resistor made especially for this purpose is shown in Fig. 10. It is possible





Courtesy International Resistor Co.

Fig. 10—*Left*: A multiplier and shunt box which enables one to make either a 4-range milliammeter or a 4-range voltmeter from a single low-reading milliammeter.
Right: A typical precision type wire-wound multiplier resistor for increasing the ranges of voltmeters, or making voltmeters of any desired ranges from milliammeters.

to secure resistors of a high degree of accuracy, having a tolerance of 1 per cent plus or minus. These perfected wire-wound resistors make it simple to convert meters into multi-range instruments with every assurance of precision. At the left of Fig. 10 is shown a combined shunt and multiplier box having adjustable resistors which enable one to make either a milliammeter having 4 current ranges, or a voltmeter having 4 voltage ranges, from a single low reading milliammeter. Using a 0-1 milliampere meter of the type shown in Fig. 5 with the proper resistors and switches, one of these multi range instruments may easily be constructed.

8A. Making a combination volt-ammeter: It is evident that the construction of the *meter movement* for a D.C. ammeter is exactly the same as that of a D.C. milliammeter or a voltmeter. The difference between these instruments lies simply in the fact, that in the ammeter, *low resistors* are connected in *shunt* or *parallel* with the meter movement; while in the voltmeter, *high-resistances* are connected in *series* with it. By using a proper terminal and switching arrangement, it is possible to make a very useful combination instrument which may be used either as a multi-range milliammeter, ammeter, or

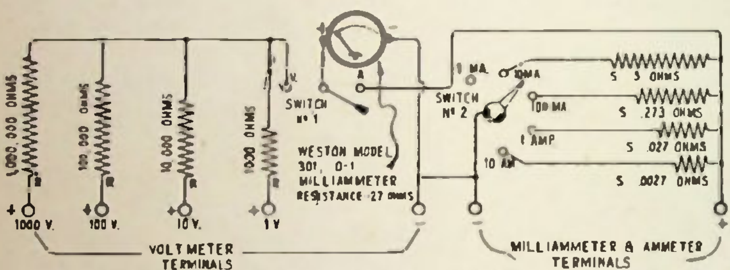


Fig. 10A—The complete connections and resistor values for making a 3-range milliammeter, 2-range ammeter and 4-range voltmeter from a single 0-1 D.C. milliammeter.

voltmeter. An ordinary 0-1 D.C. milliammeter is used for the movement. The arrangement and values of all resistors required if a Weston Model 301 D.C. 0-1 milliammeter (resistance=27 ohms), is employed, is shown in Fig. 10A. (The same arrangement, with resistors of suitable value may be used if some other make of instrument is employed.)

The reader should study the arrangement of Fig. 10A carefully. It will be seen that the resistors R are in *series* with the meter movement, and therefore make a voltmeter out of it. Resistors S are in *shunt* with it, and therefore convert it into a high range milliammeter or ammeter. Of course, these ranges may be extended, or different desired ranges may be obtained, by using resistors of different values, calculated by the methods discussed in Articles 5 and 8. Switch No. 1 is for converting the instrument into either a voltmeter or an ammeter. Switch No. 2 enables the desired shunt resistance to be selected for whatever milliammeter or ammeter range may be required.

An instrument of this kind is very useful in radio service work, since one instrument is made to do the work of several meters. As we shall see later, meters of this kind, having suitable ranges, are commonly employed in radio set analyzers.

9. **Measurement of resistance:** One of the simplest and most common methods of measuring the electrical resistance of parts used in radio equipment, is by the use of a D.C. milliammeter and a voltmeter connected to a source of steady e.m.f., such as a 4½ volt battery as shown at (A) of Fig. 11. The method consists in measuring the drop in voltage produced across the device due to this resistance, when the measured current flows through it.

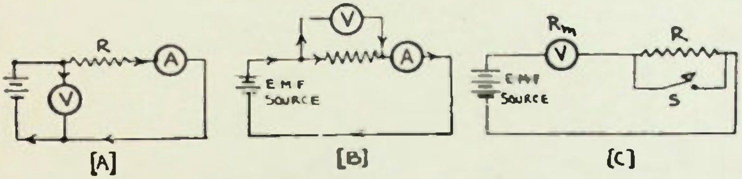


Fig. 11—(A) and (B): Methods of measuring resistance with an ammeter and voltmeter.
(C) Measuring high resistances with a voltmeter of known resistance.

When measuring very high resistance by this method the current will be small and the voltmeter should always be connected across both the resistor and the milliammeter as shown at (A). If it is connected simply across the resistor only, as shown at (B), the milliammeter which must be employed to measure the current indicates the sum of the current through the resistor plus that through the voltmeter. Since the current through the resistor is small under these conditions, the voltmeter current may be almost as great as it is, (unless a high resistance voltmeter is used) and adding this together in the milliammeter reading causes an appreciable error. It is true that at (A) the voltmeter measures the sum of the voltage drops across both the resistor and the milliammeter, but since the resistance of the average milliammeter is only from 20 to 50 ohms, adding this to the high resistance to be measured, results in only a small error.

For low resistances, the connection of (B) should be employed, for in this case the current through the resistance will be comparatively large and adding the few milliamperes of voltmeter current to the ammeter reading, does not cause much error. An *ammeter* should be used to measure the current in this case, since it will be too large for a milliammeter.

Another simple method of measuring resistances is by means of a voltmeter alone (whose exact resistance is known) as shown at (C). The procedure is to measure a D.C. supply voltage first with the voltmeter, by closing the short circuiting switch (S) which short circuits the resistance to be measured. Then the switch (S) is opened, this putting the unknown resistor (R) in series with the voltmeter, and the reading of the meter is noted again. With these readings the value of the unknown resistor may be obtained from the formula.

$$R = \frac{E_L - E_d}{E_d} \times R_m$$

Where R=unknown resistance in ohms

E_L=the voltage indicated by the meter when switch S is closed

E_d=the reading of the voltmeter when switch S is open and R is in series with the voltmeter

R_m=the known resistance of the voltmeter in ohms. (equal to the ohms-per-volt value × meter range used).

Example: Assume we have a 5-volt meter having a resistance of 1,000 ohms-per-volt, to be used to measure the value of an unknown high resistor. The total resistance of the *meter* when using the 5 volt scale is then 5000 ohms. The d.c. source is 3 volts. Thus when the meter is connected across the battery to obtain E_L the voltage is found to be 3 volts. The unknown resistor is then connected in series with the meter and the meter reads 1 volt. Then the unknown resistor is $R = \frac{3-1}{1} \times 5{,}000 =$ 10,000 ohms *Ans.*

Therefore, the only data needed to measure high resistances by this method is the resistance of the voltmeter. This information may be marked on the meter, or, if not, it can be obtained from the manufacturer. This method is not adapted to measuring very low resistances, for in this case, the readings of the meter would be practically the same for both connections.

10. The ohmmeter: The ohmmeter is an instrument which indicates the resistance of a circuit or device directly in ohms, without need for any calculations. Ohmmeters are used extensively in radio service work, an ohmmeter being contained in almost every commercial set analyzer. The principle of the ohmmeter is best understood by referring to (A) of Fig. 12. A dry cell E sends current through the adjustable zero adjusting resistor B and a milliammeter, the scale of which is marked directly in *ohms*. If the unknown resistor is connected directly across the terminals of the instrument the meter deflection will be proportional to the current and since the applied voltage is constant, the current depends on the value of the unknown

resistance. The scale of the instrument may therefore be calibrated directly in *ohms*. As the dry cell voltage diminishes with age, the setting of resistance B must be adjusted so that when the ohmmeter terminals are short-circuited, the meter will read full scale—or *zero ohms*. Many commercial types of ohmmeters are on the market, obtainable in different forms and ranges. Two of them are shown in Fig. 13.

11. Making an ohmmeter: The construction and calibration of an ohmmeter is simple and need not present any dif-

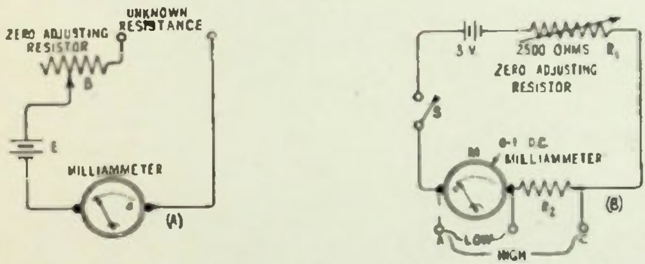


Fig. 12—(A) Elementary circuit of a simple ohmmeter having one range. (B) A 2-range ohmmeter built with a 0-1 D.C. milliammeter and resistors. This will measure resistances from 0 to 100,000 ohms, in 2 ranges.

ficulties to the average experimenter or Service Man. The instrument used should be preferably a common D.C. milliammeter with a full scale range of 1-milliampere, though a 2, 5 or 10 milliampere meter may be used, in which case the ohmmeter range will be different. The advantage of using a D.C. 1-M.A. meter is due to the fact that the drain on the dry cell battery is very low, namely, 1 mil, and the battery will retain its full voltage for a long period. The Weston 0-1 milliammeter, for instance, has 50 divisions on its scale, and it can be read accurately to about .004 milliampere.

A very useful ohmmeter can be constructed from a 1 milliampere meter M as shown at (B) of Fig. 12. It will measure resistances from about ½ ohm to 100,000 ohms, in two ranges. This meter never consumes more current than 1 mil. Therefore inexpensive resistors of low wattage rating may be employed for R_1 and R_2, also the dry cell flashlight battery will maintain its full voltage for a long time. A description of this meter follows:

R_1 is an ordinary wire-wound variable resistance with a total resistance of about 2,500 ohms, and R_2 is an accurate resistance of 2,000 ohms. (accurate to at least 1 per cent). The switch S is closed when the ohmmeter is put into use, and open at all other times to prevent the unnecessary current drain from the battery. The meter used in this case must be a 0-1 milliammeter. The three terminals shown, are used to measure low and high resistance. Suppose a low resistance is connected across "LOW." In this position the meter is being shunted, and two paths are provided for the current which varies inversely with the resistance of the parallel branches. The presence of the unknown resistance produces such a parallel branch and will reduce the current indication upon the milliammeter. Here resistor R_1 has no other purpose than to enable adjustment of the meter so that full scale deflection will be secured. It is made variable so that it can be adjusted to compensate for decrease in voltage of the battery due to age. By this means, the initial calibration of the ohmmeter is maintained even though the battery becomes old. The adjustment is made by short-circuiting the terminals of the ohmmeter with a very short piece of wire, and adjusting resistor R_1 until the pointer on the meter indicates zero resistance.

The ohmmeter may be initially calibrated in ohms by actually noticing the needle deflection when several resistors of known value are measured. If such resistors are not available, the resistance values corresponding to various meter readings may be calculated by means of the formula

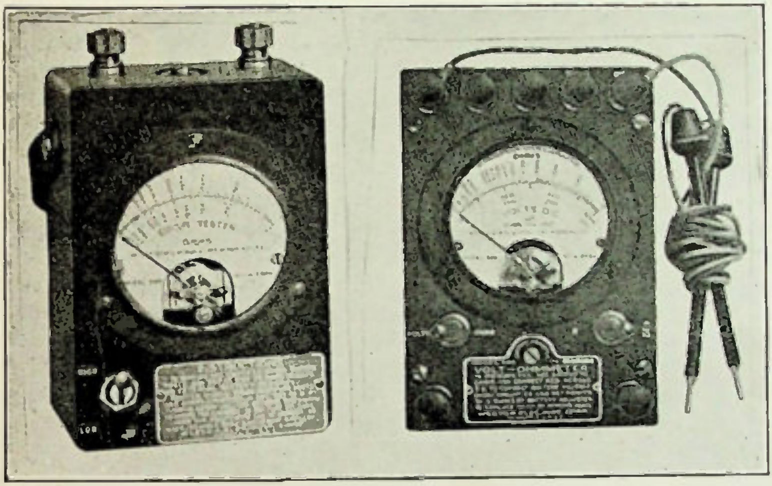
$$R_x = \frac{R_m}{\frac{M}{m} - 1}$$

Where R_x = the unknown resistance;
R_m = the resistance of the meter (see table in Art. 5);
M = the full scale range of the meter;
m = the meter reading when R_x is connected to the meter terminals "LOW".

To illustrate this point, suppose this meter has a resistance of 30 ohms and the reading of the meter when R_x is connected is .5 milliampere. Then the value of the unknown resistance R_x will be 30 ohms.

However, when a high resistance is to be measured and is shunted across terminals A — C, the value of R_2 must be considered and must be added to the resistance of the meter when solving for the unknown value by means of the formula above. Should the meter read .2 mil when the resistance is placed across terminals A — C then the value of the unknown will be 757½ ohms. Using this formula, the resistance for each scale deflection can be determined for either the low or high range of the ohmmeter. Two separate sets of calibrations will be necessary and can be marked directly to the face of the meter in line with each scale division if possible.

12. Use of the ohmmeter: The ohmmeter is one of the most necessary and useful parts of any Radio Service Man's equipment. It can be used for continuity to test whether coil



Courtesy Weston Elect. Inst. Corp.

Fig. 13—*Left*: A commercial type of ohmmeter used extensively for testing coils, resistors, circuits, etc. It has ranges of 0-5,000 and 0-50,000 ohms, which may be selected by the switch at the lower left. The single dry cell is contained inside the case. *Right*: A volt-ohmmeter having voltmeter ranges of 3, 30, 300 and 600 volts, and ohmmeter ranges of 0-10,000 and 0-100,000 ohms. The test prods provided with the meter are shown at the right.

windings, circuits, resistors, or condensors are short-circuited or open, as well as for rapid resistance measurement. The ohmmeter just described is so sensitive, that the resistance of r.f. coils, dynamic speaker voice coils, power transformer primaries, etc., can be measured to ascertain whether these units are shorted or even partially shorted. It is recommended for all Service

Men. The needle of the meter stands at the extreme full swing position (to the right) when nothing is connected to the ohmmeter terminals.

A commercial form of ohmmeter is shown at the left of Fig. 13. This has two ranges obtained by using two separate series resistors which can be selected by the switch at the lower left-hand corner. The ranges are from 0 to 5,000 ohms and from 0 to 50,000 ohms. Some meters of this type are made with several series multiplier resistors which can be put in series with the milliammeter movement to make a multi-range voltmeter out of it. Meters of this kind are called *volt-ohmmeters.* One instrument of this type is shown at the right of Fig. 13. It is used extensively in radio circuit test work and has voltmeter ranges of 3, 30, 300, and 600 volts (all 1000 ohms per volt), and ohmmeter ranges of 0-10,000 and 0-100,000 ohms. The dry cell flashlight type battery for the ohmmeter is self-contained inside the case. The test prods which are provided, are shown at the right. (See also Art. 21.)

13. Movable iron type A.C. instruments: The milliammeters and voltmeters thus far discussed have been of the magnetic type which are employed in direct current circuits. This type of meter will not function when connected in an alternating current circuit, because during one alternation the current would flow through the movable coil in one direction, and on the following alternation the current and poles would be reversed and would therefore tend to deflect it in the opposite direction. These alternations follow one another so rapidly that the moving element in tending to obey one impulse would almost immediately be caused to move in the opposite direction by the next impulse, with the result that the indicating needle remains practically stationary, trembling slightly at the zero position. Since permanent magnet instruments cannot be used to measure alternating currents, (unless a rectifier is used, see Art. 14), they are generally called *direct current instruments.*

There are several types of meters used in ordinary commercial a.c. instruments. The Weston movable-iron type is one of these, used primarily for measuring alternating currents and voltages. A detailed explanation of its construction and operation follows.

The stationary coil of this form of instrument is wound with a few turns of heavy copper wire when the instrument is to be used as an ammeter. In this case the coil is merely connected in series with the circuit. When the meter is to be used as a voltmeter, a large number of turns of fine wire are wound on the coil, and connected in series with this coil, is an accurately adjusted high resistance. As shown in Fig. 14 the moving armature M, which lies in the center of the coil C consists of a small piece of soft iron, semi-circular in shape, secured to a vertical shaft which rests in jewel bearings. The pointer P is secured to the upper end of the shaft and turns with it. A small, loose fitting, thin vane (not shown) is attached to the pointer and moves in a small air compartment. The vane, as it moves in the closed air compartment like a piston in a pump provides the damping required to prevent the pointer from oscillating, and thus makes the instrument "dead beat." Close to the movable iron sleeve, is secured a stationery piece of curved soft-iron N, triangular in shape, with a small end of the

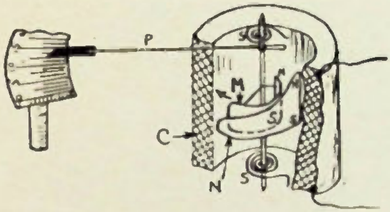


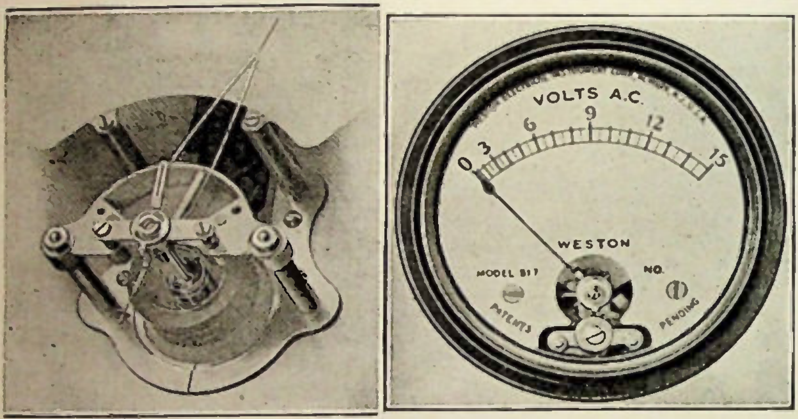
Fig. 14.—The movable-iron type movement used extensively for A.C. instruments. The repulsion between the magnetized iron vanes M and N cause the pointer to move over the scale. A portion of the coil C has been removed to show the interior arrangement.

triangle rounded off as shown. This piece of iron is securely held in place, does not move, and has no possible connection to the movable armature vane M or the shaft.

When the coil is connected in the circuit the current through it sets up a magnetic field through the center and both soft iron vanes become magnetized. The upper edges of each will always have a like magnetic polarity and the lower edges will also always have a like magnetic polarity, but when the upper edges are north poles the lower edges are south poles and vice versa. Therefore, there will always be a repulsion between the two upper edges, and also between the two lower edges of these soft iron strips no matter in which direction the current is flowing through the coil, so that the instrument can be used either in D.C. or in A.C. circuits. This sidewise repulsion tends to make the movable vane M, slide around from the fixed one N, and in doing so moves the pointer against the action of the hair springs, over the graduated scale and indicates the volts or milliamperes depending on whether the instrument is constructed and connected as an ammeter or as a voltmeter. A phantom view of a meter of this type is shown at the left of Fig. 15. An external view of a small 2-inch diameter voltmeter of this type used in radio work is shown at the right.

It is not advisable to use A.C. or movable iron type meters in D.C. circuits as they are not as sensitive as good D.C. instruments and require more current in the field coil to produce movement of the pointer since the magnetic field is practically all in air. Also these instruments have a non-uniform scale which is closely spaced near the bottom and much more open near the upper end as shown on the meter at the right of Fig. 15.

When instruments of this type are being purchased, care should be taken that their range is such that the values to be measured come in the open part of the scale rather than near the lower end where it is difficult to read the instrument accurately.



Courtesy Weston Elect. Inst. Corp.

Fig. 15—*Left*: A phantom view of the movement used in the Weston movable-iron type A.C. ammeters and voltmeters. This is the same as shown in Fig. 14.
Right: Exterior view of a small 2-inch diameter A.C. voltmeter of this type. Note the non-uniform scale—crowded at the low end.

As in the case of the D.C. instrument the A.C. meter has a definite value of internal resistance and the voltmeter scale may be multiplied by the use of the resistance form of multiplier. Since the A.C. meter requires more current to actuate it, the multiplier units must have a higher wattage rating. To determine the value of the multiplier resistance required to extend the range of a given A.C. voltmeter, the following equation should be used.

$$R_x = R_m \left(\frac{Vr}{V_m} - 1 \right)$$

Where R_x = the multiplier resistance
R_m = the resistance of the given meter
Vr = the new voltage range
V_m = the voltage range of the instrument on hand

Problem: Suppose we have a Weston 0-5 A.C. 2-inch diameter meter having an internal resistance of 10 ohms per volt. We desire to increase its range to 20 volts.

$$\text{Then } R_x = 50 \left(\frac{20}{5} - 1 \right) = 50 \times (3) = 150 \text{ ohms. } \textit{Ans.}$$

14. **Rectifier type A.C. instruments:** In the measurement of the output signal voltage produced by a radio receiver, it is exceedingly important that the measuring instrument use very little current or power for its operation. If an ordinary movable-iron type A.C. voltmeter were connected across the output terminals of the receiver, it would absorb a comparatively large prorportion of the power available and the reading obtained would be far from accurate. D.C. voltmeters requiring only one milliampere to produce full-scale deflection are easily obtainable. A.C. voltmeters of the moving iron type require from 100 to 500 M.A. in the low ranges and from 15 to 100 M.A. in the higher ranges, the power consumed by them usually being several watts.

The advantages of the low current drain of sensitive D.C. instruments can be retained for measuring low A.C. voltages and currents, such as are involved in the output circuits of radio receivers, by using a suitable sensitive D.C. instrument in connection with a copper-oxide type rectifier. A rectifier is a device which offers a high resistance to the flow of current through it in one direction, and a comparatively low resistance to the flow of current through it in the opposite direction. Thus, if the alternating voltage is applied to the terminals of a rectifier, current can flow through it only in one direction, so the current flowing is a *pulsating direct current*.

Several forms of rectifiers have been developed, but the most suitable, simple and inexpensive one yet found for use in rectifier-type instruments is known as the "copper oxide dry contact rectifier." The rectifier is connected to the D.C. meter movement as shown at (A), (B) and (C) of Fig. 16. A full-wave rectifier is employed. If current, (milliamperes), is to be measured with this arrangement, the terminals 1-2 of the complete instrument which is shown at (A), are connected in *series* with one side of the A.C. circuit in the same way as an ordinary milliammeter or ammeter. In this case, a D.C. milliammeter is employed in the instrument. If voltage is to be measured instead of current, the D.C. milliammeter employed is one of low range, and a multiplier resistor R is connected in series with the A.C. terminals of the rectifier as shown at (B);

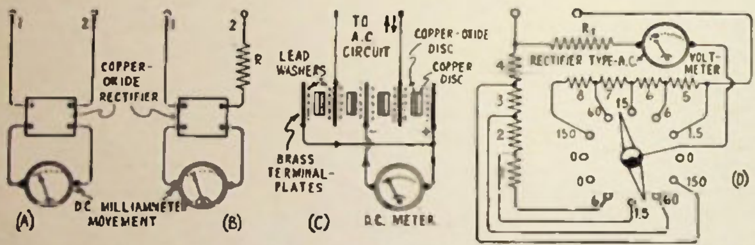
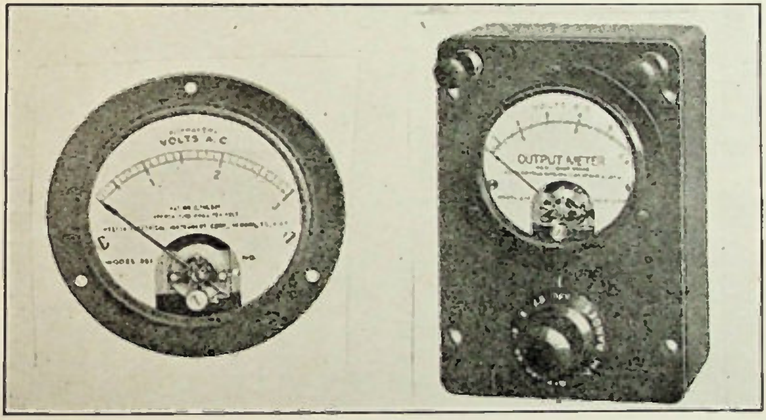


Fig. 16—(A) Connections of the rectifier to the D.C. meter movement, in a rectifier type A.C. milliammeter.
(B) Detailed connections of a full-wave copper-oxide rectifier to a D.C. milliammeter movement.
(D) Interior connections of all the parts of the copper-oxide type output meter shown at the right of Fig. 17. The shunt and series resistors are so arranged that the impedance of the meter remains constant at 4000 ohms for all ranges.

or a D.C. voltmeter can be used instead of the milliammeter. The detailed connections of the D.C. meter movement to a full-wave copper oxide rectifier are shown at (C).

Since the output of the rectifier is a pulsating direct current, the D.C. meter will read the *average value* of the pulsating rectified current applied to it. Therefore, the meter will read the *average value* of the A.C. current or voltage, which is equivalent to the *maximum value* × .901. If a meter of this type is made up by the reader, he should remember that the D.C. meter reads 90% of the true alternating current flowing in the external circuit, and therefore he must multiply all readings by 1/.901 or 1.11, to obtain the true effective value of the A.C. In meters sold commercially, the scale is already calibrated to read the true *effective value* of the A.C. A meter of this type is shown at the left of Fig. 17. Notice that the scale divisions of this type of meter are practically *uniform* rather than being of the inconvenient "square law" type (crowded at the lower end as in the movable iron type meter at the right of Fig. 15) found in other types of A.C. meters. These rectifier type A.C. meters are offered as the only practical means of constructing high sensitivity A.C. voltmeters, (particularly of low range), and low resistance A.C. milliammeters. Frequency errors introduced by the inherent properties of the rectifier cause the instrument indications to increase approximately ½ of 1% for each 1000 cycles up to about 35.000 cycles. This correction may be applied where accurate measurements are required.



Courtesy Weston Elect. Inst. Corp.

Fig. 17—*Left*: A copper-oxide type 0-3 A.C. voltmeter having a resistance of 1000 ohms-per-volt.
Right: The copper-oxide type output meter whose circuit is shown at the right of Fig. 16. Voltage ranges of 1.5, 6, 15, 60 and 150 volts may be selected by the knob which controls the multiplier switch. The impedance is constant at 4000 ohms.

15. The output meter: As explained at the beginning of Art. 14, rectifier type A.C. voltmeters are exceptionally well suited to the measurement or indication of the signal output voltages of radio receivers, on account of their sensitivity.

When used for this purpose, they are usually called *output meters.* An output meter is commonly used for indicating when the *maximum* signal output is being obtained from a radio receiver, during the procedure of aligning the tuned radio or intermediate frequency stages of the receiver. A meter of this type as shown at the right of Fig. 17. Its complete circuit arrangement as shown at (D) of Fig. 16.

This complete instrument consists of a five range copper oxide rectifier type voltmeter enclosed in a Bakelite case. Voltage ranges of 1.5, 6, 15, 60 and 150 volts are obtained by the dual selector switch. When one side connects more and more resistance (sections 1, 2, 3, 4) in *shunt* with the entire meter for the lower ranges, the other side automatically connects proper values of resistance (sections 5, 6, 7, 8) in *series* with the entire meter at the same time. These resistances are so proportioned that the instrument presents a constant non-inductive load of 4000 ohms to any circuit to which it may be connected, regardless of which voltage range is being used. It is arranged in this way, since the standard loud speaker or output transformer primary impedance which is across the radio receiver output during normal operation is also approximately 4,000 ohms.

The instrument may be connected directly in place of a magnetic (cone type) loud speaker, or of a dynamic speaker having a self-contained transformer. If, however, the instrument is to be substituted for the voice coil of a dynamic speaker, it must be shunted by a resistance approximating that of the voice coil. If the speaker is left in the circuit, the meter may be connected directly across the voice coil or across the primary of the transformer. Since the impedance of the instrument is constant for all ranges, and the output voltage is measured directly, it is easy to compute the actual power output of the radio receiver and the necessary adjustments can be made on the receiver during a test, to give the highest signal output voltage and power.

It is possible to make a fairly satisfactory output meter to be used merely for indicating when the output of a radio receiver is *maximum* while aligning the tuned stages, by connecting an ordinary 1000 ohms-per-volt d.c. voltmeter of suitable range, in *series* with a crystal detector, (preferably of the fixed Carborundum type).

Copper oxide rectifier type output meters are a very useful aid in measuring the signal voltage output, or computing the power output of radio receivers; in determining the maximum gain or amplification when "lining up" or "aligning" the R.F. or I.F. stages of radio receivers; in comparing the amplification produced by several radio tubes, in measuring the comparative selectivity of R.F. tuners; in determining the amplification produced by an amplifier or radio receiver when a known calibrated input voltage is applied to the input of the amplifier or receiver; in observing the period or per cent of fading, to set or keep the volume of amplifier or sound projection equipment at an approximate constant value, etc. The output meter enables the Radio Service Man to perform many phases of radio servicing more quickly and efficiently. Its use will be considered again later, in connection with tuning and intermediate condenser line-up procedure.

REVIEW QUESTIONS

1. Explain how you could prove that a magnetic field always exists around a current-carrying conductor?
2. Draw a diagram showing the magnetic field around a straight current carrying conductor.
3. Now draw a diagram showing a coil of wire having 6 turns with current flowing through it. Indicate on this, just how the magnetic field inside and around the coil would look if it were visible.
4. Where are the magnetic poles on the coil in question 3? Mark them on the diagram.
5. Draw a sketch and explain the operation of the Weston movable coil D.C. meter movement. Why does the movable coil turn when current is sent through it?
6. Since the mechanical construction of the movable coils of a Weston model 301 D.C. voltmeter, ammeter and milliammeter are all exactly the same, what then is the essential difference between these instruments?
7. How must a voltmeter always be connected in a circuit? Why?
8. How must an ammeter be connected in a circuit? Why?
9. Draw a diagram of a 6 volt storage battery connected so as to supply current to the filament of a vacuum tube in series with a 10 ohm rheostat. Indicate how you would connect an ammeter in the circuit to measure the current flowing, also indicate the connections of a voltmeter to read, (a) the voltage of the battery; (b) the voltage across the tube filament; (c) the voltage drop across the resistor.
10. A certain 0-1 D.C. milliammeter has a resistance of 50 ohms. Calculate the resistances of the shunts required to extend its range to, (a) 1 ampere; (b) 10 amperes; (c) 50 amperes. What is the multiplying factor which must be applied to the meter scale readings in each case? Draw a diagram showing how you would connect these shunts to the meter.
11. A voltmeter having a sensitivity of 1000 ohms-per-volt, has three ranges, 15 volts, 150 volts and 450 volts. What is the value of the series multiplying resistance used for each range? Draw a diagram of the connections. How much current must flow through the movable coil in order to produce full-scale deflection?

12. What is the essential requirement in a meter necessary to measure e.m.f. accurately and how is it fulfilled in the construction of a high resistance voltmeter?
13. What are the essential requirements of satisfactory meter multiplier resistors? How accurate need their resistance value be?
14. Explain by a practical example how a voltmeter having a comparatively low resistance may cause an appreciable change in the voltage of the circuit it is connected across. Show how the use of a high resistance voltmeter (1000 ohms or more per volt) eliminates this trouble.
15. Explain the construction and operation of the movable iron type A.C. ammeter. Why can this type of meter be used on either A.C. or D.C.?
16. What is a rectifier?
17. Explain the construction and operation of the rectifier type A.C. instruments? What are their advantages over the movable iron type?
18. What is an output meter used for? What does it consist of?
19. Explain the principle of operation of a simple ohmmeter (with sketch). What is the advantage of the ohmmeter method of resistance measurement over that of using a Wheatstone bridge? What are its limitations?
20. Draw the circuit diagram and explain how you would measure the value of a rather low resistance by means of a voltmeter and ammeter.
21. Draw the circuit diagram and explain how you would measure a high resistance roughly, by using a voltmeter alone.
22. A filament rheostat is the resistor in question 20. The voltmeter across it reads 6 volts and the ammeter in series with it reads 0.5 amperes. Calculate its resistance.
23. A voltmeter having a resistance of 100.000 ohms reads 86.5 volrs when connected in series with the secondary winding of an audio transformer across a source of voltage. When the voltmeter is connected across the voltage source alone, it reads 110 volts. What is the approximate resistance of the winding? What would be the first voltmeter reading if the transformer winding were open at some point?
24. How does an ohmmeter indicate a short circuit in a condenser?
25. How does an ohmmeter indicate an open circuit in a resistor?

CHAPTER 3.

SIMPLE ELECTRICAL TESTS

NEED FOR TESTING — TESTS FOR OPEN CIRCUITS — SHORT CIRCUITS AND GROUNDS — TESTING FILTER AND BY-PASS CONDENSERS — CHECKING RESISTANCE VALUES — THE WHEATSTONE BRIDGE — USING THE OHMMETER — TESTING COILS.

16. Need for testing: Many troubles may occur in parts of radio receivers, and it is necessary to know not only how to repair or replace the inoperative part, but also to test for, and locate it first. Since a radio receiver contains many separate circuits in which the inoperative part might be located, it is first necessary to *analyze* or diagnose the entire receiver, in order to locate the particular circuit in which the trouble lies. The method of doing this will be studied in Chapter 4. Then each part in that circuit is tested by the simple tests now to be studied, in order to determine just which part is inoperative, and what the nature of the trouble is. It may be a short-circuit, an open circuit, a grounded circuit, etc. The various electrical instruments studied in Chapter 2 play a very important part in these tests.

We will first consider the various simple tests for determining the simple troubles mentioned above, by means of individual testing instruments. Later we will discuss the use of instruments arranged conveniently in groups, in the form of service kits and set analyzers for facilitating more rapid diagnosing and localizing of these troubles.

17. Tests for open-circuits, short-circuits, and grounds: Although the best instrument for use in testing individual parts or circuits for open-circuits and short-circuits is an ohmmeter of some type similar to those described in Articles 11 and 12, it is possible to use such simple arrangements as a battery and a pair of earphones, etc., as shown at (A) of Fig. 18. Every time the two leads A — B are touched to the circuit in question and a loud click is heard in the earphones it indicates that the circuit being tested is "closed." If the circuit is

"open," no click at all or a very faint one will be heard. In this case, the circuit is not *continuous*. When testing condensers, a very faint click will be heard even if the condenser is perfect.

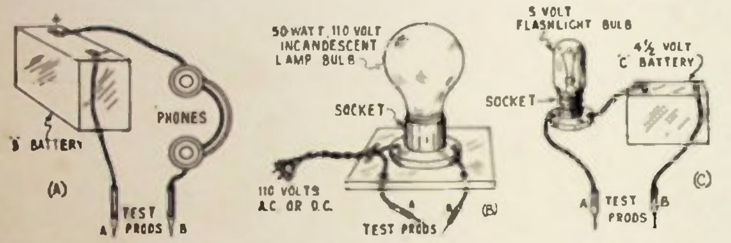


Fig. 18—Three simple continuity testers for locating open circuits.
(A) Tester consisting of a "B" battery and a pair of earphones.
(B) Tester consisting of a 110-volt incandescent lamp and voltage supply.
(C) Tester employing a small 4½ volt "C" battery, or flashlight batteries, and a 5-volt flashlight bulb.

Two other adaptations of this method which are very handy where other testing equipment is unavailable, are the combination of a lamp in series with the light line circuit as shown at (B), and a flash light cell and bulb pictured at (C). Here when the bulbs light, the circuit is closed and when they do not light at all, the circuit is "open." It must be remembered however, that when the circuit as shown at (B) is used with an A.C. line source to test condensers, it is possible that the bulb will glow more or less because the condenser will permit an alternating charging current to pass into it when a condenser of high enough capacity is being tested. Also if the resistance of the device being tested is high, it will not allow enough current to flow through the lamp in the tester to light it up—even if the circuit is continuous. This must be remembered when analyzing the results of this test.

In many instances an actual short-circuit may not occur between two sides of the circuit, but instead, a rather high resistance leakage path, which is usually termed a *high resistance ground*, or a *high resistance leak*, may occur. When testing for such a condition, it can be seen that the emergency set-ups as described in the previous paragraph, will not suffice, as they serve primarily for testing for open and short circuts. High resistance grounds or leaks are probably best tested by means of an ohmmeter, since then the exact value of the resistance of the leakage path, even if it is high, will be indicated.

18. Testing filter and by-pass condensers: Condensers may be tested by any method which indicates open and short circuits, but a condenser may also be leaky. For this reason it can be seen that one of the best tests is usually by means of an ohmmeter. A good condenser will not permit direct current to flow through it and will hold the charge when a D.C. voltage nearly equal to its rated voltage is impressed. This latter quality applies only to condensers of higher capacities from 0.1 mfd. and upwards. A leaky condenser will cause some steady deflection or reading on the ohmmeter when the ohmmeter terminals are connected to it. With the testing of higher capacity condensers, the needle of the ohmmeter will "kick" for a moment and return to its normal position if the condenser is good.

However, it is highly possible that a condenser may show a high resistance when the ohmmeter test is used and still be imperfect, as the dielectric in it may break down only when the high voltage existing in the radio circuit is applied to it. A tinfoil-paper type filter condenser may be tested for breakdown by applying its rated D.C. voltage primarily to its terminals by means of a block of B batteries or some D.C. current source and noting whether it holds a charge. Immediately after charging, the charging source should be disconnected and the condenser terminals should be short circuited with a screw-driver or piece of wire as shown at (A) of Fig. 19. The discharge should produce a flash or spark, the size of a flash depending on the capacity of the condenser and the voltage used for charging. If the condenser is bad or leaky, no flash will be produced because no charge has been stored. In this case, the condenser should be discarded or cut out of the circuit.

The testing of electrolytic condensers presents a different problem, for they are constructed differently and have different operating characteristics. Therefore, tests other than those used for paper condensers must be used. These condensers are "self-healing" that is, if the dielectric film breaks down due to the application of too high a voltage, it re-forms upon removal of the high voltage and acts as good as new again. Nevertheless, electrolytic condensers may become inoperative due to drying out of the electrolyte, or mechanical damage taking place in them.

An electrolytic condenser may be tested by connecting it directly to a source of d.c. voltage, (about 400 volts, for a condenser rated at 450 volts d.c. and from 6 to 8 volts d.c. for low-voltage type condensers so rated), and measuring the leakage current flowing through it, by means of a suitable milliammeter as shown at (B) of Fig. 19. Electrolytic condensers of different manufacture differ as to the leakage current and some idea of the general value to be expected may be obtained from the following figures for two typical condensers of this type tested with 400 volts d.c. For a 10 mf. condenser, the leakage current should not exceed about 1.0 milliampere.

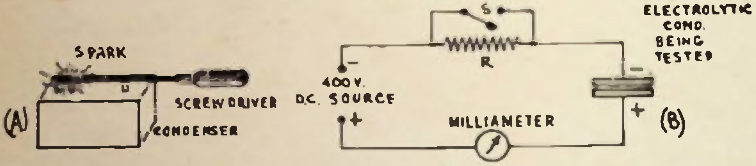


Fig. 19—(A) Testing a condenser for "short" or "open" circuit by charging it with a D.C. voltage source and then shorting its terminals and noting the spark discharge produced.
(B) Testing an electrolytic condenser by measuring the amount of current (leakage current) which flows directly through it when it is connected to a source of D.C. voltage.

For a 4 mf. condenser, it should not exceed about 2.4 milliamperes. Care should be taken to connect the condenser to the line terminals with the proper polarity, i.e. the positive line terminal should be connected to the positive (center) terminal of the electrolytic condenser. Also to prevent burn-out of the milliammeter if the condenser should by chance happen to be short circuited, a protective resistor R, of a value depending on the voltage of the testing source and the range of the milliammeter used, should be connected in series with the circuit at the start when the voltage is applied. Switch S should be open. If no excessive current reading results, it may be assumed that no short circuit exists in the condenser and the switch S may be closed. This shorts the protective resistor out of the circuit.

Of course it is possible to quickly check the quality of an electrolytic condenser without resorting to the method just explained, by substituting for it in the circuit, a condenser that is known to be perfect. Because of the fact that electrolytic condensers are used to filter the hum or A.C. from some rectified circuit, a 2 or 4-mf. paper condenser can be substituted for the electrolytic condenser to determine its condition and efficiency.

by noting its filtering qualities as evidenced by the amount of hum produced by the loud speaker when it is substituted.

19. Checking resistance values: When testing the receiver for various defects it is often necessary to check various values of resistors or other parts. This may be done by any known method of resistance measurement, whether by the voltmeter-ammeter method, by the use of a Wheatstone bridge or more conveniently with the aid of a suitable ohmmeter. Perhaps it would be well to understand the Wheatstone bridge method which should be used where accurate measurement is required.

20. The Wheatstone bridge: The ordinary form of Wheatstone bridge consists of four resistors connected in the form of a diamond, with a resistor in each side of the diamond as shown at (A) of Fig. 20. Resistor X is the one whose value is unknown and is to be measured; R is the resistor of known value; S and T are also known. A low voltage battery connected as shown to points A and C will cause current to flow in the resistors when the battery switch is closed.

The current from the battery divides at A, one part flowing through path ABC, the other along ADC; the two branches uniting at C and flowing back to the battery. Resistors S and T are so adjusted that when the galvanometer switch is closed, the galvanometer pointer stays at zero, indicating that no current is flowing through the galvanometer. This is called "balancing the bridge." Under these conditions, the points B and D must

Fig. 20—(A) Simple Wheatstone bridge circuit. X is the unknown resistor whose value it is desired to measure.
(B) Dial type bridge for rapid field test work.
(C) Simple slide wire form of Wheatstone bridge.

be at the same electrical potential, for if any difference of potential existed between them, it would send current through the galvanometer when the key was closed. When this electrical condition is secured, it may be proved mathematically that the relation $X = \frac{RS}{T}$ holds true for the resistances. This is the fundamental equation of the Wheatstone bridge. S and T are called the *ratio arms* of the bridge.

The formula for the Wheatstone bridge may more easily be remembered by the equation $XT = RS$, or that the products of the resistances of the opposite arms in the bridge are equal. Thus X times its opposite arm T is equal to R times its opposite arm S. The accuracy of the determination of resistance X depends on the accuracy of the ratio arms S and T, the accuracy of the standard resistance S, the sensitivity of the galvanometer G, and the relative resistances of all four arms of the bridge.

Probably the simplest practical form of Wheatstone bridge is a *slide wire* type shown at (C) of Fig. 20. Point D is a slide contact which is moved along the resistance wire ADC until the point is found for which there is no deflection of the milliammeter or galvanometer G. The ratio S/T is then the ratio of the length of the two parts of the resistance wire. This is true because since the wire AC is uniform, the resistances of pieces of it are proportional to the lengths of the pieces. A rule or scale mounted under the slide wire A C makes it easy to read off lengths S and T when the bridge is balanced. The same formula derived above is used for calculating the value of resistance X, only instead of using the resistance in ohms for S and T, the *lengths* of the slide are used instead. The slide wire bridge is very simple and inexpensive, and is capable of quite accurate measurements if care is taken in its construction and use.

A compact, commercial form of Wheatstone bridge designed to permit rapid and accurate measurement of resistance is shown at (B) of Fig. 20. The resistances S and T are varied by means of switches controlled by dials in order to "balance the bridge." The entire unit, complete with the battery and galvanometer, is enclosed in a small case, and is portable.

21. Using the ohmmeter: A precaution must be observed when using an ohmmeter for resistance measurement. When the terminals of an ohmmeter, (see Arts. 10, 11 and 12), employing a 0-1 milliampere meter are held with the hands, a deflection can be noted upon the meter because the resistance of the body, which is thereby introduced across the ohmmeter terminals, is less than 100,000 ohms. For this reason it is important that the fingers or the hands be kept free from the resistor, or the metal of the test prods, when making high resistance measurements. It may often be found that a resistance which should be of a certain definite value will be some percentage from its rated value. Whether this percentage is too much for efficient operation of the radio receiver depends en-

tirely upon the circuit in which it is used. For all practical purposes however, if the result of the measurements is within ten percent of the rated value of the resistance, it may safely be assumed that it is in good condition, remembering, that the result is entirely dependent upon its use in the circuit.

22. Testing coils: In radio receivers, two main types of coils are used, those wound on an iron-core, (such as power and audio transformers and filter and audio chokes), and those coils which have an air core (such as R.F. coils and chokes). It is possible for the windings of any of these units to become open, shorted or partially shorted.

Any of the continuity testing devices already described may be used to test coils, as most often the defect, if any, lies in either a short or an open circuit in the windings. However, in the case of partial shorts, it is necessary to use a good ohmmeter such as described in Art. 11, which is capable of measuring resistances as low as ½ ohm. Especially when testing R.F. coils, power transformer primaries, output transformer secondaries and dynamic speaker voice coils, etc., is such an instrument necessary, for the ohmmeter will detect a partially shorted coil even though the entire coil be of but a few ohms resistance. The reader may wonder how it is possible to tell whether a coil is partially shorted unless the full normal resistance is known. In most radio receivers there is usually another coil that is similar to the one suspected of containing a short circuit, and the resistance of one may be compared to the resistance of the other. For example, a receiver usually has two to four tuned stages necessitating in most cases the use of from three to five R.F. coils. In most cases, these coils are wound in like manner and have like characteristics, so their resistances may be compared. Some sets use two filter chokes and the resistances of these can usually be compared.

Sometimes, iron-core coils become grounded to the core at two points. This causes a short-circuit between the two grounded points in the winding. It is wise when testing these units, to test from all terminals to the core as well as between terminals. This condition is not infrequent and at times will cause trouble in the radio receiver and much wasted effort on the part of the Service Man to isolate the trouble.

When checking power transformers the resistances of the primary can be checked for a partial short only when some idea of the true normal resistance is known. Power transformer primary resistances usually range from a few ohms to even perhaps 25 to 50 ohms. In the case of audio transformers the primaries may be from several hundred to even several thousand ohms. Secondaries of audio transformers may have a D.C. resistance generally of several thousand ohms. It may be wise to note in some book, that is kept handy, the resistances of different makes of transformers and coils when they are tested, for this information may some day be of assistance in locating partially shorted units.

REVIEW QUESTIONS

1. Why is an ohmmeter a very useful instrument for testing resistors, coil windings, etc., for open circuits, short circuits, etc.?
2. What is meant by "testing a circuit for continuity?"
3. A short-circuited primary winding in an audio transformer is suspected as being the cause of trouble in a radio receiver. The resistance of the primary winding of another similar transformer in the receiver is found by measurement to be 2,000 ohms. Draw a circuit diagram, and explain how you would determine whether the first transformer primary has a short-circuit between its turns or not.
4. Explain 2 ways of checking the value of a grid-bias resistor supposed to be of 3,000 ohms resistance.
5. Suppose that a 1-mf. bypass condenser is connected across the resistor. How will the operation of the receiver be affected if this condenser is short-circuited due to failure of the dielectric between the plates? How would you test the condenser to determine if it was shorted?
6. Would it be satisfactory to test the primary winding of an audio frequency transformer for continuity by means of the test arrangement shown in (B) or (C) of Fig. 18? Give your reasons for your answer.
7. What two satisfactory methods could be used for performing the test outlined in question 6?
8. Explain how to test a paper-tinfoil type filter condenser to make absolutely certain that it will operate satisfactorily in a 300 volt circuit.
9. Explain the method, and draw the circuit connections, showing how to test a 400 volt 8-mf. electrolytic filter condenser. The manufacturers' instructions state that the maximum leakage current at rated voltage should not exceed 2 milliamperes.
10. Explain the method of measuring resistance by means of a Wheatstone bridge. What are its advantages?

11. What is meant by "balancing" the Wheatstone bridge?
12. An unknown resistance X is measured by the arrangement shown at (C) of Fig. 20. When the bridge is balanced it is found that with R=20 ohms, S=30 and T=70. What is the value of the unknown resistance?
13. A condenser is tested by the method shown at (A) of Fig. 19. No spark is noticed either when the charging source is connected to it, or when the screw driver is shorted across its terminals. What does this indicate? Explain!
14. What would happen if an alternating current voltage was applied for testing an electrolytic condenser? Explain!
15. What indications would be obtained, if a very high resistance were tested by each of the methods shown in Fig. 18, and this resistance was O.K.?

CHAPTER 4.

THE SET ANALYZER & THE RECEIVER

SERVICING PROCEDURE — ANALYZING THE RECEIVER WITH INDIVIDUAL METERS — THE SET ANALYZER IDEA — DEVELOPING THE METER SWITCHING SYSTEM — TYPES OF ELECTRICAL SWITCHES — DEVELOPING A PRACTICAL ANALYZER — COMMERCIAL SET TESTERS OR ANALYZERS — JEWEL PATTERN 444 ANALYZER — WESTON MODEL 566 ANALYZER — SUPREME AAA1 DIAGNOMETER — HICKOK MODEL SG4700 ANALYZER — DAYRAD TYPE 880 ANALYZER.

23. Servicing procedure: When a radio receiver becomes inoperative, it is usually due either to the failure of one or more of the tubes, or trouble in one of the parts or circuits of the receiver proper. The serviceman's task is to determine the location and nature of the trouble in the most direct and rapid way possible, and to make such replacements or repairs as are necessary to put the set back into proper operating condition. The element of time is important in modern servicing, since work of this kind is usually charged for on a time basis. Consequently, every effort has been made to develop methods and instruments which speed up radio service work, and enable troubles to be located in even the most complicated modern receivers, in a very short time. These test instruments will be studied in this, and following chapters.

In testing any radio receiver for the cause of trouble which may be making it totally inoperative or else operating unsatisfactorily, a considerable amount of information may be obtained by first testing the individual tubes for "emission" or "trans-conductance" (formerly called "mutual conductance"). In many instances this test will reveal one or more of the tubes to have become inoperative, in which case it is only necessary to replace the tube in order to get the set working satisfactorily.

If the tubes all check up properly, the voltages which actually exist at the various prongs of the tubes when they are in the receiver may be checked with a suitable voltmeter. This procedure is called *diagnosing* or *analyzing* the receiver, and usually enables one to determine in just which circuit the trouble lies, for trouble occuring in any circuit associated with a tube will usually cause a change in the voltage existing at the tube prong connected to that circuit. After the circuit in which the trouble lies has been located in this way, the particular unit which is inoperative, may be located definitely by applying the proper separate continuity tests and resistance measurements which we have already studied, to the individual parts in that particular circuit. Thus, there are really two main steps to radio receiver servicing, first the *diagnosing* or *analyzing*, and then the *trouble localizing*, identification, and correction.

24. Analyzing the receiver with individual meters: Every radio receiving tube has either three, four, or five individual external circuits depending on its type. If it is a direct heater type three-electrode tube, it has a filament, a grid, and a plate circuit. If it is a separate heater type three-electrode tube, it has a filament, a cathode, a grid and a plate circuit. If it is a separate heater type screen grid or pentode tube, it has a filament, cathode, control-grid, plate, and screen grid circuit. Keeping this in mind, it is evident that it is possible to analyze the various circuits of a receiver by testing the voltages existing at the terminals of the tube sockets.

In most modern receivers, it is quite difficult, and undesirable from the point of view of the time consumed, to reach directly the various coupling transformers, resistors, condensers, and so on in order to make preliminary tests. In almost all receivers, the main circuits go more or less directly to the tube socket connections, which are easily reached for test work. Therefore, a receiver is usually *analyzed* by measuring the voltages existing at all of the tube socket terminals and measuring the currents flowing in some of the circuits. In most cases, a correct interpretation of these voltage and current readings will indicate just which of these circuits the trouble lies in.

To illustrate how these circuits may be analyzed, let us consider the typical screen-grid R.F. amplifier stage shown in Fig. 21. The methods of analyzing the circuits of this tube and stage may be duplicated for any other stage in the receiver. In the grid circuit of the tube we have the secondary of the preceding R.F. transformer with the tuning condenser C_1. In the plate circuit is the primary L of the next R.F. transformer, one end of the primary being connected to the plate of the tube, the other end connected to the plate filter system consisting of the resistance R_1 and the by-pass condenser C2. The other end of the resistance R_1 connects to that terminal of the plate supply unit which supplies plate voltage to the R.F. amplifier tubes.

Of course in a complete receiver, several tubes comprise the radio frequency amplifier, but the circuits of each individual tube are closely similar to the one shown here. Where the tube is an audio amplifier, instead of the

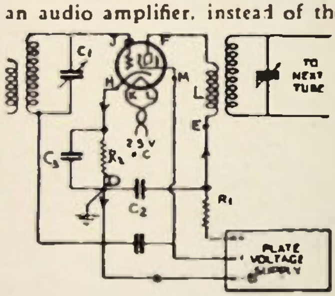


Fig. 21—The individual filament, cathode, grid, screen grid, and plate circuits of a typical screen grid amplifier tube in a radio receiver. Note that each of these circuits terminates at the tube socket and tube.

R.F. transformers we would have audio transformers. In the case of the intermediate amplifier in a superheterodyne, intermediate transformers would be used. Slight variations from this fundamental circuit will be found; but if this normal arrangement is kept in mind it will make circuit testing a simple task. The early receivers used three element tubes in the radio frequency stage of the circuit diagram. The circuits of these older receivers are essentially the same, except for the added cathode and screen grid elements.

To check the voltages appearing at the various circuits, individual voltmters may be used. For battery and D.C. electric receivers, only one voltmeter is required for this work but for A.C. operated receivers both a D.C. voltmeter and an A.C. voltmeter are necessary. A single combination voltmeter of the copper oxide rectifier type already studied is often used for this purpose. The D.C. voltmeter should have a resistance of 1,000 ohms or more per volt and have scales reading 0-10, 0-250, and 0-750 volts. A meter of this type is shown at the left of Fig. 9. It has low current consumption due to this high sensitivity and resistance, and does not materially affect any of the voltage readings.

An A.C. voltmeter of the general type shown at the right of Fig. 9, and having ranges of 0.4, 0-8, and 0-150 volts is also very useful. The two lower scales are for reading filament voltages of A.C. type and rectifier tubes, the 150 volt scale is for checking the A.C. electric light line voltage. We will now consider the use of separate instruments, merely to develop the method of analyzing circuits. Later, we will see how the modern set analyzer performs all of these functions in a rapid simple way with one or two multi-range instruments. We will develop the idea of the modern set analyzer step by step for clarity and simplicity.

To check the filament voltage in Fig. 21. the A.C. voltmeter is connected across filament terminals K-L. To check the plate voltage, the D.C. voltmeter is connected between point H the cathode and point F the plate. (All voltages in a direct heater type tube are always referred to the negative terminal of the filament. All voltages in a separate heater type tube are always referred to the *cathode* as the reference terminal. This is taken as the point of lowest potential in the tube.) If the correct voltage reading is obtained between cathode and plate, it indicates that whatever is connected in the plate circuit of the tube, (in this case it is the primary winding L of a transformer), is not open. It also indicates that the B voltage supply unit is operating satisfactorily. If no voltage reading is obtained between H and F, a test should be made between H and E. If a reading is obtained here, it indicates that an open circuit exists in the transformer winding connected in the plate circuit between F and E. If no reading is obtained yet, a test should be made between F and D. (D will usually be grounded to the frame of the chassis.) If a reading is now obtained, it indicates that an open circuit exists in grid bias resistor R_2. The screen grid circuit can be checked by connecting the voltmeter from H to M. The control grid circuit can be checked by connecting it across H and J (the cap on the tube). This will indicate the grid bias voltage drop across the grid bias resistor R_2.

This simple test may be repeated at the socket of each tube, until the tube at which the improper voltages exist is located. The particular circuit at which the improper voltage exists can then be traced, and the individual parts in it tested for open or short circuits, etc., by the methods already described. If the plate and grid voltages on all the tubes are found to be low, the power supply unit circuits may be suspected and should be checked up. Abnormally low output voltage would in all probability be caused by a broken down filter condenser. To determine exactly which one is shorted, all of the filter condensers would have to be tested individually. A simpler way is to disconnect one condenser unit at a time from the circuit, until the output voltage rises to normal value. The condenser which causes this to take place, when it is removed from the circuit, is then the "shorted" unit.

25. The set analyzer idea: The procedure just outlined indicates in a general way how the circuits of each tube in a receiver may be analyzed to locate, by means of two simple

electrical measuring instruments, the particular circuit in which trouble exists. The equipment used however, has one serious objectionable feature which makes it impractical for use in efficient modern test work. When receivers were constructed with all tube sockets mounted on an open baseboard, with every connection easily accessisble, this method of testing was simple to apply. Modern receivers are constructed with the tube sockets, resistors, wiring and most condensers, mounted underneath the chassis. Transformers and chokes are mounted in cans. Therefore testing by this method would necessitate the complete removal of the chassis from the cabinet for every service job, and the testing at the tube socket terminals with the set in an inverted position—which is rather awkward, inconvenient, and wasteful of time.

The testing manipulations may be greatly facilitated and speeded up, by bringing all of the circuits of the socket of the tube to be tested, to an extra tube socket into which is placed this tube taken from the receiver socket. This may be conveniently done by employing a dummy plug exactly resembling the base of the vacuum tube, and having prongs arranged in the same order. A wire connects to each prong, and these wires are all brought out, usually in the form of a cable, to a similar socket in the tester, into which the tube taken from the receiver is placed.

The idea involved in this is shown in an elementary way in Fig. 22. At (A) we have a circuit diagram of a typical R.F. amplifier stage employing a single 3-electrode tube. The conventional symbol for the vacuum tube is indicated. At (B) the actual connections to the 4-prong tube socket T are shown, the socket terminal markings corresponding with the tube terminal markings at (A). At (C), is illustrated the method of using a dummy plug and 4 wire cable for extending to a separate tube socket S outside of the receiver, all of the individual circuits which go to the original tube socket T in the receiver. The tube taken out of socket T is placed in socket S. In the case of a 5 terminal tube, a five wire cable would be employed, etc.

The fundamental analyzer idea shown at (C) of Fig. 22 is employed for practical testing by arranging socket S and all the meters required for testing, together in the set analyzer. The various meters and switching arrangements for testing are permanently connected in the various circuits between the dummy plug and the test socket S. A very simple analyzer arrangement of this kind is shown in Fig. 23. A study of this diagram will show that individual meters are used for determining the various voltages and the plate current of the tube in the circuit being analyzed. This particular tester has not been designed for the testing of circuits in which screen grid tubes are utilized, but with slight modifications it could be adapted for this purpose.

A study of Fig. 23 shows that the set tester or analyzer idea is merely one designed for convenient testing. Instead of bringing the testing instru-

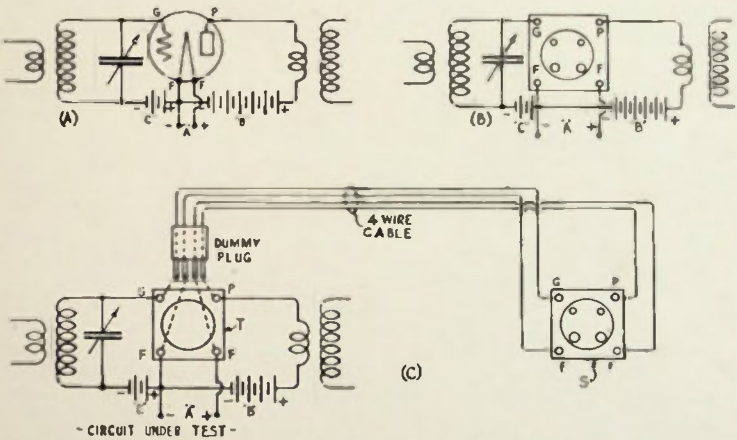


Fig. 22—(A) Conventional circuit diagram representing a 3-electrode tube connected in a T.R.F. amplifier circuit.
(B) The same circuit, showing the actual connections to the tube socket terminals.
(C) How the individual circuits of a tube may be extended to a point outside the receiver by means of a dummy plug, 4 wire cable, and a duplicate tube socket. This is the fundamental principle upon which all set analyzers are constructed.

ments to the terminals on the tube socket, which are usually very inconveniently located—and doing all of the testing in the limited cramped quarters in the receiver; we remove the tube from the receiver socket, extend each individual tube circuit out to the tester by means of the plug and cable, and connect the ends of these extended circuits to the tube taken out of the receiver—the testing instruments being automatically connected properly in between—and do our testing conveniently with plenty of room to work in, and with testing instruments and switching arrangements already connected up in the circuit to perform all the required tests simply and quickly. This is the basis of the set analyzer or tester idea. Of course, in order to make intelligent use of tests of this kind, it is necessary to know just what the voltages at the various terminals of each tube socket should be under normal operating conditions. This data is usually furnished by the receiver manufacturer, or may be obtained from service manuals. Most commercial set analyzers and testers are provided with instruction books containing tables showing the correct voltage readings for most of the standard makes of receivers.

A typical table of this kind—for a Majestic Model 20 A.C. electric receiver—is reproduced below from the instruction book for the Weston

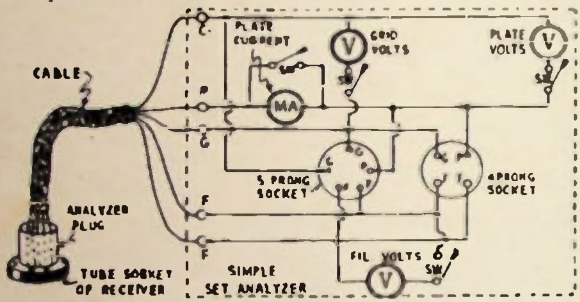


Fig. 23—The elements of a simple set tester or analyzer which permits of rapid testing of the voltages existing at the terminals of any tube socket in the receiver. The analyzer really extends the circuits of the tube socket to a point outside the receiver for convenient testing by means of the various instruments provided. The tube taken from the receiver is plugged into the analyzer tube socket.

Model 566 Type 2 Radio Set Analyzer. Notice that all of the important data concerning the receiver is contained in this table.

MAJESTIC—MODEL 20 CHASSIS

Type Tube	Tube Position	"A" Vts.	"B" Vts.	"C" Vts.	Screen Vts.	Screen Current	Cath. Vts.	Nor'l MA.	Grid Test MA.
'51	1 R.F.	2.3	180	0	90	—	3	5	6.2
'51	1 Det.	2.3	180	0	87	—	8	0.8	1.1
'51	1 I.F	2.32	150	0	90	—	3	4.0	5.2
'27	Osc.	2.32	90	0	—	—	—	4.0	5.1
'27	2 Det.	2.32	255	10	—	—	21.6	0.8	1.0
'45	1A.F.	2.36	275	45	—	—	—	29.0	33.0
'45	P.P.	2.36	275	45	—	—	—	29.0	33.0
'80	Rect.	4.8	410	—	—	—	—	40.0	per anode

LV—117. Vol. Con. Max.

The analyzer is provided with both a 4-prong and a 5-prong tube socket, with the corresponding terminals on both, connected in parallel. This enables either 4-prong or 5-prong type tubes to be tested. Also, the

5-prong plug furnished for plugging into the receiver socket is provided with a removable 4-prong adapter, for use when the circuits leading to a 4-prong tube are to be tested. The exact procedure to be followed in using a set analyzer will be discussed later.

26. Developing the meter switching system: The use of so many individual instruments to test the different voltages, and also the plate current, of a tube circuit would make the analyzer expensive, and unwieldy. It is possible to reduce the number of meters required by using a single D.C. instru-

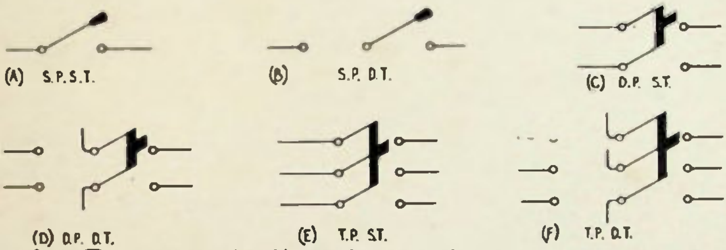


Fig. 24—The common "knife" switches used extensively in electrical work. These contact arrangements can also be obtained in push-button type switches, (see Fig. 25).

ment that will measure all the D.C. voltages and plate current. This can be rapidly connected to the various circuits at will by a properly designed switching arrangement.

27. Types of electrical switches: At first glance, the switching arrangements used in set analyzers may seem rather complicated, but a systematic study of the main types of switches used and their circuits, will greatly assist the reader to become familiar with them. The reader is probably familiar with the different types of *knife switches* commonly used in radio and electrical work. Some of these are shown in Fig. 24. They are as follows:

(A) single-pole single-throw (S. P. S. T.)
(B) single-pole double-throw (S. P. D. T.)
(C) double-pole single-throw (D. P. S. T.)
(D) double-pole double-throw (D. P. D. T.)
(E) triple-pole single-throw (T. P. S. T.)
(F) triple-pole double-throw (T. P. D. T.)

While this type of switch is simple and perfectly satisfactory from an electrical standpoint, it is seldom used in set analyzers due to the fact that it requires too much space for mounting and manipulation. It is possible to construct switches in other forms which are more compact, and equally efficient. The mechanical arrangement employed does not affect the electrical function of the switch in any way. A very popular form of switch used in set analyzers is shown in Fig. 25. This is called the *push button* type.

At (A) we have a single-pole single-throw switch. It is composed of 2 blades made of low resistance spring metal. When the button above the panel is pressed, blade 1 is pushed down so that its contact piece makes

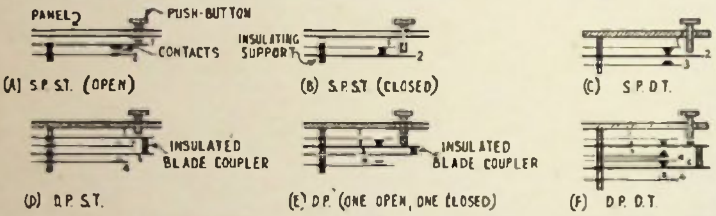


Fig. 25—Push-button type switches. These can be constructed more compactly than the knife-switches of Fig. 24, and are therefore more desirable for use in radio set analyzers.

contact with that of blade 2. On the other hand it is possible to arrange the blades so that when the button is pressed as shown at (B) the long blade 2 is pushed away from blade 1, thus breaking the circuit. The combination of the first two mentioned switches is shown at (C) where is pictured, a single-pole double-throw switch. When the button is pressed, blade 2, which ordinarily makes contact with blade 1, is pushed down making contact with blade 3 and at the same time breaking contact with blade 1. At (D) can be seen an arrangement whereby double-pole single-throw switches may be constructed with as many poles as required. Pressing on the button forces the long blades 1 and 3, which are coupled together by means of a piece of insulating material, into contact with blades 2 and 4. By slightly different mechanical arrangements, it is possible to construct the switch to perform many switching operations. The switch at (E) shows a method of arranging the blades so that when the push-button is pressed, one circuit is opened and another circuit is closed. By using two S. P. D. T. switches with the long blades coupled, we would have a D. P. D. T. switch as shown at (F). The blade coupling piece should be made of good insulating material such as Bakelite.

There is another form of switch which is very useful for some applications in analyzers. This is called the *tap switch* and is shown in Fig. 26. It consists of one or more arms of spring metal such as brass or phosphor bronze, arranged to be rotated over one or more contact points by means of a knob or dial. A *simple* tap switch is shown at (A). This is employed where one side of a circuit is to be switched to any one of several other circuits in turn. A *bipolar* tap switch is shown at (B). This is used for switching both sides of a circuit to both sides of any of several circuits. The bipolar type is used

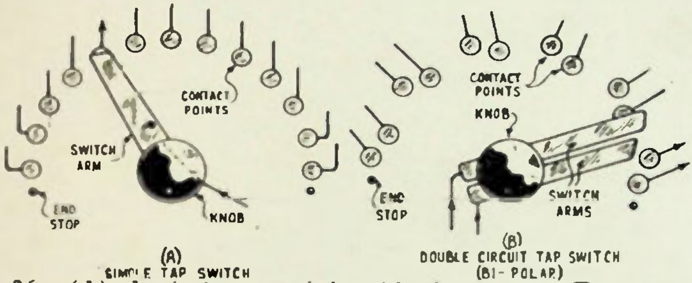


Fig. 26—(A) A single tap-switch with 6 contacts. The switch arm may be moved over these contacts by means of the knob.
(B) A bipolar tap-switch with 6 pairs of contacts. Each switch arm touches only its own set of contacts when rotated.

extensively in single D.C. meter analyzers to make it possible to employ one meter to test all D.C. voltages and current in the tube circuit.

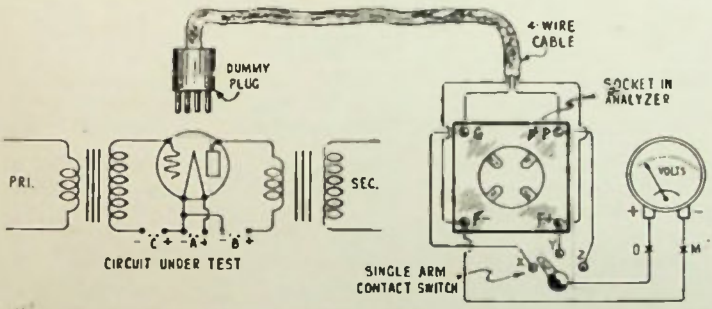


Fig. 27—A voltmeter may be used with a single arm tap-switch for checking the grid, plate, and filament voltages at the terminals of the tube socket in the analyzer, as shown.

28. Developing a practical analyzer: To more easily understand the principles and the basic design of the finished modern set analyzer, it will be well to briefly trace the stages

in its evolution. The first set analyzers were very simple, and of course, home-made. To measure the D.C. voltages existing at the various terminals of a tube with one meter, a single arm tap switch was used in conjunction with the meter and arranged somewhat as shown in Fig. 27. When the switch was placed on contact Z, the plate voltage was read on the meter; when the switch was placed on contact Y, the filament voltage was read, and when the switch was placed on contact X, the grid voltage was read. However, on the latter the meter read

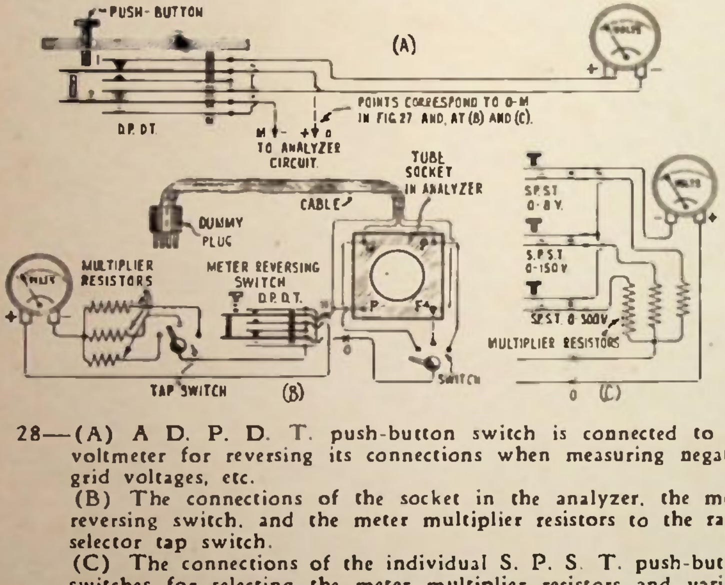


Fig. 28—(A) A D. P. D. T. push-button switch is connected to the voltmeter for reversing its connections when measuring negative grid voltages, etc.
(B) The connections of the socket in the analyzer, the meter reversing switch, and the meter multiplier resistors to the range selector tap switch.
(C) The connections of the individual S. P. S. T. push-button switches for selecting the meter multiplier resistors and various ranges.

"backwards" since the grid of an amplifier tube is always maintained negative with respect to its filament and in this test the *negative* grid was being connected to the *positive* terminal of the meter. Thus it became necessary to employ a double-pole double-throw switch arrangement as shown at (A) of Fig. 28 to reverse the polarity of the meter for the grid voltage reading, in order to secure the proper positive meter reading. Upon tracing this diagram the reader will find that depressing the switch button and blades 1 and 2, causes the meter connections to reverse. This switch was also necessary in cases where the filament voltage reading was reversed, as in series filament receivers, etc. Since the filament voltages employed were seldom more than 6 volts, it was difficult to accurately read this small deflection when a meter with a range of 0-150 volts (which was suitable for reading the plate voltages) was used. Therefore it became necessary to use a low range voltmeter having a full scale reading of 8 volts, with the proper multiplier resistances in series with it so that any one of a number of required higher ranges could be secured for the other tests.

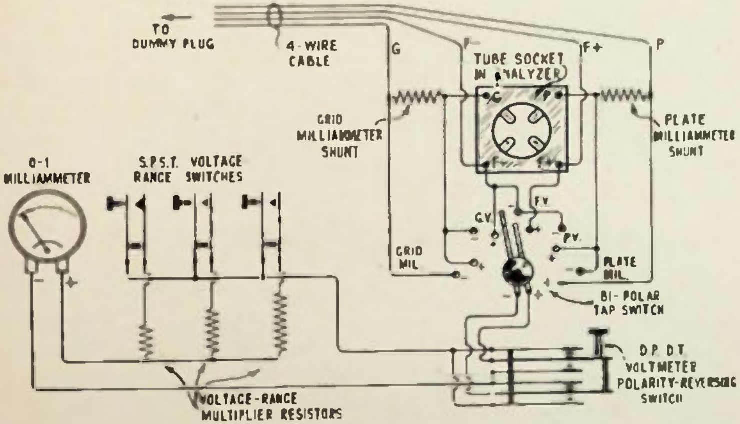


Fig. 29—The same circuit arrangement as in (B) of Fig. 28, excepting that a "bipolar" tap-switch is used to connect the meter to the different circuits of the tube.

The arrangement is shown at (B) of Fig. 28. The switch used to vary the range of the voltmeter was either a single contact arm tap switch as at (B) or a number of single-pole single-throw push button switches connected as shown at (C). The latter arrangement enables any range to be selected by merely pressing the proper push button.

With this arrangement it was possible to measure all the D.C. voltages of a tube circuit regardless of the voltage or the polarity. However, it was also important that the plate and grid currents of the tube being tested be measured. This could only be done by breaking into the plate and grid circuits of the tube and inserting a milliammeter of proper range depending upon the type of tube being tested. This would mean however, that an additional milliammeter would have to be used, unless the single meter employed in our analyzer thus far was a milliammeter used with proper multiplier and shunt resistors to enable it to measure both voltage and current. In order to make possible the use of a single meter it was necessary to employ a different switch arrangement than that shown in Fig. 28, and to wire up a bi-polar switch to connect the milliammeter to the different circuits of the tube as shown in Fig. 29. The student should trace the meter connections for each position of the tap switch. The presence of the milliammeter shunt resistors in the grid and plate circuit of the tube has but little or no effect upon the grid and plate voltage readings, for their resistance is very small. For instance, when an 0-1 milliammeter is used, a 10 mil. shunt has a resistance of approximately 3 ohms and a 100 mil. shunt is still less. The only other switches in the analyzer are those necessary to vary voltage ranges and current ranges, and where desired the meter reversing switch can be incorporated.

In order that the analyzer be capable of measuring all voltages in a receiver using D.C. tubes or A.C. tubes it is necessary to use also an A.C. voltmeter to check the filament voltages of the A.C. tubes. At the same time, if this meter has a range of 150 volts it can be employed in the measurement of A.C. line voltages and if the range of the meter is as high as 800 volts, then the output voltage of the high voltage secondary of a power transformer may also be checked. Thus, with two meters it is possible to check any voltage existing in a radio receiver, as well as the plate and grid current drawn by each tube. A set analyzer employing a D.C. milliammeter with an 0-1 mil. range and an A.C. voltmeter with ranges 0-4, 0-8 and 0-150 volts in conjunction with a bi-polar tap switch, and all necessary push-button switches, multiplier and shunt resistors, may be easily constructed at comparatively little expense. Such an analyzer with the constants of all the necessary resistors is pictured in Fig. 30.

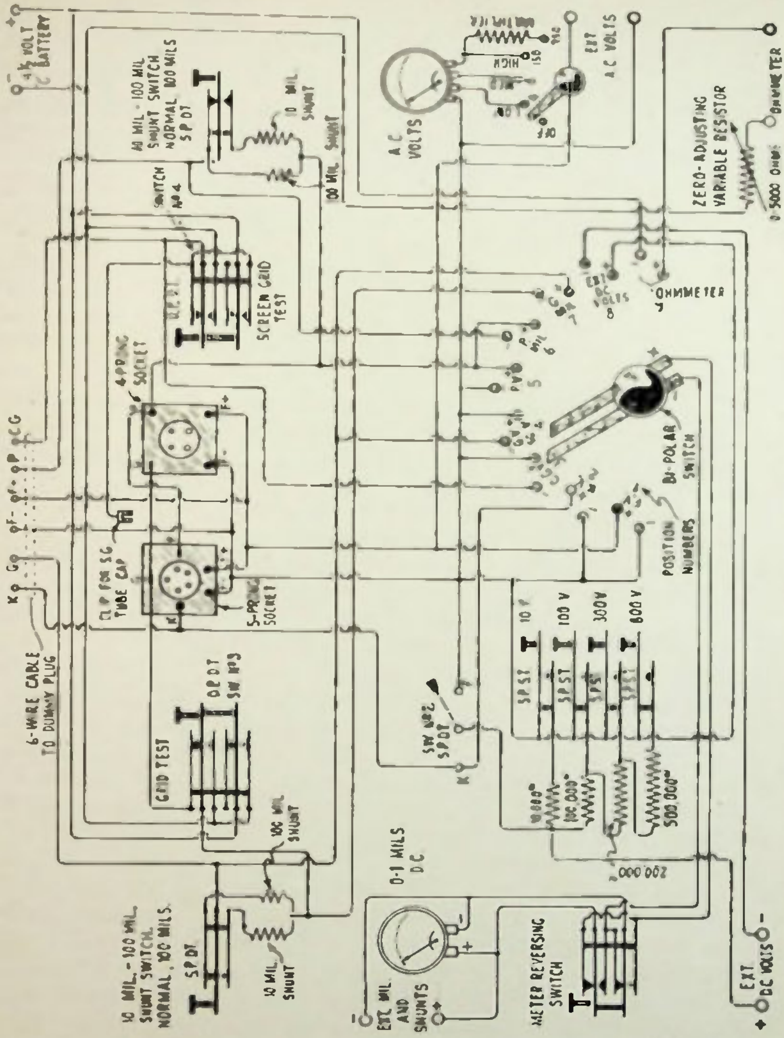


Fig. 30—The schematic diagram of a complete radio set analyzer. It employs a 0-1 D.C. milliammeter and an A.C. voltmeter, together with all necessary tap switches, multiplier and shunt resistors, push-button switches, etc., to enable it to be employed for servicing modern radio receivers. The constants of all resistors are shown. This analyzer may be constructed at comparatively low cost by the reader.

Besides being capable of making all the various voltage and current measurements at the socket terminals of a tube in a receiver, this analyzer (Fig. 30) will measure the filament emission of a full-wave rectifier tube, test continuity of circuits, measure resistances, and test all tubes including screen grid tubes whether they be used in a screen grid circuit or as space-charge amplifiers. The resistors used to make a high resistance D.C. voltmeter from the 0-1 D.C. milliammeter must be accurate to at least 1 per cent, if any degree of precision is to be obtained. The values are R_1 10,000, R_2 100,000, R_3 200,000 and R_4 500,000 ohms. These will make the milliammeter a voltmeter with ranges of 0-10, 0-100, 0-200, and 0-500 volts. The current shunt resistors may be purchased or wound by hand after the internal resistance of the milliammeter is definitely known. When this internal resistance is definitely determined, the exact value required for the 10 mil. and 100 mil. shunt resistors may be obtained by using the formula already studied in Art. 5. If a Jewell meter whose internal resistance is 30 ohms is used, the approximate value of the 10 mil. shunt will be 3 ohms. A commercial wire-wound filament resistor may be secured and the required number of turns removed in order to make the 10 mil. shunt. The 100 mil. shunt can be made in a similar manner, (see Art. 5).

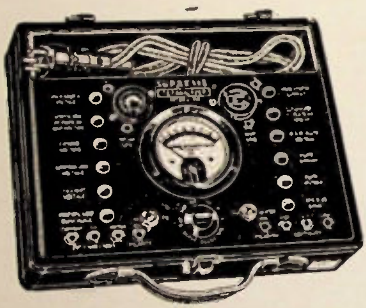
A small 4½ volt C battery is incorporated into this tester in such a way that it can be used with the D.C. meter as an ohmmeter with the proper zero adjusting resistances, and also to measure the trans-conductance of a tube by measuring the change in plate current produced when this battery is connected into the grid circuit by the use of the D. P. D. T. switches No. 3 and No. 4, the latter being used for screen grid tubes.

The bi-polar switch, with the S. P. D. T. switch No. 2 which connects one leg of the voltmeter to the cathode where indirect heater type tubes are tested, or to the negative filament where direct heater type tubes are tested, is used to obtain all D.C. voltage and current readings. When the bi-polar switch is in position No. 5 the plate voltages are read using the proper voltage range switch. In positions No. 6 and No. 7 the milliammeter is used to measure either plate current or grid current respectively. With the bi-polar switch in position No. 2, cathode voltages are read with respect to the heater, and also the screen voltage of a pentode power tube may be checked. In most receivers, the cathode voltage will read positive where a conventional cathode bias resistor is used. On the other hand some sets have the heater connected to some positive potential, and the reversing switch must be used to correctly read the cathode voltage which will be negative. There are a few sets where the cathode is connected directly to the heater and when this is found, no reading will be obtained. When the bi-polar switch is in the No. 4 position, screen grid voltages and grid voltages are checked. When screen voltage is being measured however, the reversing switch must be used as this potential is *positive* with respect to the cathode. With the switch in position No. 3, negative control-grid voltages are read. However, if the meter reads backwards it is possible that the tube is being used as a space-charge amplifier with the control grid having a positive bias. In this case, the meter polarity reversing switch should be pressed.

The current of one plate of a full-wave rectifier tube may be indicated when the bi-polar switch is at position No. 7. The current of the other plate is measured when the switch is in the usual plate position No. 6. Screen grid current is also measured on position No. 7. Tubes other than screen grid tubes may be tested by measuring the normal plate current as compared with the reading obtained when switch No. 3 places a 4½ volt battery into the grid circuit. The screen grid tube is tested by using switch No. 4.

Binding posts or tip-jacks may be used on the sides of the analyzer for external use of the meters as shown. With the bi-polar switch in the No. 8 position, the voltmeter is made available for these external measurements. When continuity or resistance measurements are made, the bi-polar switch must be in the No. 9 position where the meter is placed in series with a variable resistor for full scale adjustment of the ohmmeter when the test prods are short circuited. The scale of the 0-1 milliammeter may remain without change, or the different voltage and current ranges may be marked directly upon the scale. Most instrument manufacturers will supply scales, already marked if desired. A five to four prong adapter should be secured when the test plug is used in four prong sockets.

29. Commercial set testers or analyzers: The test circuits and set analyzer we have considered are extremely simple, though the one described in the preceding paragraphs is very efficient and in most cases will serve as well as a factory built analyzer. Modern set analyzers are provided with rather complicated switching arrangements which usually contain one or two meters to be used for measurements on both A.C. and D.C. These meters are provided with several multiplier and shunt resistors and switching arrangements, which enable various ranges to be obtained, and enable the operator to quickly switch them to the various circuits to measure the voltages and currents. In addition, suitable terminals are provided for the



Courtesy Supreme Instruments Corp.

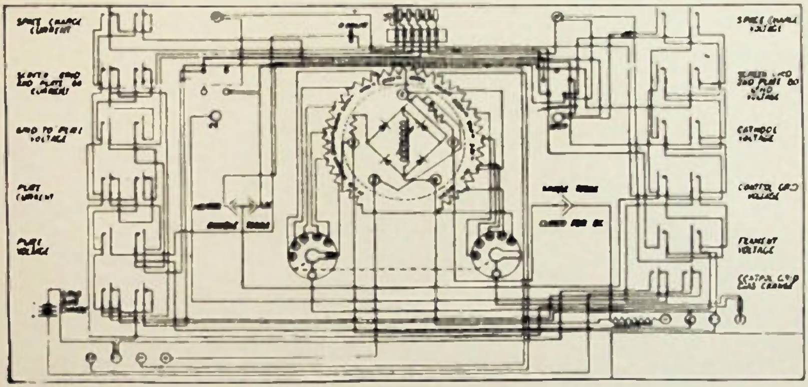
Fig. 31—A typical radio set tester and analyzer arranged in a portable carrying case. A single copper-oxide type meter, with a specially designed switching arrangement performs all the necessary tests. The dummy plug and cable are in the compartment at the rear. The circuit diagram is shown in Fig. 31A. (Supreme Model 90.)

connection of test prods and leads for using the meters for making individual tests on parts in the receivers, etc. These include voltage and current tests, continuity tests, resistance measurements, etc. Complete detailed instructions are furnished with these testers by the manufacturers in each case.

A typical set tester or analyzer which is representative of these devices is shown in Fig. 31. Others are shown in following illustrations.

This set analyzer employs a single meter of the copper oxide rectifier type (see (C) of Fig. 16), measuring A.C. and D.C. voltages in six ranges up to 900 volts, and A.C. and D.C. currents in five ranges up to 300 milliamperes. It may also be used as an output meter (see Fig. 16) in lining up or adjusting the tuning condenser sections in a gang condenser, and adjusting the tuned circuits in the i.f. amplifiers of superheterodynes. Terminals are also provided for making external measurements and tests. The complete circuit diagram of this analyzer is shown in Fig. 31A. Notice the connections of the copper-oxide type meter and voltage multiplier system at the center.

With the increasing complexity of receiver circuits and the development of the single dial control superheterodyne and multi-stage broadcast receivers, many manufacturers are in-



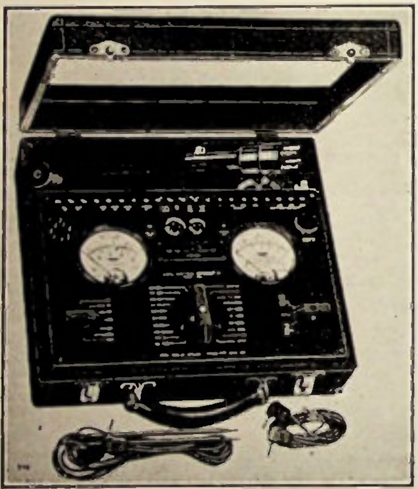
Courtesy Supreme Instruments Corp.

Fig. 31A—The complete schematic circuit diagram of the radio set analyzer shown in Fig. 31. Notice the connections of the single copper-oxide type meter and the multiplier resistors and shunts at the center. Also notice the various push-button switches at the left and right for connecting the meter to the various circuits of the tube.

corporating output meters and oscillators into their analyzers, to align and properly balance the tuned circuits of broadcast receivers. This will be studied later. To enable the reader to more thoroughly acquaint himself with the different methods employed in analyzer construction, and to have on hand working diagrams of the popular commercial set analyzers, several pages will be devoted to descriptions of the latest instruments of the leading manufacturers.

30. Jewel pattern "No. 444" analyzer: This analyzer is equipped with two instruments, and is shown in Fig. 32. The schematic circuit diagram is shown in Fig. 33. Note the liberal use of rotary switches. This analyzer can be used for making all tests on either battery operated or electric receivers.

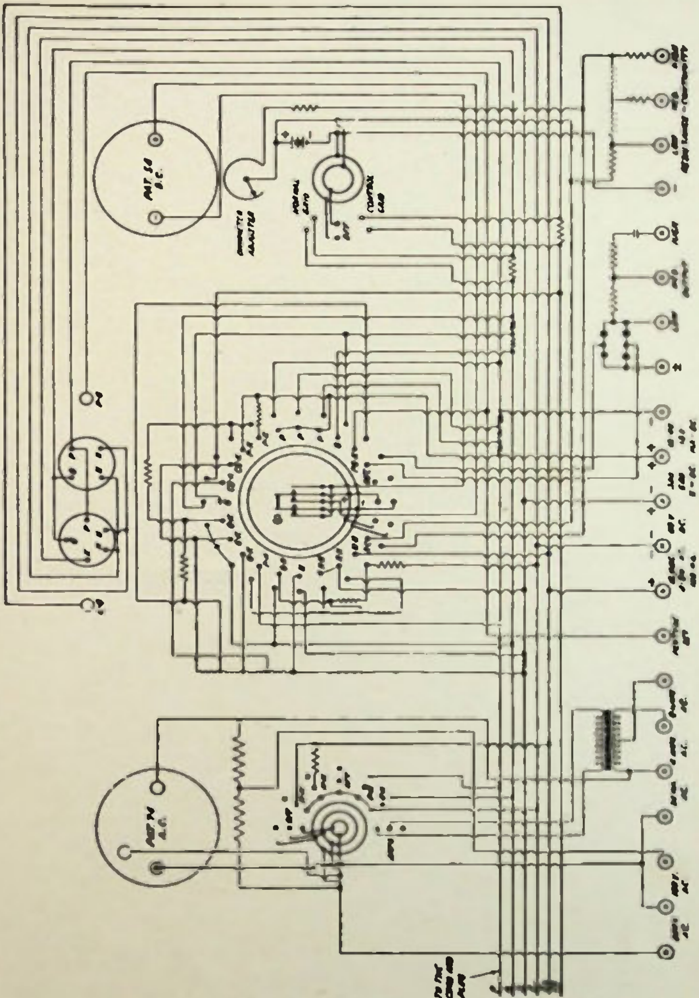
The combination A.C. milliammeter, ammeter and voltmeter with scales to read up to 20 and 120 milliamperes, 4 and 8 amperes, and 4, 8, 160 and 180 volts, (making 8 scales in all), is used for all A.C. measurements, and is at the left. This meter employs an accurately tapped current transformer instead of the usual shunts in order to facilitate changing the current scales on it. The D.C. instrument at the right, is a combination



Courtesy Jewell Elect. Instr. Co.

Fig. 32—A typical set analyzer employing two meters, a main selector switch at the center, and two switches at the sides. The cable and adapters are in the compartment at the rear. (Pattern 444.) See Fig. 33 for the circuit diagram.

milliammeter, voltmeter, ohmmeter, and output meter. The ranges are 12, 60 and 120 milliamperes; 6, 12, 30, 60, 120, 300 and 600 volts, 0-1,000, 0-10,000 and 0-100,000 ohms for the ohmmeter; and 1, 10 and

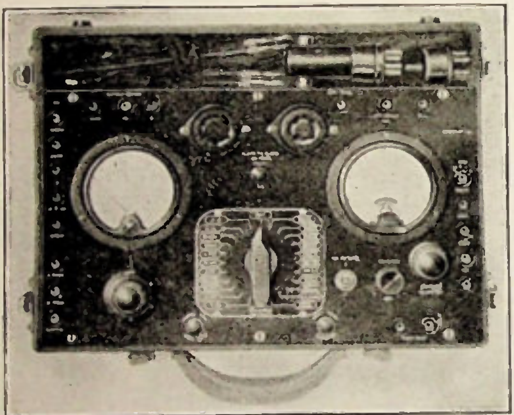


Courtesy Jewell Elect. Instr. Co.

Fig. 33—The complete schematic circuit diagram of the Jewell 444 set analyzer shown in Fig. 32.

50 volts for the output meter. The output meter consists of a copper-oxide rectifier used with this D.C. meter.

Complete operating instruction, tables and charts for capacity and resistance measurement, test prods, and extension leads are furnished with the analyzer. In order to assist the operator in making rapid tests all instrument ranges are selected by the large selector switch at the center and the two smaller ones at the sides. The various terminals of the 4 and 5 prong sockets are designated by the letters K, G, P, H_1 and H. These refer respectively to the *cathode, grid, plate* and the two *filament* or heater terminals. The selector switch is engraved so as to show the proper combination of these terminal markings. For instance, when taking a current reading, a single letter indicates the circuit in which the instrument is connected. When taking voltmeter readings, the letters shown indicate the two terminals between which the voltmeter is connected. The panel is supplied with 4 and 5 prong adapters to fit all types of tubes now used in radio receivers.

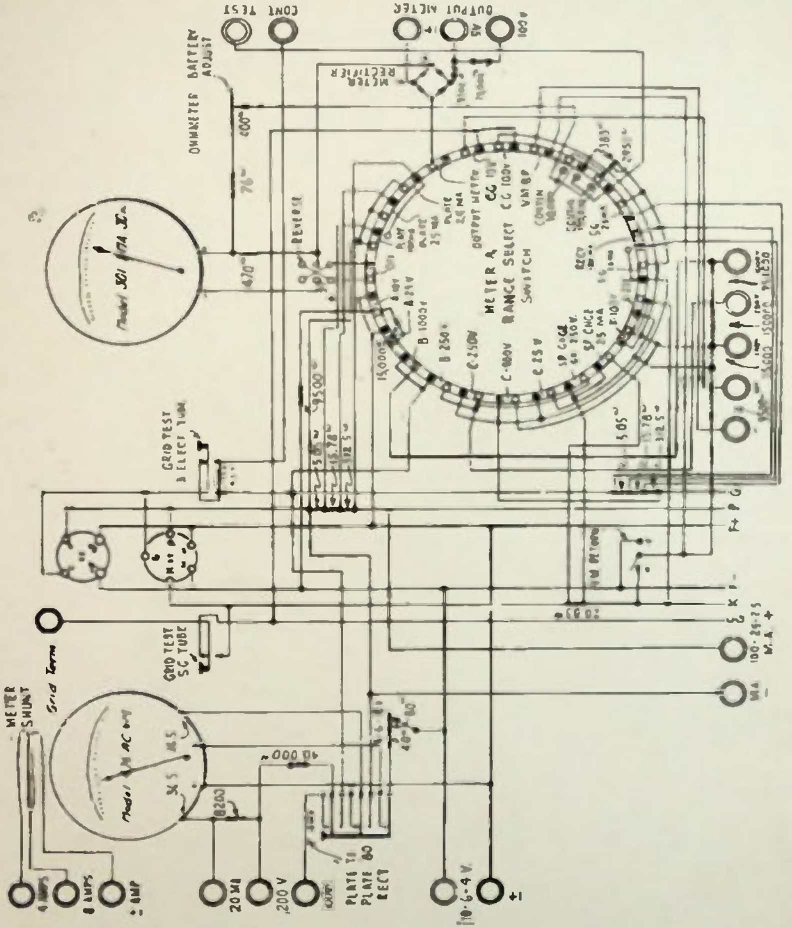


Courtesy Weston Elect. Instr. Corp.

Fig. 34—A typical commercial set analyzer which employs two multi-range meters and a rotary type tap switch for switching them properly into the various circuits. (Model 566.) See Fig. 35 for the circuit diagram.

Tube checking is performed in the analyzer by using a small "C" battery which may be connected into the grid circuit by means of a switch. This causes a change in the plate current of the tube under test—which is read on the milliammeter connected in its plate circuit. The change which this produces in the plate current is a measure of the mutual conductance of the tube. This is a good indicator of the condition of the tube.

The capacity of condensers may be checked by applying 110 volts 60 cycle A.C. from the electric light line to the condenser with the A.C. milliam-



Courtesy Weston Elect. Instr. Corp.

Fig. 35—The schematic circuit diagram of the Weston 566 set analyzer shown in Fig. 34. The single meter and range selector switch at the center performs most of the switching operations. The terminals at the sides of the analyzer are provided so the meters may also be used for making external tests for continuity, resistance, etc.

meter in series. Two ranges of capacities, .05 to 1.0 and .25 to 10 mf. can be checked in this way. The readings of the A.C. milliammeter are referred to a chart supplied with the analyzer. From this, the capacity value is found.

31. Weston set analyzer "Model 566": The Weston Model 566 analyzer shown in Fig. 34 illustrates an example of one in which the use of push-button switches has been abandoned almost entirely in favor of rotary type tap switches. The main selector switch at the center is of this type, the switch blade and contacts below the panel being operated by the knob or dial on top. This aids materially in simplifying the operation of the analyzer during tests. The complete circuit diagram is shown in Fig. 35.

An A.C. and a D.C. meter are used. The A.C. meter at the left, is a combination milliammeter, ammeter and voltmeter having ranges of 20 and 100 milliamperes, 4 and 8 amperes, and 4, 8, 16, 200, and 1,000 volts. The combination D.C. meter has ranges of 2.5, 25 and 100 milliamperes; and 10, 100, 250, 1,000 volts. The latter may also be used as an output meter having ranges of 5 and 100 volts, by means of the dry rectifier provided. Both meters may also be used for any external measurements. The scale of the D.C. meter is also calibrated in ohms for use as an ohmmeter with ranges of 0-10,000 and 0-100,000 ohms. Directly under the A.C. meter at the left is a 3 point dial operating a switch which changes the multiplier scale for filament voltage readings on A.C. tubes.

At the right below the main selector switch is the "grid-test" push button switch for changing the C-bias by 4.5 volts. The resultant plate current change is an indication of the condition of the tube. When testing screen grid tubes, pressing the "S. G. Tube Grid-test" push-button, connects the control grid to the cathode. This also causes a change in the plate current, the amount of this change being an indication of the condition of the screen-grid tube being tested. All types of screen-grid, and pentode tubes as well as the ordinary forms of tubes, may be analyzed.

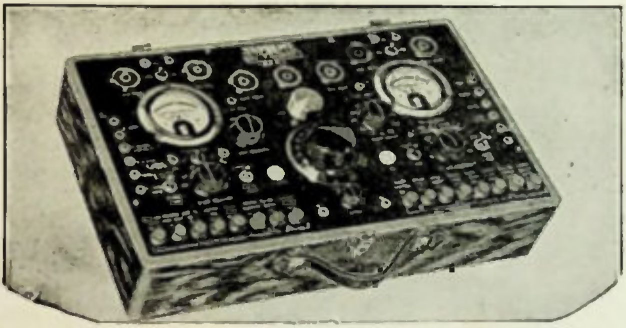
A number of ranges are available for measuring capacities by means of the output meter and the A.C. meter. Charts are provided which give the capacity for any scale reading. Inductance may also be measured by connecting it in series with the 115 volt 60 cycle A.C. electric light line and the 200 volt range terminals on the A.C. meter. A chart gives the inductance value corresponding to the various scale readings.

The rear compartment of the analyzer (Fig. 34), contains from left to right, two sets of test wires and prods for external testing of circuits and parts, the 5 prong plug for inserting into the receiver socket, and the 4-prong adapter used when circuits to a 4-prong tube are to be tested.

32. Supreme AAA-1 diagnometer: This instrument, shown in Fig. 36 is a veritable portable testing laboratory incorporating in a single carrying case, a complete set analyzer,

A.C. tube tester, shielded oscillator, ohmmeter and megohmmeter, and a capacity tester. With this arrangement, almost every conceivable test can be made.

This analyzer employs two instruments. Milliampere ranges of 2.5, 10, 25, 100 and 250 milliamperes, and 2.5 amperes, are available for measuring either A.C. or D.C. current by means of the copper oxide rectifier type meter and its associated scale selector switch. These ranges are also available for external tests. A D.C. milliammeter is always connected in the plate circuit. This arrangement provides plate current readings of tubes and circuits under analysis without the necessity for the manipulation of any current switches while voltage tests are being made. The copper-oxide recti-



Courtesy Supreme Instr. Corp.

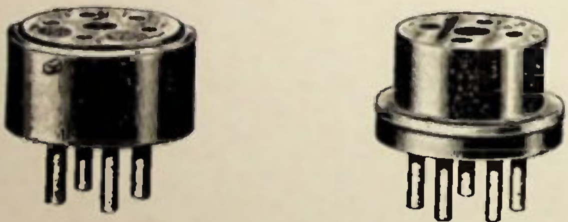
Fig. 36—The "AAA-1 Diagnometer" which combines in a single carrying case a set analyzer, A.C. tube tester, shielded oscillator, ohmmeter, output meter, megohm meter and capacity tester. The oscillator dial is at the center. Terminals are also provided for using the meters for external tests.

fier meter also provides both A.C. and D.C. voltage ranges of 2.5, 10, 25, 100, 250 and 1,000 volts. A range of 2,500 volts for external measurements is also provided. This is useful in public address or talkie equipment test work. Two 2500 ohm-per-volt ranges of 40 and 200 volts are also provided.

The separate tube checker incorporated into this Diagnometer has five tube testing sockets, to which the proper voltage is applied by means of selector switches. A suitable switch is also included to select the proper A.C. power supply potentials, ranging from 100 to 240 volts. Proper filament voltage (from 1.5 to 7.5 volts) may be obtained for any type of tube under test, by means of a "filament heater" selector switch. The grid bias potentials are provided by the voltage drop occuring in a biasing resistor. This arrangement enables a "grid or mutual conductance" test to be made on the tube. An oscillation test for matching tubes is also included, as well as tests for indicating the gas content of the tube under test, and arrangements for indicating the cathode-heater leakage of cathode type tubes.

In the completely shielded oscillator, the "harmonic principle" is utilized, whereby the range of 90 to 1500 kilocycles is available without changing coils. The harmonic frequencies are obtained by operating the type '31 oscillator tube with a comparatively high negative grid biasing potential, causing the tube to operate along the "lower bend" of the grid-voltage plate-current characteristic curve and so producing distortion of the wave-form of the oscillator's output signal. This distorted wave-form is composed of a fundamental frequency determined by the setting of the main vernier tuning dial, and several multiples or "harmonics" of this frequency. These harmonics may also be utilized. The oscillator tube may be either battery or A.C. operated. The strength of the radio frequency signals applied through the "dummy antenna" to the radio receiver under test may be varied smoothly by the tapered output control or "attenuator." The copper oxide rectifier type voltmeter connected in series with a self-contained condenser is used for measuring the output of the receiver under test, when this oscillator provides the signal voltage.

Several resistance measuring ranges are provided in the Diagnometer, by means of the ohmmeter circuit formed by the D.C. voltmeter connected in series with a battery. When the self-contained 3-cell, (4½ volt) flashlight battery is employed, resistance measuring ranges of 0-500 and 0-500,000 ohms are provided. By using an external 45 volt battery, it is possible to obtain a range from 0 to approximately 5 megohms. Making use of a potential of 250 volts D.C. which may be obtained from the Diagnometer, continuity testing up to 25 megohms is possible.

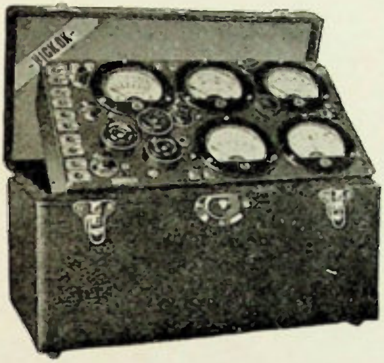


Courtesy Readrite Meter Works

Fig. 36A—Typical adapters for use with set analyzers. The one at the left enables a 5-prong analyzer plug to be inserted into a 4-prong tube socket—the "cathode" terminal remaining unconnected. That on the right is for adapting a 4-prong plug to a 5-prong socket.

By means of charts included with the instruction book, condenser capacities from approximately .002 to 10 mf. may be measured, as well as the leakage of paper condensers—up to approximately 4 megohms. Leakage is indicated by applying 250 volts D.C. to the paper condensers under test and measuring the leakage currents.

The schematic circuit diagram of this Diagnometer is not reproduced here, as it is too complicated to be of value when reproduced in so small a size. An interesting feature of this device is that it may be carried in a case mounted on a wall, or back of a test bench as a test panel. In this way it is instantly convertible from a portable laboratory to a complete test panel.



Courtesy Hickok Elect. Instr. Co.

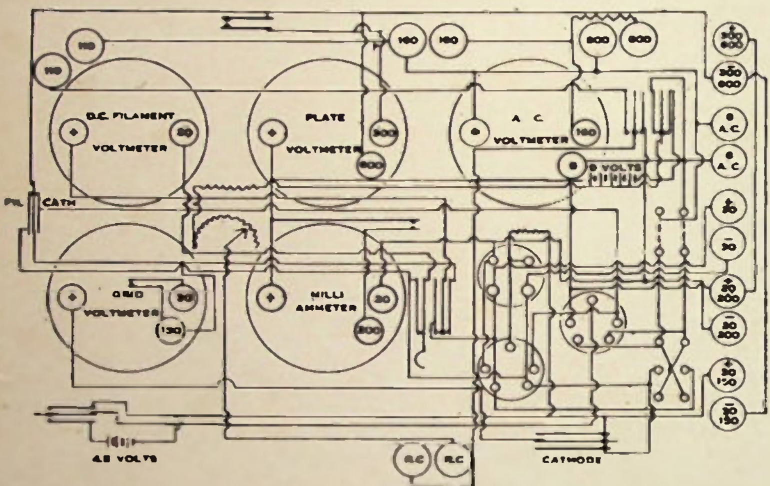
Fig. 37—A typical set analyzer in which separate meters are employed to measure the voltages and currents at each of the circuits of the tube being analyzed. (Type S.G. 4700.) See Fig. 38 for the complete schematic circuit diagram.

33. Hickok "Model S.G. 4700" analyzer: This analyzer, shown in Fig. 37, uses a separate meter to measure the voltages and currents at each circuit of a tube. This arrangement eliminates complex switching circuits, and all voltage and current readings in connection with the tube circuit under test, are indicated simultaneously. The schematic circuit diagram is shown in Fig. 38.

The three D.C. voltmeters used, have a resistance of 1333 ohms per volt, which means that they are so sensitive that a current of only 0.75 milliampere flowing through them will cause full scale deflection. The D.C. filament voltmeter, which is also used to measure the control grid voltage applied to screen grid tubes, has a range of 0-30 volts. The grid voltmeter has two ranges of 30 and 150 volts respectively, with the zero mark in the center of the scale so that either positive or negative voltages may be indicated without the need of any reversing switch arrangement. The plate voltmeter has two ranges, 300 and 600 volts.

The A.C. voltmeter has three voltage ranges, a low scale of 8 volts by which all values from 1 to 8 volts may be read in 1/10 volt values, a 160 volt scale for line voltages, and a high range of 800 volts to measure power transformer high voltage secondaries. This meter is also calibrated directly in microfarads permitting capacities from .25 to 15 mf. to be measured by the use of the 110 volt A.C. line as a source of voltage.

Scales of 20 and 200 milliamperes are provided on the plate milliammeter, as well as a direct reading ohmmeter scale making possible the checking of resistance values from 20 to 20,000 ohms. Any of the meters may be used individually for any external tests.



Courtesy Hickok Elect. Instr. Co.

Fig. 38—The complete circuit diagram of the analyzer shown in Fig. 37. Notice that five separate meters are used. This eliminates the complex switching arrangements and permits all the readings required at any tube socket, to be taken simultaneously.

Tubes are tested by noting the change in plate current (a measure of the "mutual conductance" or "transconductance") produced by introducing the voltage from a 4.5-volt "C" battery into the grid circuit of the tube under test. This is accomplished quickly by means of a push-button switch.

34. Dayrad "Type 880" set analyzer: The Dayrad analyzer, shown in Fig. 39, contains two meters, one for A.C. and the other for D.C. measurements. Its schematic circuit diagram as shown in Fig. 40. By means of a 17 position selector switch, two 3-position selector switches for changing the meter range, and 12 push-button switches, any voltage or current measurement in a broadcast receiver may be made. Amplifier tubes are tested by the "grid voltage change" method as in the other analyzers described.

There are three milliampere ranges of 5-25-125 milliamperes, and five D.C. plate voltage ranges of 6 to 255-50-125-150-500 volts. Provision has also been made whereby the A.C. meter can read A.C. milliamperes. Capacity measurements may be made directly, as the A.C. meter is also

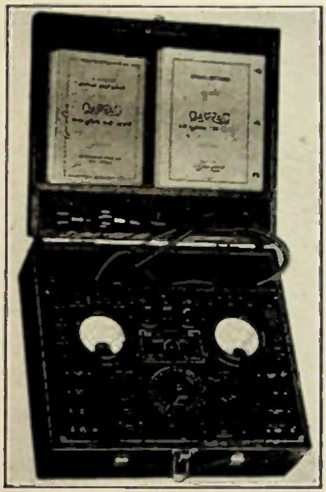


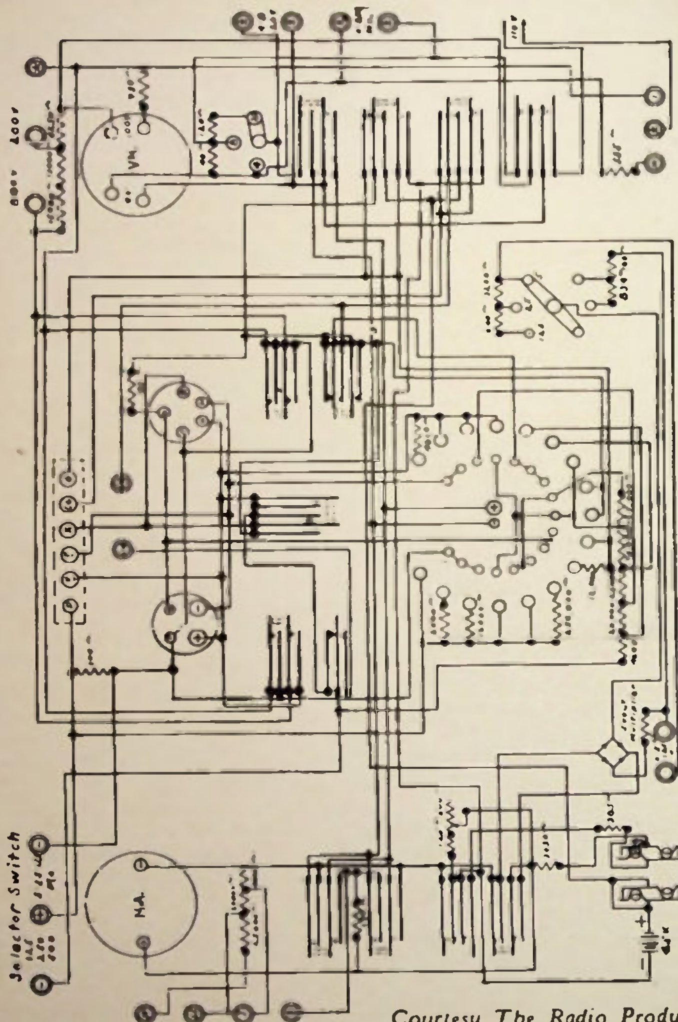
Fig. 39—Another typical set analyzer in which two multi-range meters and a selector switch are employed. Notice the cable 5-prong plug and 4-prong adapter in the rear compartment. The circuit diagram of this analyzer is shown in Fig. 40 ("Type 880").

Courtesy The Radio Products Co.

calibrated in microfarads. When this meter is connected to a 115 volt A.C. line it is possible to measure capacities in two ranges from 0 to 10 mf.

A dry rectifier is used with the D.C. meter to measure A.C. voltages with a sensitivity of 1000 ohms-per-volt in the three ranges of 5, 25, and 125 volts. This combination on the lower ranges is used as an output meter. The scale of the D.C. meter is calibrated directly in ohms, to be used as an ohmmeter in resistance measurements. Two ranges are provided, 0-10,000 and 0-100,000 ohms. The adjustable resistor is used to compensate for any drop in the voltage of the 4.5 volt C battery employed in the ohmmeter—due to age.

As in the case of the various other analyzers described, all adapters, leads, test prods, instructions and charts necessary to operate the analyzer efficiently and accurately are supplied with it. A compartment at the rear of the carrying case, see Fig. 39,



Courtesy The Radio Products Co.

Fig. 40—The complete circuit diagram of the set analyzer shown in Fig. 39. Note the connections of the meter selector switch at the center and the liberal use of push-button switches throughout.

is provided for these miscellaneous parts. The test plugs and cable are shown in this illustration.

35. Comparison of analyzers: A close study of the illustrations, schematic circuit diagrams and brief descriptions of the few representative commercial set analyzers just reviewed, will reveal the fact that in general they are all designed to accomplish essentially the same results i.e., analyzing the circuits of a radio receiver in which trouble of some kind exists, and then determining the exact nature of the trouble after the circuit in which it is located has been isolated. The Supreme AAA1 Diagnometer contains additional equipment such as the independent tube tester, and shielded oscillator, which other analyzer manufacturers have seen fit to market as separate test instruments. The use of selector and push-button switches for obtaining various ranges on the instruments, and for switching the instruments properly into the various circuits in order to make the required tests has become almost standard practice. The incorporation of suitable arrangements for making the meters available for use as ohmmeters, capacity testers, and for any separate outside tests or measurements has also become general practice. Of course the exact switching arrangements and layouts differ somewhat in the different testers. It is evident that great pains have been taken in the design of these analyzers to make them compact and readily portable, rugged, reliable, and complete in the sense that they will make practically any tests required in radio service work. A considerable amount of very clever design work has gone into the development of the switching arrangements and circuits, the main object being always to promote speedy manipulation in all test operations—for time means money to a radio service man and to the customer who must pay the bill for his services.

REVIEW QUESTIONS

1. In your opinion what is the difference between an "inoperative" receiver and a "defective" receiver?
2. Why is it a good plan to test all of the tubes of a receiver first, when starting to analyze the receiver? What information will this test supply?
3. What are the two main steps in servicing a radio receiver after the tubes have been found to be in good condition? Explain each, briefly.

4. Why is it possible to obtain a great deal of information regarding trouble in a receiver, by simply checking the plate and grid currents and the voltages existing at the terminals of the various tube sockets?
5. Draw a diagram and explain how the circuits leading to any tube in a receiver may be extended to any point outside the receiver, by means of a dummy plug, extension cable and a duplicate tube socket.
6. What is the value of this idea in radio service work?
7. Explain how you would check the filament, plate, and grid voltages of a 227 type separate heater tube by the arrangement explained in question 5.
8. Explain the advantages of using meter switching and range multiplying arrangements in radio set analyzers so as to permit of the use of one or two meter movements for all voltage and current tests.
9. What is a push-button switch? What advantages does this type of switch possess?
10. Draw a sketch of a push-button type switch which will close 3 circuits when the button is pressed down, and will open 2 of these circuits and close 2 separate ones when the button is released. Explain its construction and operation.
11. How does a tap switch differ from a push-button switch. What can it do that neither a knife switch or a push-button switch can do?
12. What is a radio set analyzer or tester? What is the advantage of using a set analyzer or tester instead of a number of separate meters for testing radio receivers?
13. Explain briefly, with the aid of sketches, the circuit arrangement and operation of a simple set analyzer. What tests can it make?
14. Why is it necessary to provide a means for reversing the voltmeter connections in a set analyzer when reading the grid voltage? Explain with the aid of a diagram.
15. Why is an A.C. voltmeter required in a set analyzer?
16. Explain in detail just what failure to obtain any readings at the following terminals of a tube socket in a receiver indicates: (a) across the filament; (b) from cathode to plate; (c) from cathode to control grid.
17. Explain in detail how you would proceed to diagnose the trouble and definitely locate it in a simple 5 tube tuned radio frequency receiver.
18. Explain at least 4 features which representative commercial set analyzers possess which are designed to speed up radio servicing and test work.
19. Why is it advantageous to be able to test the capacity and leakage of condensers with a set analyzer?
20. Of what value is the ohmmeter in a set analyzer? The output meter?

Chapter 5.

TROUBLE SHOOTING THE RECEIVER

FORMULATING A PLAN FOR SERVICING — PRELIMINARY STEPS IN TROUBLE SHOOTING — PRELIMINARY CHECK OF THE ANTENNA-GROUND SYSTEM — PRELIMINARY TESTS FOR CAUSE OF NOISY RECEPTION — PRELIMINARY TESTS ON THE RECEIVER — VALUE OF THE PRELIMINARY TESTS — GENERAL USE OF THE SET ANALYZER — PROCEDURE IN USING THE SET ANALYZER — INTERPRETING THE ANALYZER READINGS — TROUBLE SHOOTING THE RECEIVER OUTPUT CIRCUIT — TROUBLE IN THE SPEAKER FIELD WINDING — ADJUSTING DYNAMIC SPEAKER VOICE-COILS — RE-CENTERING PHONO PICKUP ARMATURES — LOCATING THE CAUSE OF "HUM" IN A RECEIVER — LOCATING CAUSE OF "FADING" — LOCATING CAUSE OF "DISTORTION."

36. Formulating a plan for servicing: The proceedure of testing to find the nature and location of the trouble in radio equipment, is commonly called "trouble shooting." It should be the ambition of every Radio Service Man to become expert in locating trouble quickly and directly. The ease and rapidity with which a receiver is analyzed or diagnosed, depends largely upon the technical knowledge and practical experience possessed by the individual, as well as the test equipment he has available. It is impossible for one to become an expert "trouble shooter" unless he has a thorough knowledge of the fundamental principles upon which the different parts in radio receivers operate, and the circuits which are employed in the main types of sets. This knowledge can only be gained by a thorough training in electrical and radio principles, and by constant reading of current radio trade magazines and books. Every man should work out his own definite course of proceedure for locating the nature and source of any trouble that may cause the receiver to operate unsatisfactorily or make it cease to operate entirely. The radio

set analyzer is a valuable aid in this work, but as we shall now see, intelligent radio servicing consists of more than merely operating a set analyzer. The Service Man must also learn to observe and recognize symptoms which the analyzer may not disclose at all. This chapter has been written to serve as an outline and a guide for the development of a thorough, rapid system of "trouble shooting" by the novice. He will undoubtedly add many additional tests and tricks to his procedure as his experience in radio service work on the many different types of receivers increases.

37. Preliminary steps in trouble shooting: Before any effort is made to diagnose the receiver, the Service Man should question the set owner in order to acquaint himself with all the information the owner can give. In many cases, the data obtained by these questions will give some indication of the probable source of the trouble before any testing is actually done. Upon arrival at the customer's home, questions such as these should be asked.

(a) "What is your complaint?"
(b) "How long has the set been acting this way?"
(c) "Did your set ever have the same trouble before?"
(d) "Did the set stop suddenly?"
(e) (If the trouble is noisy reception), "At what periods of the day and evening is the set noisy?"

These questions will usually lead to others, and an idea of where to begin trouble shooting may be obtained from them. Under no circumstances should the customer be asked the question, "What is the trouble?", for if this were known, the probability is that a Service Man would not have been called in.

The receiver switch should now be turned on, and after allowing the tubes to heat up properly, an attempt should be made to tune in a station as loudly as possible. The next step to follow depends upon what happens as this is done. It is very likely that a clue to the trouble will be obtained quickly by carefully noting the symptoms exhibited by the receiver, and making a few preliminary routine tests which take only a few minutes to perform. Some of the symptoms are as follows: the set may not play at all; it may play weakly; reception may be noisy or intermittent; the tone quality may be poor; the loudspeaker may blast on loud notes; one or more tubes may not light up; the set may oscillate; etc. We will now consider some of the preliminary tests which may be made part of every Service Man's routine, since they will disclose troubles that the set analyzer will not reveal. They can be made without removing the receiver chassis from the cabinet.

38. Preliminary check of the antenna-ground system: If the tubes light up properly but there is little or no volume when the set is tuned and the volume control is turned up to the "maximum" position, the "B" battery voltages should be checked at once if it is a battery operated receiver. If it is an electrically operated receiver, the antenna-ground system should be checked over at once in either of the two following ways:

A rough comparative test of the signal pick-up capability of the antenna may be made by tuning the receiver to a broadcast or an oscillator signal with the volume control at "maximum" and then disconnecting the antenna wire from the receiver. The signal strength should fall off very noticeably when the antenna is disconnected. If a broadcast or oscillator signal is not available, the antenna wire should be disconnected and repeatedly tapped on the "Ant." binding post of the receiver. A loud "clicking" sound should be emitted by the loudspeaker when this is done. The *absence* of these reactions usually indicates an *inefficient* antenna circuit.

A high resistance ground is often the cause of weak signals. The efficiency of the ground circuit may be checked in a similar manner, although

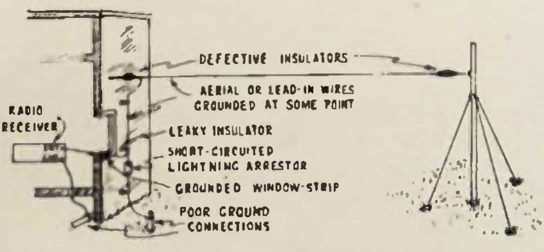


Fig. 41—Places in a typical antenna-ground system where troubles may originate.

there may not be a very large drop in volume when the ground lead of an A.C. operated receiver which employs "grounding condensers" for minimizing hum effects is removed. These constitute a low-impedance path for the r.f. signals to the power supply circuit, one side of which is generally grounded.

A more detailed test of the antenna-ground system, is to carefully inspect as much of the antenna and ground wires as are conveniently accessible. The lead-in and aerial portions of the antenna should not touch any grounded metal objects at any point. All aerial and ground joints should be properly soldered to prevent corroded connections. The insulation on the window lead-in strip should also be examined. The strip should *not* be nailed to the window sill. The possible defects in an outdoor antenna system are shown in Fig. 41. The ground clamp should be *clean* and *tightly* fastened to a *clean* portion of the object used for grounding, (usually a water pipe).

A quick test to determine if the antenna is grounded at any point, may be made by connecting an ohmmeter between the antenna and ground leads, (when they are disconnected from the receiver), and measuring the insulation

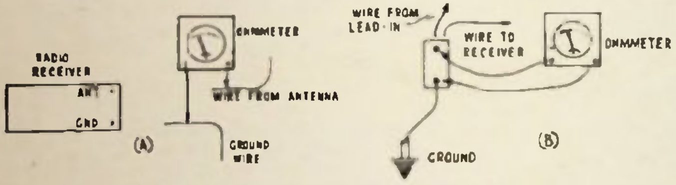


Fig. 42—(A) Testing the antenna circuit for a possible ground by connecting the lead-in wire and the ground wire to an ohmmeter and measuring the resistance of the insulation between them. (B) Using an ohmmeter to test the lightning arrester for a possible short-circuit.

resistance between them, as shown at (A) of Fig. 42. The tests shown at (A) or (C) of Fig. 18 may also be used, if an ohmmeter is not available. The lightning arrester may also be tested for leakage or short circuits by means of an ohmmeter as in (B) of Fig. 42, or by the arrangements of (A) or (C) of Fig. 18. All wires should be disconnected from one terminal of the arrester first. Thre should be *no continuous circuit through* the arrester. The wires should be connected back to it again after the test.

39. Preliminary tests for noisy reception: If the complaint is one of "noisy reception," it is possible that the condition is caused either by a defective tube, or by some loose connection or broken wires within the receiver or the antenna-ground system. It is also possible that it may be caused by inferior or defective electric appliances, or electrical machinery, operated within the vicinity of the rado receiver. The following preliminary test may be made:

While the noise is being received strongly, disconnect both the antenna and ground wires from the receiver terminals. Of course the broadcast program will not be heard when this is done. Usually, it is best also to short the "Ant" and "Gnd" terminals on the set by a *very short piece* *of wire.* If the *noise* does not disappear or decrease in strength when this is done, the trouble is most likely in the radio apparatus itself. This should now be tested until it is located. On the other hand, if the noise disappears or diminishes in strength, the cause is generally located outside the receiver. In this case, the problem is usually more difficult, for the disturbance may be set up by an electrical device located in some unknown place hundreds of feet away from the receiver or antenna, and it must be located.

The complaint of noisy reception is such a common one with our modern screen grid electric receivers of extremely high sensitivity, and the use of so many electrical appliances in the modern home, that the different tests and filters required to track down and eliminate the sources of noise will be considered in detail as a separate subject in Chapter 8. The reader is referred to this chapter, if he is particularly interested in this phase of radio servicing.

40. Preliminary tests on the receiver: If the foregoing tests do not result in disclosing the cause of the trouble, or if the receiver does not operate at all, attention should now be directed to the receiver itself. There are several preliminary tests which require only a few minutes to make, and which will often enable the Service Man to quickly localize the trouble in the receiver without removing the chassis from the cabinet, or using the set analyzer.

There are but two main types of broadcast receivers in common use in the United States at the present time. These

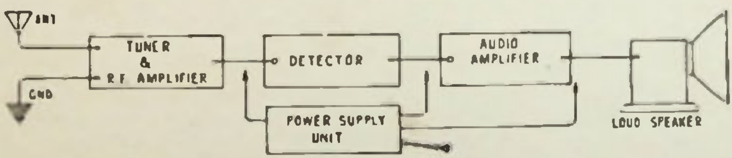


Fig. 43—Functional block-diagram showing the sequence of the main parts in a typical T.R.F. receiver. The signal voltages act on the antenna-ground system at the left and the action proceeds through the parts of the receiver from left to right.

are, the tuned radio frequency type of receiver, and the superheterodyne which has attained great popularity during the last few years. Of course the receivers of different manufacturers differ greatly as to individual circuit and tube arrangements, parts design and layout, etc., but they may all be resolved down to these two main types. Every radio receiver consists of several separate electrical units which perform distinct functions in its operation. These units may be all built together into a single chassis, but for the purposes of receiver analysis it is very convenient to consider them separately.

The usual tuned radio frequency type of broadcast receiver consists of the *tuner and radio frequency amplifier*, the

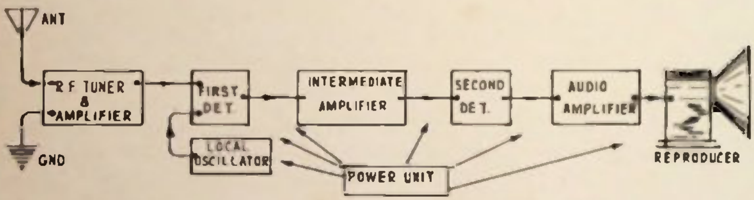


Fig. 44—A functional block-diagram showing the sequence of the main parts of a typical superheterodyne type of receiver. The power supply unit supplies all filament and plate power to the tubes.

detector, the *audio frequency amplifier*, the *reproducer* or *loud speaker*, and the *power supply*. A simple block diagram showing these units in their proper sequence from left to right as the radio signal progresses through them is shown in Fig. 43. The block diagram showing the sequence of the main parts in a superheterodyne receiver is shown in Fig. 44. A study of this diagram shows that the signal impulses progress from the antenna-ground circuit to the *R. F. amplifier;* thence to the *first detector* or *"mixer"* tube, (*the local oscillator* also feeds into this); then through the *intermediate frequency amplifier;* through the *second detector;* through the *audio amplifier;* and finally into the *loud speaker*. The *power supply unit* feeds the necessary power to properly operate the tubes, in each of these systems. In many superheterodynes, particularly the midget type receivers, the R.F. amplifier ahead of the first detector is not employed, the signal being fed directly to a tuned circuit ahead of the first detector or "mixer" tube.

There are several simple tests which usually enable the Service Man to tell quickly in just which of these main portions of a receiver the trouble lies. These tests are as follows:

Tap the detector tube sharply with the finger. If this causes a ringing sound in the loud speaker, it indicates that the audio frequency amplifier, the loud speaker, and the power supply unit are at least operating and we may pass on to the next test at the detector. If no ringing sound is produced, attention should be directed to individual tests on each of these parts. These will be considered later. The quick test for the detector

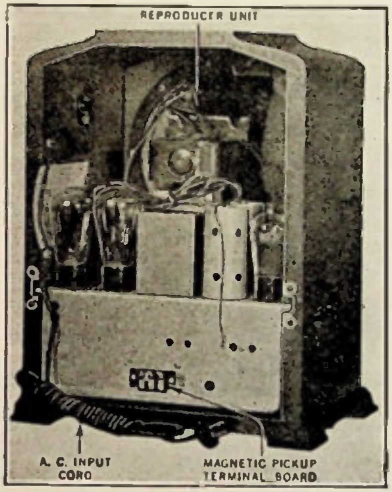
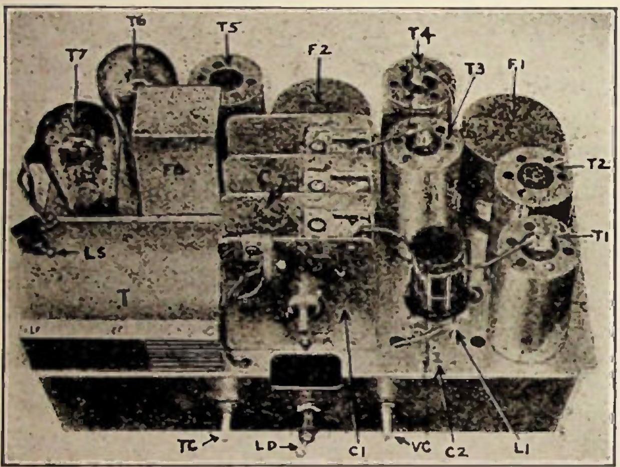


Fig. 44A—A typical midget type T.R.F. receiver mounted in its cabinet with a dynamic cone speaker (reproducer) visible above the set chassis. Note the compact arrangement of all of the tubes and other parts mounted above the base. Many of the parts are mounted underneath this base.

Courtesy R. C. A. Victor Co.

consists in placing a finger, or the antenna lead, upon the grid terminal of the detector tube while it is in the socket. A loud hum should be heard if the *detector*, audio amplifier, loud speaker and power supply are functioning. Should the detector be a screen grid tube, this test should be applied to the control grid cap of the tube—with the connecting clip removed. If this test fails to indicate the location of the trouble, it is probable that it is in the radio or intermediate frequency end of the receiver. At any rate, the detector, audio amplifier, loud speaker and power supply have been eliminated from suspicion for the time being.

Suppose the receiver is of the T.R.F. type and that the detector and parts following it are shown to be operating by these tests, then the next step is to locate in just which portion of the radio frequency amplifier the trouble lies. This can be determined by first removing the *last* R.F. amplifier tube and inserting the antenna wire into the *plate* prong hole of the socket, so that it makes contact with the plate terminal contact piece in the socket. The receiver should then be tuned to a local station which is normally received very loudly, to see whether any reception can be obtained. If this stage proves satisfactory, this tube should be replaced, and the one from the stage immediately preceding the last R.F. withdrawn, and the antenna wire placed upon the plate terminal contact piece of that tube



Courtesy Pilot Radio & Tube Corp.

Fig. 44B—A top view of a typical midget superheterodyne chassis. Note the 3-gang tuning condenser C, power transformer T, filter condenser block F_B, tuning coil L_1, tubes and tube shields T, intermediate frequency coils and shields F_1, F_2, etc. This is what the Service Man sees when he removes the chassis from the cabinet.

socket. This procedure should be continued until the inoperative stage is found.

Still another method by which receiver failures can be quickly isolated, and one used by scores of Service Men, is the practice of removing and reinserting each tube from its socket and carefully noting the "click" produced in the speaker, the last audio tube being removed first. If no click is heard upon removing a tube, it is almost certain that the faulty stage or circuit has been located, and that particular part of the set should be tested thoroughly, the trouble found and repaired.

At the same time, the receiver chassis should be removed from the cabinet and a visual and mechanical inspection of the set should be made.

Wires may be loose, burnt out, grounding against the chassis frame, shorting against each other, etc. Tubes whose filaments are burned out can easily be spotted at once by the fact that they do not light up. Each tube should be tapped lightly, but firmly, with the finger (and the result noted by the sound from the loud speaker), to determine if any of its elements are loose or shorted. Unless the receiver is in operating condition, the last mentioned test will be ineffective, as no indication will be given by the loud speaker.

41. Value of preliminary tests: The reader may wonder at this point, why, if the radio set analyzer studied in Chapter 4 is so helpful and important in radio service work, has it not been mentioned thus far in the tests described for locating the trouble in the receiver? The answer to this logical question is that while a Service Man could start a service job by immediately bringing his analyzer into use and taking all necessary readings at the various tube sockets in the receiver in order to locate the trouble, it has been found by experience that in the majority of cases, radio receiver troubles are of such a nature that the trouble can be located more quickly if the Service Man makes the preliminary tests mentioned thus far in this chapter first, if the symptoms of the trouble are the common ones mentioned. After these tests are understood and practiced, they take but a few moments to perform, and are carried out almost automatically by most Service Men. If these tests show the trouble to exist in the antenna--ground system, the Service Man need not waste time testing the entire receiver, but may proceed at once to localize the trouble in the antenna-ground system. Likewise, if these tests show the trouble to exist in the detector circuit or the R.F. amplifier, etc., of the receiver, the set analyzer may be used immediately to test the circuits of the tube in the particular stage suspected—without taking the time to test the circuits of all the other tubes.

If the receiver will not operate at all, and these preliminary tests do not give any clue to the possible location of the trouble, the set analyzer must be resorted to, and the circuits at each tube socket must be analyzed with it.

42. General use of the set analyzer: All commercial set analyzers are supplied with detailed instruction books which explain the proper manipulation and use of the various push-buttons, selector swtches, adapters, meters, etc., for making the various tests. Since the arrangements of these buttons, selector

switches, etc., differ in the different makes of analyzers, it is not desirable to go into a detailed explanation of these manipulations here. For example, the reader can quickly find out by reference to his instruction book, which button or switch needs to be manipulated on his particular analyzer for making say a plate voltage test, or a grid voltage test, etc. We are interested more in the general procedure of analyzing the receiver, and interpreting the readings obtained. It is not enough to merely manipulate a set analyzer according to the instruction booklet accompanying it. The readings obtained on it must be intelli-

VICTOR—Model "Micro-Synchronous"
Line Voltage 112—Voltage Tap 120—Volume Control Full

[illegible]	[illegible]	[illegible]	[illegible]									
			OPERATING VOLTAGES					MIL-AMPERES				
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	224	1 R.F.	2.15	172	2.5	80	-	-	2.5	5	2.5	
[illegible]	224	2 R.F.	2.15	172	2.5	80	-	-	2.5	5	2.5	
[illegible]	224	3 R.F.	2.15	172	2.5	80	-	-	2.5	5	2.5	
[illegible]	224	Det.	2.15	75*	-	2.5	8	-	-	-	-	
[illegible]	227	1 A.F.	2.15	65	-	0	-	-	1.5	1.8	.3	
[illegible]	245	PP-AF	2.25	185	-	36	[illegible]	-	10	22	3.0	
[illegible]	245	PP-AF	2.25	185	-	36	-	-	10	22	3.0	
[illegible]	280	-	4.8	-	-	-	-	36	36	-	-	
[illegible]												
[illegible]												

Courtesy Jewell Elect. Instr. Co.

Fig. 45—A typical set data chart. This gives the readings which should be obtained at the various tube sockets of a particular model and make of receiver. Booklets containing charts of this kind for the various standard makes and models of receivers are issued by the set analyzer manufacturers and by some set manufacturers.

gently interpreted in order to determine where the trouble lies and what its nature is.

Interpreting the readings of the analyzer depends upon the circuit design of the receiver, and it is often absolutely essential that knowledge of the circuit diagram of the receiver under test be known in order to determine the trouble. This is especially true with modern electric receivers of complicated design. Circuit diagrams of most of the radio receivers manufactured in the United States can be obtained from Radio Service Manuals compiled especially for this purpose.

Of course no Service Man can tell whether the voltage and current readings he is obtaining at the tube sockets with his analyzer are correct or not, unless he knows just what these readings should be for the particular model of set he is testing. This information can be obtained from the following three sources:

He should make it a habit to test all new models of receivers which are issued, whenever possible. The readings obtained at the tube sockets should be recorded and filed away for future reference. Most manufacturers of set analyzers issue booklets containing records of the various voltage and current readings which should be obtained at each of the tube sockets in the popular makes and models of receivers—when the receiver and tubes are in normal operating condition. Some receiver manufacturers also supply this information in their service bulletins. A typical Set Data Chart of this kind is reproduced in Fig. 45.

43. Proceedure to follow in using the set analyzer: As the general arrangements of the circuits and meters, and the ideas involved in the modern set analyzer, have already been studied in Chapter 4, they will not be discussed again here. It will be remembered that the main purpose of the analyzer is to extend the various circuits terminating at any tube socket in the receiver to a point outside the receiver, for convenience in testing by means of suitable measuring instruments which may be rapidly switched into the various circuits for this purpose. The detailed proceedure for analyzing the receiver follows.

A. Starting the analysis: The first step is to place the radio receiver in as nearly good operating condition as is possible. If it is battery operated, all batteries should be properly connected. If it is operated from the electric light socket, connect it to this circuit properly. Turn on the set, and make such adjustments as are normally necessary to tune it for the proper response to broadcast signals. In general all tests should be made with the volume control in the "maximum volume" position, since the maximum voltages are generally supplied to the various circuits with this setting. A second set of readings with the volume control in the "average working position" is also helpful in locating trouble in some receivers.

B. Place for the tubes: During the tests, all tubes should be left in their respective sockets in the receiver, with the exception of the tube from the socket under test. The analyzer plug is placed in this socket, and the tube is placed in the proper socket on the panel of the set analyzer, (see (C) of Fig. 22).

C. Checking the power supply: The first electrical check should be made on the power supply unit to determine whether it is supplying normal voltages to the various circuits of the radio set. If the set is of the battery operated type, check the voltages of the various batteries by making use of the analyzer voltmeter terminals provided for "external tests," and the test leads provided. If the battery voltages are low, they should be recharged or replaced. (A 45 volt "B" battery unit should be discarded when its voltage drops to about 30-35 volts when in use.)

D. Checking the line voltage: If the receiver is supplied with power by direct connections to the house electric light circuit, the line voltage supplied to the receiver should be checked with the proper voltmeter, to make sure it is of the correct value for the set, as indicated in the instruction book or on the nameplate of the set.

E. Checking the rectifier tubes: The rectifier tube or tubes should be checked by placing each one in the analyzer in turn, and placing the analyzer plug into the tube socket. The A.C. filament voltage and the current flowing through each plate of the tube should be checked by manipulating the proper switches. The total plate current in a half-wave rectifier tube (type '80) is equal to the sum of the currents through each plate. The analysis of the conditions indicated by these and all following readings will be considered in detail later.

F. The voltages applied to the rectifier tube plates by the secondary winding of the power transformer should next be checked by means of the high range of the A.C. voltmeter. In the case of a half-wave rectifier tube, the voltmeter is switched to read the voltage between the Plate and Filament. In the case of a full-wave rectifier, a reading is taken from P to F and from G to F.

G. Analyzing the amplifier circuits: After the source of power to the radio set has been checked in this way, the next procedure is to check the current and voltage supplied to all terminals of each tube in the circuit. The usual practice is to check the tubes in the order in which the signal passes through them, that is, start with the antenna stage and end with the power amplifier or output stage.

Each tube should be removed from its socket in turn, in the above order, placed into the socket of the analyzer, and the plug of the analyzer placed into the same socket of the receiver from which the tube was removed. By pressing the proper buttons and manipulating the proper switches, as explained in detail in the instruction book accompanying the particular analyzer employed, all of the important voltage and current readings existing at each tube socket may be obtained. The number of readings taken is dependent upon the type of tube used. For a complete analysis of the circuits to a 3-element tube, it is necessary to measure the following values: (1) plate voltage, (2) plate current, (3) grid voltage, (4) grid current, (5) filament voltage. Where cathode, screen grid or pentode tube circuits are being analyzed, the following additional measurements should be known: (6) cathode voltage, (7) screen grid voltage, (8) screen grid current.

Inserting the plug of the analyzer into the tube socket of a radio frequency or detector stage of a receiver will detune that stage during the test, due to the added capacity, inductance and resistance of the analyzer circuits, so that whatever signals may be heard before plugging into the socket may be weakened or eliminated during the test. Instead of broadcast signals, a hum or other circuit noises may be emitted from the loud speaker while the set analyzer is plugged into one of the radio tube sockets. This does not, however, affect the continuity tests, nor indicate any defect in the radio or in the set analyzer.

H. Testing the tubes: In many instances, weak, shorted, or burned-out tubes are causes for an inoperative receiver. Therefore, every tube in the receiver should be tested and a new one substituted for each found to be bad. Radio receiver servicing, to be profitable, necessitates the speediest form of work, consistent with accuracy and productive of good results. With this in mind, the Service Man may wonder which is the best and most suitable test for a vacuum tube. The three important electrical characteristics of a vacuum tube are its *amplification constant*, *plate impedance* and *trans-conductance*, (formerly called *mutual-conductance*). It would appear that all three quantities would have to be measured in order to tell whether the tube is in good condition or not. Actually, however, this is not necessary for ordinary rapid service testing. If we can measure one of these factors we will have a check of the other two, provided we know what the normal characteristics of the particular type of tube being tested, should be. The characteristic usually chosen for measurement in commercial tube checkers and analyzers used by radio Service Men and dealers, is the *trans-conductance*, for this is the most important quantity to determine. If a test indicates a tube to have a normal value of trans-conductance, we can be reasonably sure that the amplification constant and plate impedance are also normal, since, if any change due to the presence of gas, low electron emission, or disarrangement of the tube's electrodes should occur in a tube, the transconductance would be affected.

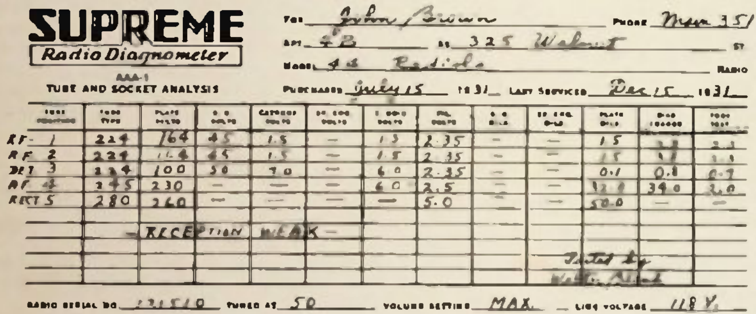
Fortunately, we do not have to measure and calculate the actual exact value of the trans-conductance in order to check the condition of a tube—all we need is some indication that the tube has a *normal value* of trans-conductance. If we change the grid voltage of the tube under test by a definite amount, and note the change which this produces in the plate current, we will have in effect an indication of trans-conductance, and from a suitably prepared chart we can determine whether the change in plate current that we noted was normal for that type of tube. This is called the "grid change" method of tube testing. It is the basis for testing tubes in practically all the common set analyzers and tube checkers.

For testing 3-electrode tubes, the analyzer is usually provided with a switch or push-button which connects a 4.5 volt flashlight battery into the grid circuit, thereby changing the grid potential by 4.5 volts. The change which this produces is read on the plate milliammeter and is recorded (see the last three columns on the extreme right of Fig. 46.) The value of this *plate current change* is a measure of the trans-conductance and worth of the tube.

For testing screen grid and pentode tubes, the 4.5 volt flashlight battery is connected in the *control grid* circuit when the proper button or switch is operated.

In some analyzers the flashlight battery is connected so as to make the grid voltage *more negative*, thus causing the plate current to *decrease*. In others, the battery is connected so as to make the grid voltage *more positive*, thus causing the plate current to *increase*. It is evident therefore, that a chart giving the expected plate current changes for the various types of tubes must be supplied with the analyzer by the manufacturers, since this chart must be compiled on the basis of the particular voltage conditions employed in the test with that particular analyzer.

By making the "grid test" in this way at the time the circuits of a tube are analyzed by the analyzers, the condition of the tube itself may be ascer-



Courtesy Supreme Instruments Corp.

Fig. 46—A typical radio set analysis chart on which the readings obtained by a set analyzer have been recorded by a Service Man. Charts of this kind enable the Service Man to keep a permanent record of every set he is called upon to service.

tained. Definite allowable variations from the "plate current bias change" values shown in these charts cannot be specified, since a relatively large change in trans-conductance causes only a small change in tube performance as judged by a listening test under receiving conditions. It may be generally stated that a tube which will show *no* change in plate current when manipulating the proper "bias change" switch, will not amplify signals well, but that tubes which are within about 25% of the values on these charts, or of their calculated mutual conductance values, will generally operate satisfactorily. When the plate current changes are less than one-half of those specified on the chart, however, the tubes should generally be replaced. Tubes which cause noisy operation of a receiver should be replaced irrespective of their test readings.

The testing of tubes will be considered in greater detail later in the chapter devoted to tube testing. A table of trans-conductance values will be found here also in Fig. 107.

I. Recording the readings: It must be evident at this point, that quite a few instrument readings are obtained during the complete analysis of all the tube circuits of a receiver. It is difficult, and not advisable, to try to keep all these readings in mind for comparison and study, particularly with receivers having many tubes. It is much better to record all readings on a suitably prepared Analysis Chart as soon as they are taken. Charts of this kind may be prepared by the Service Man or may be purchased from the manufacturer of the analyzer.

A typical chart of this kind, in which the readings from a set analysis have been recorded, is shown in Fig. 46. Notice that space is also provided for recording other valuable information which may be very helpful if any question arises later regarding the condition of the receiver and the work done on it. The reverse side of this particular chart is provided with a space for stamping or imprinting the telephone number, address, and other advertising data, of the radio servicing establishment. Below this space is tabulated, in the form of a customer's account statement, the various servicing items which generally constitute the basis of service charges, the arrangement being such that the various service adjustments are suggested to the radioman in the proper order. In commercial servicing, it is suggested that a copy of the chart be furnished to the owner of the radio set so that he may have a record of the condition of his set with an indication of the work done with the corresponding charges. A copy of the chart may be retained for future reference and for a record of the customer's full name, address, and telephone number where mailing lists or other follow-up plans are utilized by the servicing establishment.

44. Interpreting the analyzer readings: After all of the readings have been obtained with the analyzer, they must be

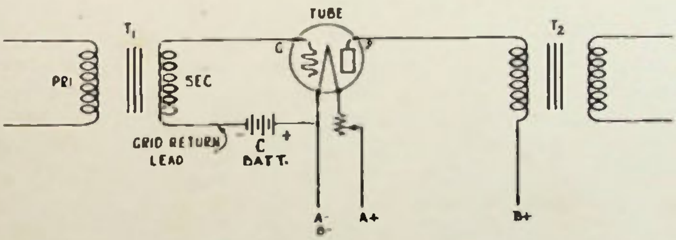


Fig. 47—In battery operated receivers the C-bias voltages for amplifier tubes are obtained by means of one or more C batteries connected in the grid-return circuit, as shown.

compared with the readings which should be obtained under normal conditions of operation. As explained in Art. 42, and shown in Fig. 45, charts giving the correct voltages and currents which should exist at the various tube terminals are available for many popular receivers. Of course if a tube tests O. K., and the proper voltages and currents exist at its terminals, as revealed by the analyzer test, both the tube and its circuits may be dismissed from all suspicion for the time being. If the tests indi-

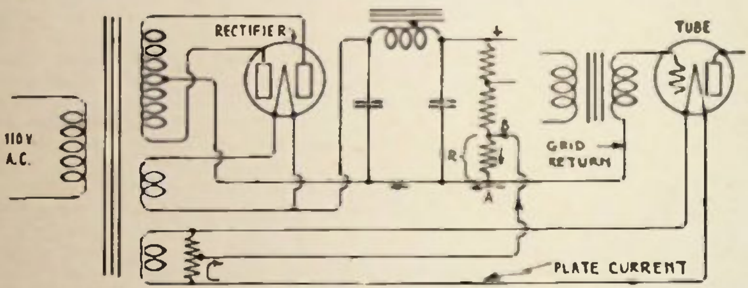


Fig. 48—One of the several circuit arrangements employed for obtaining the required C-bias voltage in many old electric receivers which use direct-heater type tubes.

cate that one or more of the currents or voltages are not at normal value however, the Service Man must interpret the readings in terms of what may be wrong with the circuits connected with that particular tube. This is the part of the trouble-shooting proceedure in which the experience, radio and electrical knowledge, and keenness of mind of the Service Man are required most, for intelligent servicing. He must learn to understand the language in which the set analyzer points out the location and cause of the trouble.

In order to quickly and fully comprehend the meaning of the readings obtained during the analyzing of the receiver, it is extremely important to consider certain parts of complete receiver systems. Each receiver has its own circuit peculiarities, and manufacturers do not employ the same means for securing grid bias voltages, coupling R.F. and audio stages, etc., in all models and types of receivers. The different methods employed have great bearing upon voltage and current indications when trouble exists, and special attention should be paid to these points. Let us take first for our discussion the subject of grid bias.

A. Interpreting the grid bias voltage readings: In all modern electrically operated radio receivers, the grid bias voltages applied to the tubes are obtained by means of the voltage drops produced by the passage of current (usually plate current from the tubes) through resistors of proper values. For the purpose of our discussion, no attempt will be made to offer a lengthy technical explanation from a theoretical standpoint. In most battery-operated receivers, only the audio amplifying tubes receive any grid bias voltage, and this is usually obtained by a small "C" battery connected in series with the "grid return" wire of that stage, as shown in Fig. 47. The negative terminal of the battery goes to the grid side of the circuit.

Where direct heater type tubes such as the 226, 171A, 245, etc., are employed in an A.C. electric receiver, two methods of securing the proper grid bias voltages are commonly employed. The first method can be most easily shown by the portion of a complete receiver circuit, shown in Fig. 48. The path of the flow of the plate current of the tube is shown by the arrows. This current flowing through resistor R (which is a portion of the voltage divider resistor), produces a voltage drop across it, so that the potential of point A is lower than that of point B. The grid return circuit of the tube is connected to A, therefore it is at a lower or negative potential with respect to point B and the electron emitter of the tube. Several manufacturers have used this method for biasing all the tubes in the receiver. The Kolster models 6J and K20, and Stromberg Carlson models 635 and 636 are examples of this.

The second C-bias arrangement also used with direct heater type tubes is shown at (A) of Fig. 49. This is more popular. Here, the resistor R is connected in the plate return circuit. The plate current, I_p, of the tube flowing through resistor R causes a fall of potential in it, so that the electric

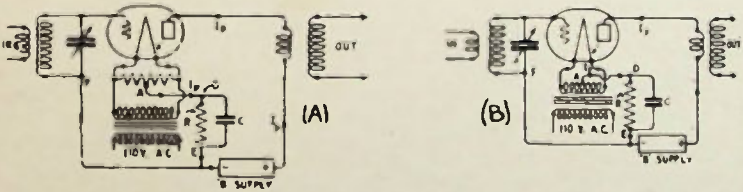


Fig. 49—Two arrangements of another method of securing C-bias voltages in old electric receivers employing direct-heater type tubes (see text).

potential of point E is lower than that of point D. The grid return F, and the grid, being connected to point E, are therefore maintained at this definite negative or lower potential (C bias voltage) than the filament, (electron emitter). In this arrangement, a center-tapped resistance connected across the filament is used, the center tap of which is connected to the bias resistor R at point D. In some cases, this center-tapped resistor is omitted and the filament supply winding on the power transformer is center-tapped instead, as shown at (B). In either case, the operation is the same.

When indirect heater type tubes such as the 227 and the 224 are employed, grid bias is secured in the manner shown at (A) of Fig. 50. The resistor R is connected in the plate return circuit of the tube. The plate current flows from the plate to the cathode, through the resistor R, which pro-

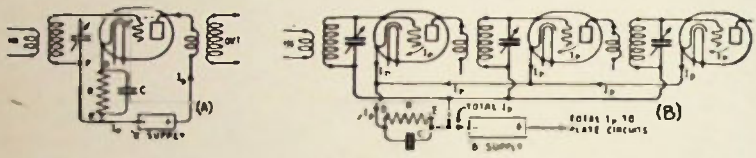


Fig. 50—(A) Obtaining the negative grid-bias voltage for a separate-heater type tube by making its plate current flow through resistor R. This makes the potential of point E lower than that of the cathode terminal D.

(B) Using a single grid-bias resistor R for obtaining negative grid-bias voltage for several similar separate-heater type tubes in an amplifier.

duces a voltage drop, this drop being the bias voltage applied to the tube. In the interests of economy, in radio receivers employing several tubes of the same type operated at the same voltages, a single resistance is sometimes used to obtain the proper negative grid bias voltages for all these tubes. This arrangement, shown at (B) of Fig. 50, has the disadvantage however, that it tends to increase the liability of inter-stage coupling occurring in the amplifier circuits served by the common bias resistor.

Grid-bias resistors usually have a by-pass condenser shunted across them. The size of condenser to use is determined by the part of the receiver it is used in. It has become common practice to use by-pass condensers of .1 to .5 mfd. for shunting grid bias resistors of R.F. amplifier tubes. In audio frequency circuits, the capacity of the by-pass condenser used, is from .5 mfd. to 4 mfd., depending upon the lowest frequency response desired. A capacity of 1 mfd. has been used extensively.

As an illustration of the desirability of knowing something about the circuit arrangement of the receiver when interpreting the set analyzer readings, let us assume that a particular receiver is to be diagnosed. The analyzer plug is inserted in say the last audio tube socket, and the tube placed into the socket of the analyzer. According to the manufacturers' specifications, we should obtain say a plate voltage of 250 volts, a plate current indication of 32 mils, and a negative grid bias voltage of 50 volts. We find the plate voltage and current normal, but the grid bias voltage indicated upon the meter is only 8.5 volts. This would lead to the conclusion that there is some trouble in the grid circuit, but upon examination of the circuit diagram we find that this stage is resistance-coupled to the preceding tube as shown in Fig. 51. The grid leak R_2 has a value of 500,000 ohms and allowances must be made for the drop in voltage caused by the flow of the meter current through the

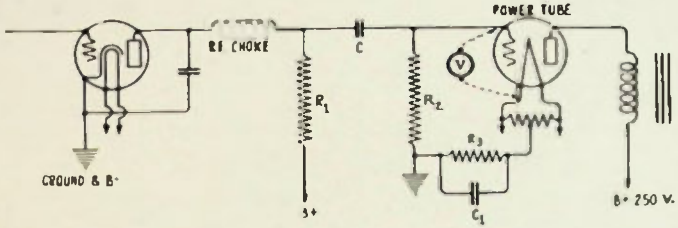


Fig. 51—A typical circuit arrangement of a power tube resistance-capacity coupled to the detector tube preceding it.

resistor. This accounts for the grid voltage reading of only 8.5 volts when a voltage of 50 volts actually exists there. If the tube were transformer coupled to the preceding stage, the resistance of the audio transformer secondary would be too low to have any appreciable effect on the bias voltage indicated on the meter.

As another example, let us assume the plate voltage and plate current readings are excessive, and no grid bias voltage reading is obtained. It is

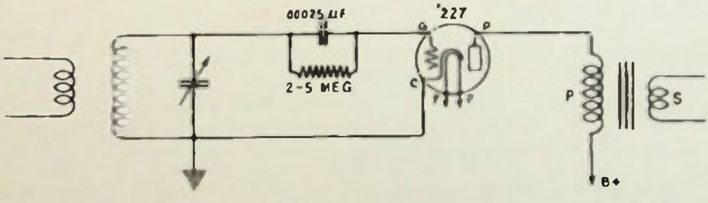


Fig. 52—The circuit arrangement of a typical grid leak-condenser detector employing a '27 type separate heater tube.

evident from Fig. 51 that this condition may be caused either by an open transformer secondary winding or an open grid leak resistor R_2 (depending on the type of coupling used), a shorted bias resistor R_3, or a short-circuited by-pass condenser C_1. It is then necessary to test each of these three parts independently by the most suitable methods, (see Chapter 3), in order to determine just which one is at fault. If the grid bias resistor R_3 were open, no plate voltage or current indications would be obtained, since this resistor completes the plate circuit. When resistance R_2 is open, not only will this be indicated upon the analyzer by no grid voltage reading, but it will evidence itself by symptoms of choked or choppy reproduction from the loud speaker. At times the by-pass condenser C_1 will open-circuit. If the condenser is used in an R.F. circuit, the symptoms usually are, oscillation, and general instability of the receiver. When the condenser is used in an audio stage, an open unit will result in oscillation and poor low frequency response. The same symptoms will result in the case of the indirect heater tubes. However, when a type 227 tube is used as in Fig. 52 in a grid leak-condenser detector circuit, little or no grid voltage will be indicated upon the meter because of the presence of the grid condenser and the grid leak, whose range is usually from 2 to 5 megohms. Here the cathode is connected directly to the B— and no cathode voltage will be secured. When power or grid bias detection is employed, the arrangement of (A) in Fig. 50 is used, and cathode-grid

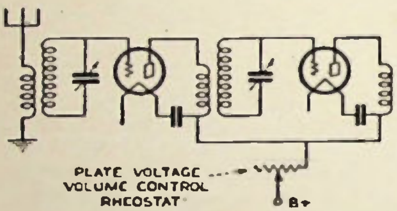


Fig. 53A—A typical R.F. amplifier arrangement in which volume control is obtained by a variable resistance in the plate circuits of the R.F. tubes. This was used in many of the older battery sets.

voltage can be read. Should this same tube be used as a radio or audio frequency amplifier, cathode-grid voltage will also be noted because of the bias resistor used, (resistor R in (A) of Fig. 50).

B. Interpreting the plate voltage readings: In cases where a lower R.F. plate voltage reading than ordinarily obtained is indicated, the exact manner in which the tube is being used should be determined before any decisions are made. In the older receivers using 3-electrode type tubes in the R.F. amplifiers, manufacturers often employed a fixed and somtimes a variable resistance, the latter being in the form of a volume control, or to control oscillation. Where it is found that a volume control as in Fig. 53A is used to vary the plate voltage upon the tube, this control should be turned on full, before any voltage tests are made.

If the analyzer shows no plate voltage on any one tube, the trouble may be caused by either a faulty volume control, faulty plate resistance or an open plate coupling device (such as the choke in parallel-feed circuits, the primary of an A.F. transformer, or the plate resistor in a resistance coupled stage). Most often however, it will be found that instead of having a resistance in the plate circuit of an R.F. tube to cut down oscillation, this resistance will be in the grid circuit. It is then called a grid suppressor, and is connected as shown in Fig. 53B.

Suppose no plate voltage reading is obtained at the sockets of any of the R.F. amplifier tubes employed in a receiver. This may be caused by either a

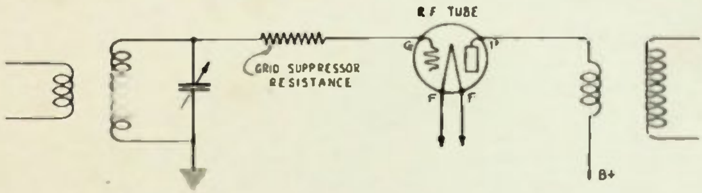


Fig. 53B—The connections of a "grid-suppressor" resistor in the grid circuit of a 3-electrode R.F. amplifier tube to suppress oscillation. This scheme was used in many of the early T.R.F. receivers.

failure of the bias resistor (should this be common to all these stages as at (B) of Fig. 50), or to an open section of the voltage divider in the power pack—not taking into consideration the possibility that a wire somewhere in the plate circuit may have broken or come loose. If it is noted that the

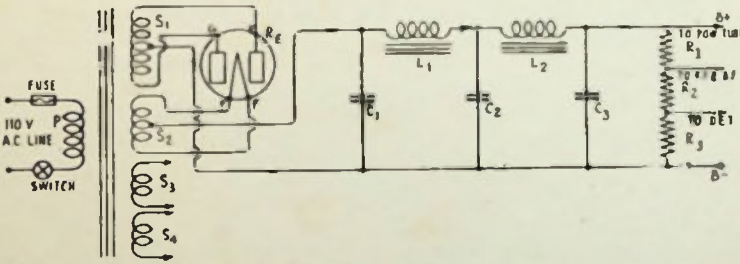
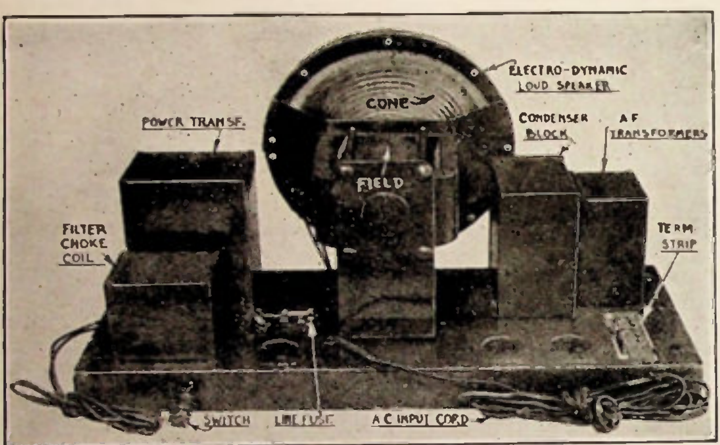


Fig. 54—The fundamental circuit arrangement employed in all typical power supply units in A.C. electric receivers. In many, only a single filter section is used.

plate voltage on the power output tube, (which usually receives the highest voltage of any tube in the receiver), is lower than normal, and all other corresponding voltages are also lower, there is the strong likelihood that the

R.F. by-pass condenser has become leaky or partially short-circuited.

C. Interpreting the power supply unit readings: If no plate voltages, or abnormally low plate voltages, are read at the sockets of all the tubes in the receiver, it is likely that the trouble lies in the power supply unit. The power supply unit is composed of a power transformer, a rectifier, a filter system composed of one or more filter chokes and several filter condensers, and a voltage divider or resistance bank sometimes connected as shown in the diagram of Fig. 54. The power transformer consists of a primary winding



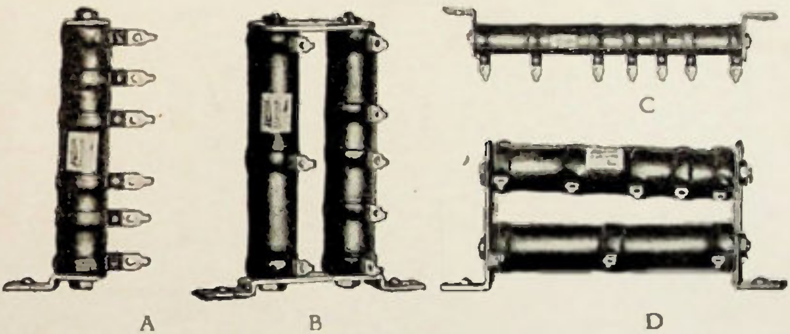
Courtesy R. C. A. Victor Corp.

Fig. 54A—A typical power amplifier unit from an A.C. electric receiver. This contains the power supply unit, the last audio stage, and the loud speaker. The parts of the power supply unit are encased in protecting steel cans. They are labeled in the illustration.

P and several secondary windings, on a laminated steel core. One secondary winding contains more turns than the primary. This is called the high voltage secondary (S_1). Other low voltage windings supply current for the filament of the rectifier tube (S_2), and for the filaments of the other tubes used in the receiver (S_3 and S_4). The A.C. current that is rectified by the rectifying tube Re, becomes a pulsating direct current. This is delivered to the filter system, composed of the iron core chokes L_1, L_2, and the filter condensers C_1, C_2, C_3, which smooth out the pulsating component and deliver a smooth D.C. voltage to the voltage divider. The circuit shown in Fig. 54

is that of a typical conventional power supply unit. Of course minor variations in this circuit arrangement will be found in the various makes and models of receivers—especially in the filter and voltage divider systems.

Should an open-circuit occur in one of the chokes, no voltage will be delivered to the voltage divider and therefore no plate voltage will exist at the tubes in the receiver. If any one of the condensers C_1, C_2, or C_3 becomes shorted, no voltage at all—or a very low voltage, will exist at the plates of the tubes in the receiver. The most common trouble occurring in power packs is that of shorted filter condensers. When the plates of the rectifier tube becomes red it is also a sign of a shorted filter condenser, usually C_1. Should C_2 short, sometimes the rectifier tube plates will also become red-hot and the choke L_1 will heat up considerably. Shorted filter condensers of the tin-foil paper type must be replaced by new ones of similar capacity and voltage rating. Faulty electrolytic condensers must be replaced if they do not re-form their insulating film when removed from the source of voltage temporarily.



Courtesy Aerovox Wireless Corp.

Fig. 54B—Several typical forms of voltage divider resistors employed in the power supply units of electric radio receivers.
(A) A single, tapped resistor with vertical mounting.
(B) A double, tapped resistor with vertical mounting.
(C) A single, tapped resistor with horizontal mounting.
(D) A double, tapped resistor with horizontal mounting.

Testing of the voltage divider resistor does not present many difficulties, for the resistance of each section may be measured quickly with an ohmmeter. Should section R_1 be open, no voltage will be obtained on any of the tubes except the power output tubes; if R_2 is open, the detector plate will receive no voltage. Whether the resistance R_3 is open or not, voltage readings will be obtained at each section of the voltage divider. The only effect of an open R_3. will be to slightly increase the voltage at the other taps and cause slight instability of the receiver operation.

A frequent cause for an inoperative power pack is a shorted or partially-shorted high voltage secondary winding. When this occurs it is probable that the rectifier tube filament will burn out and the light line fuse will "blow." Open-circuited filter condensers are very often the cause of an annoying hum that accompanies broadcast reception, or when the set is in operation, but not tuned to a station. The condensers may be tested by any one of the several methods outlined in Chapter 3, or by the substitution of another that is known to be good.

D. Inoperative receiver which checks O.K: Suppose a receiver is analyzed, and all tubes and voltages are found to be normal, also the an-

Fig. 54C—Three typical arrangements of dry electrolytic filter condensers employed extensively in power supply units.
Left: A single 8 mf. 500 volt condenser.
Middle: A 2-section condenser having 8 mf. per section.
Right: A 3-section condenser having 8 mf. per section.
In all of these, the metal container connects to the "negative" side of the circuit.

tenna-ground system is O.K.; but still the receiver does not operate. This is a case where reliance must be placed on the ability of the individual who must rapidly effectuate a repair. Trouble shooting in cases of this kind brings into play the real ability of a Service Man. Tapping the detector tube, brings forth a "bong" from the reproducer. This effect eliminates, for the time being, the possibility of a faulty detector and audio system and attention must next be centered upon the R.F. amplifier. Remove the last R.F. tube and place the antenna wire on the plate terminal of that tube socket. In this way the primary of the last R.F. transformer is being used as an antenna coil and its tuned secondary feeds into the detector tube. The receiver should then be tuned to ascertain whether any station may be picked up, (weakly of course). If this stage is good, we may be able to pick up one or two of the more powerful broadcasters. Should no response be had however, this section of the tuning condenser should be suspected, for if this is shorted we will get no pick up. It should be tested for a short, with the secondary winding of the tuning coil disconnected. If the stage is good, the tube should

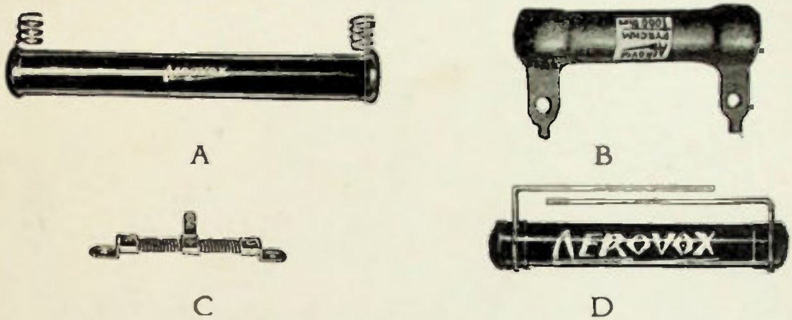


Fig. 54D—Some typical forms of fixed resistors employed in modern radio equipment, and which may need to be replaced.
(A) A wire-wound enameled resistor with flexible wire leads.
(B) The same type of resistor with metal tab terminals.
(C) A center-tapped wire-wound resistor. The wires are not covered.
(D) Solid moulded carbon resistance element with wire terminals. This makes a suitable non-inductive comparatively high resistance unit of medium current carrying capacity.

be reinserted in its socket in the receiver, and the tube in the preceding stage removed. The antenna wire should then be placed in contact with the plate terminal of this tube socket and the receiver tuned again. If no reception is obtained the tuning condenser section for that stage should be tested, with the secondary of the tuning coil *disconnected*. This procedure should be carried out with each stage until the faulty circuit is found.

The test for a shorted tuning condenser section with ordinary means would involve disconnecting the tuning coil across which it is connected. If use is made however, of an ohmmeter of the type shown at (B) of Fig. 12, whose resistance range is as low as ½ ohm, it will not be necessary to disconnect the condenser from the coil or in any way alter the wiring in the receiver. The ohmmeter terminals should be placed directly across the condenser section and the tuning knob rotated slowly over the full range. If the condenser "shorts" at any position, a zero ohm reading will be obtained.

If the condenser is good, the resistance of the tuning coil will be indicated upon the ohmmeter.

It is also possible that in the receiver discussed above, instead of a shorted tuning condenser, the secondary or the primary winding of one of the R.F. coils may be shorted. When either of these two conditions occurs the receiver will usually be inoperative, though in some cases weak reception may be had.

E. Weak signals but receiver checks O.K: Suppose however, that we find all voltages and currents in the receiver to be normal and the audio

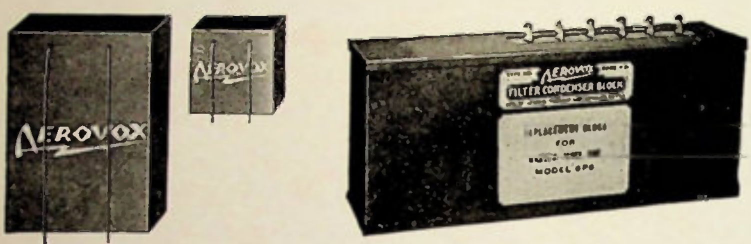


Fig. 54E—Typical filter condensers designed especially for replacement purposes in radio receivers. They are impregnated and enclosed in cardboard boxes.

Left: A 2 mfd. filter condenser with pig-tail leads.
Middle: A 1 mfd. by-pass condenser.
Right: A complete filter condenser replacement block for a Majestic Model 9P6 power pack.

portion of the receiver good, but only very weak reception can be obtained. The coils and all condensers also test perfectly. In this case perhaps, one is at a loss as to the method or means necessary to locate the trouble unless previous experience on the same type of receiver is possessed. The trouble may be due to poorly aligned R.F. stages or to the presence of some high resistance soldered joint in the secondary tuned circuits of the R.F. tubes. These high resistance joints are caused by poor soldering on the part of the constructor and though causing very little, if any, effect on voltage readings, offer a comparatively high resistance path to the feeble signal voltages. The best way to determine whether such a joint exists in the secondary circuit is by means of the ohmmeter. When testing for this condition in a grid leak-condenser detector stage, it must be remembered that "infinite resistance" indication will be obtained upon the ohmmeter because of the grid condenser and the very high resistance of the grid leak. Here the only remedy would be to test from the grid condenser side of the secondary coil to B—.

F. Resistance coupled amplifier troubles: Due to the existence of various resistors and condensers in a resistance-coupled audio amplifier, many difficult service problems may arise in sets employing this form of amplification. In most cases the coupling condenser used (condenser C in Fig. 51) is less than .1 mfd. and in some instances as low as .001. It is easy to test these units for short circuits by means of any continuity indicating device. Besides, when such a component is shorted, it will usually be evidenced by some irregular reading of the grid bias of the coupled stage. Where the grid bias ordinarily is say 50 volts and the voltage actually impressed upon the plate terminal of the preceding tube is practically the same voltage, then no grid bias voltage will be indicated when this condenser is shorted. Where the plate voltage of the preceding tube is higher than the grid bias of the coupling stage, then the grid bias voltage indicated upon the meter will read positive. Besides these unusual voltage indications, this defect is made apparent by very weak and greatly distorted reproduction.

Where the condenser open-circuits, the receiver symptoms will be, little or no response, and in the former case, "distorted." Due to the difficulty in testing for an open-circuit occurring in this low capacity coupling condenser,

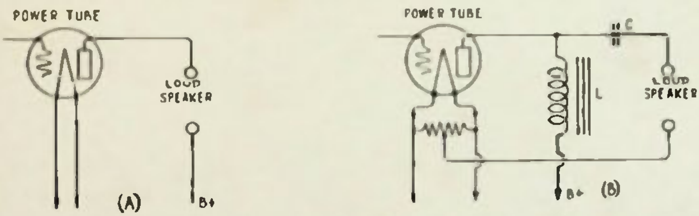


Fig. 55—(A) Connecting the loud speaker winding directly into the plate circuit of the power tube.

(B) Use of the choke and condenser coupling arrangement for magnetic speakers. This keeps the heavy plate current of the power tube out of the delicate windings of the speaker.

when such a unit is suspected, the best method is to shunt another condenser of similar capacity across the suspected unit. Care should be taken however, to keep the fingers free from the terminals as this may cause a feed-back howl or whistle. The circuit of a typical resistance coupled amplifier stage is shown in Fig. 51.

45. Trouble shooting the receiver output circuit: The Service Man should be familiar with the methods used by manufacturers to couple loud speakers or reproducers to receivers. In the early sets, which employed magnetic type loud speakers, no provision was made to safeguard the fine wire coils of the speaker, which was simply connected in series with the plate circuit of the last audio tube as shown in (A) of Fig. 55. Later receiver designs incorporated a choke-condenser combination as shown

at (B), to keep the high direct plate current from the delicate windings of the speaker, and consequently preventing burn-outs of these speaker windings.

If the condenser C in (B) of Fig. 55 should become short-circuited due to the high voltage, it will be evidenced by choked and distorted re-

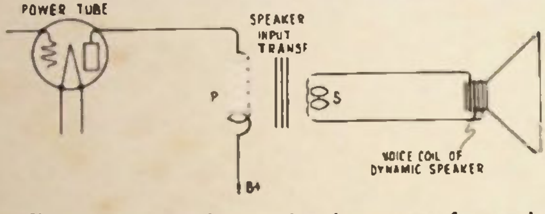


Fig. 56—The connection of a speaker input transformer between the plate circuit of a single power output tube and the voice-coil of a dynamic speaker. (See Fig. 57)

production, sounding very much like a lack of grid bias upon one of the audio tubes. In some cases, no signals will be heard at all. Should the choke L_1 become open, then of course, the plate of the power tube will receive no voltage and operation ceases.

Dynamic speakers usually have a very low resistance *voice coil* of comparatively few turns. Therefore, the voice coil has a low impedance and

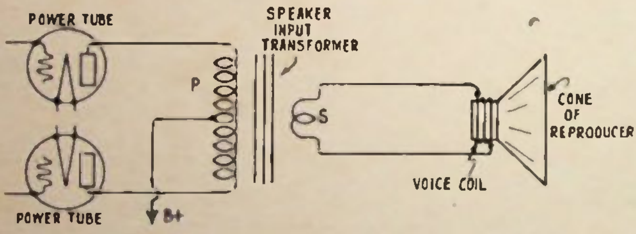


Fig. 57—The same connection as that of Fig. 56—for two power tubes in push-pull.

acts practically like a pure resistance. The impedance of voice coils in dynamic speakers is usually between 5 to 15 ohms, with the possible exception of speakers such as the Colonial and the Peerless which employed a single turn copper voice coil, having an impedance of less than .001 ohms. Since the impedance of power amplifier tubes is so much greater than that of the voice coils, in order to secure the efficient transfer of undistorted power from the plate circuit of the tube to the voice coil, an impedance matching transformer of proper design must be used. The primary of this transformer is connected is series with the plate circuit of the power amplifier tube as shown in Fig. 56, the low-impedance secondary, being connected directly to the voice coil of the speaker.

Where a push-pull power amplifier stage is used, the primary of the input transformer is usually center-tapped as shown in Fig. 57, and it is wise, when one of the tubes is found to be without plate voltage, to test for an open-circuit in that section of the primary of the output transformer. This transformer is usually located at the speaker itself, and not contained within the receiver proper.

46. Trouble in the speaker field winding: While on the subject of dynamic speakers it may be well to discuss the field

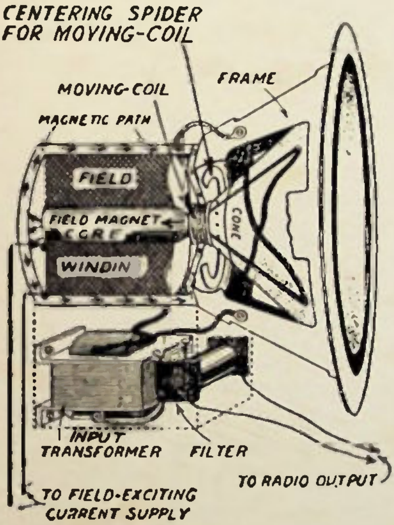


Fig. 57A—A typical dynamic speaker with the field shown cut open to illustrate the arrangement of the field coil, field core, and moving-coil. The input transformer and high note filter (if one is used are shown below).

coil of the speaker. In most A.C. operated receivers this coil is often made to serve as a choke in the power pack filter system as shown in Fig. 58. In some receivers, the field coil is tapped so that it can be used both as a choke and as part of the voltage divider system. In both cases there is a certain voltage drop across the field coil due to the current flowing against its resistance. In some cases, in order to energize the field coil a separate power supply is used. This may consist of a power transformer and dry disc rectifier connected as shown in (A) of Fig. 59, or a power transformer and a rectifying tube pictured at (B).

47. **Adjusting dynamic speaker voice-coils:** The voice coils of dynamic speakers frequently get out of adjustment. Due to the fact that many different methods are used to effec-

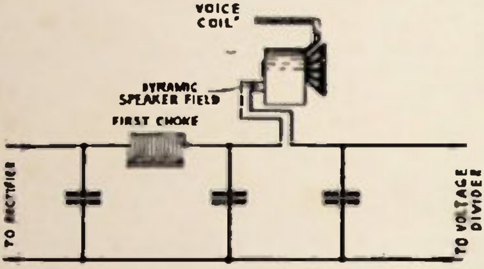


Fig. 58—The fundamental method of connecting a dynamic speaker field coil as a filter choke in the B power supply unit. In this way the total plate current taken by the tubes in the receiver, serves to energize the speaker field, and the field itself performs the additional useful function of acting as a choke to help smooth out the "B" current.

tively "float" the voice-coil and to prevent it from rubbing against the sides of the pole-pieces, too lengthy an explanation would be necessary here to cover the procedure for re-centering the voice-coil of any speaker. At any rate, when a voice-coil is to be re-centered, its mounting screws should be loosened first to permit of easy adjustment. The proceedure follows:

The *primary* of the input transformer to the voice coil may be connected directly to a 60 cycle 110 volt line, and by using the 60 cycle note derived from this source, the voice-coil may be moved from one side to another until the best response is obtained, and the coil is moving freely without rubbing against the pole-pieces. To aid in quickly centering the coil, roll a piece of wrapping paper of the proper thickness, into the form of a small tube, such that it may be slipped between the inside of the voice-coil form and the center core leg pole-piece. This centers the coil. Now tighten the fastening screws and remove the paper. If the receiver is in operating condition, the signal used during the adjusting may be obtained by connecting the antenna wire to the "grid," (or "control grid"), terminal of the detector tube.

Magnetic reproducers may also be adjusted by connecting them to an A.C. source. In this case however, instead of the voice coil being re-centered, it is necessary to center the armature, so that it is equi-distant between the pole-pieces of the permanent magnet. Should any number of turns in a magnetic reproducer become shorted, the response will be slightly distorted and lower in volume.

48. Re-centering phono pickup armatures: Magnetic phonograph pick-ups operate on much the same principle as

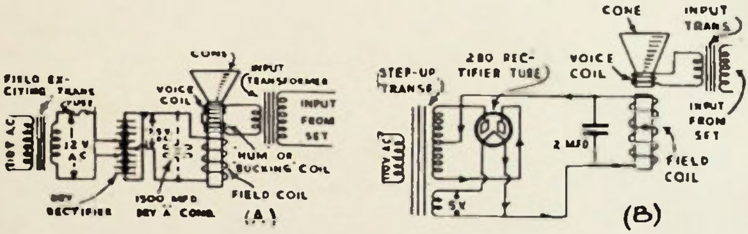


Fig. 59—(A) How a dry-plate rectifier may be connected to supply current from the 110 V. A.C. line to the speaker field coil. Hum may be reduced by a dry electrolytic filter condenser, or by a "hum-bucking coil," connected as shown.
(B) How a vacuum tube rectifier and power transformer are connected to change the A.C. line current to smooth D.C. for the field coil.

magnetic speakers. The "unit" here is the same, except for the addition of some device to hold the phonograph needle to the armature. The adjustment for re-centering the armature of a phonograph pick-up is the same as for magnetic speakers. In many cases however, in order to make adjustments, it is necessary to remove the permanent magnet. If this must be done, under no conditions should the magnet be kept free for even a moment, from some piece of iron or steel across its poles. Failure to do so, will result in a weakened magnet and consequent poor pick-up device. The best way to avoid this trouble would be to place a nail or bar of iron across the poles of the magnet before it is removed.

49. Locating cause of "hum" in a receiver: There are many serious complaints that the Service Man may meet with, that may involve a great deal of time to find. These complaints are hum, fading, intermittent reception, and distortion which will now be considered in the order mentioned.

We will first discuss the complaint of hum in a receiver, where that condition was not present at any time before. As has been previously stated, in the majority of cases, this hum may be caused by either an open filter condenser or a shorted choke coil, or both, in the filter system. In other cases, should one side of the center-tapped filament resistor R in a circuit as shown in Fig. 60 become open, a loud hum will result. The existence of this open section of the center tap resistor will not be brought to light during the voltage analysis of the set, for every circuit will still be complete. When such a defect is suspected, it will be necessary to make an actual test of the center-tapped resistor in question. The remedy, of course, is to replace the resistor with a similar one. When any by-pass condenser in a receiver is "open," there is a strong probability that hum may result, and each condenser unit should be tested for open circuit. Some receivers use a potentiometer instead of a fixed center-tapped resistor to obtain the exact electrical center of the filament secondary. The position of the potentiometer arm may have been disturbed, thus causing the filament secondary to become unbalanced, resulting in hum. These units are called "hum controls," and are usually easily accessible for the purpose of adjustment without disturbing the receiver chassis. Hum is often caused by a faulty tube that tests perfectly upon any tube tester. In most cases these tubes are those of the indirect heater type. The reason for the hum is due to faulty insulation qualities between the heater and the cathode of the tube, resulting in electrical leakage from the heater to the cathode. Where 227 tubes of this kind are used in audio frequency stages, or in the detector stage especially,

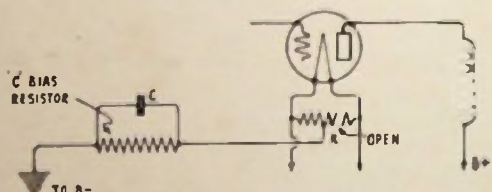


Fig. 60—How a center-tapped filament resistor may become "open" thus upsetting the electrically neutral condition of the center-tap and causing hum.

this annoying condition will be noted. When a screen grid tube is employed as a detector, care should be exercised in choosing the one to be used. In receivers where the 224 is used as a detector and a slight amount of hum is complained of, the first step to eradicate this condition should be the replacement of the detector tube until a suitable one is found. A rectifier tube having low emission is often the cause of hum in a receiver. It may easily be detected because it will cause all plate and grid voltages to be lower than normal.

50. Locating cause of "fading": Of all the complaints ever encountered in radio servicing, the most serious and difficult problem to solve is that of "fading." This complaint may be caused by a defect in practically any part in the entire receiver and the antenna-ground system. It is therefore, very difficult to ascertain and locate the cause. However, experience with the repeated failure of a definite part in a certain model of a receiver helps to ease this task greatly.

In some cases, trouble may be due to a faulty condenser that opens and closes circuit intermittently, to a break in a wire-wound resistor where the open-circuit is not perceptible to the naked eye, and in others, where there may be a high resistance leak or poorly soldered joint in the circuit. Every case has its own method of attack and solution, and that which may be said about one set may not be true in another. When any receiver is to be serviced where there is a complaint of fading, sufficient time should be allowed. The best course of procedure is to connect the receiver, to place it in operating condition. The receiver should be tuned to a broadcast station whose signal is known to be constant and steady. After this is done only one thing is left, that of waiting for the fading to occur. By the term fading, is meant the gradual falling-off of volume with slow recovery. When the set does fade, condensers and resistors should be bridged with others so that if an open circuit in one of these units does take place its effect may be counteracted. An idea of the many conditions which may cause fading, may be obtained from the results obtained from observations on a receiver afflicted with fading troubles. In this particular model of receiver on many different occasions, various components were found to cause fading. The small 0.1 mfd. condensers in the resistance coupled audio stage were found to be the most frequent cause of fading when they open-circuited. The variable condenser stator plates were mounted on porcelain brackets. A sudden jar or jolt would cause a break in the porcelain, permitting the stator to shift slightly at the least vibration, causing fading. The R.F. coil secondaries were wound very tightly, and upon extreme changes in temperature or due to heavy vibration, the ends would snap at the lug, which would make and break contact with the wire, causing fading. It is evident that troubles of this kind can only be found by keen observation. Probably the most frequent cause of fading however, is due to defective screen grid tubes. When these tubes are tested with the ordinary set analyzer the defect is seldom disclosed, but if checked with a good A.C. separate tube tester, it will be made instantly apparent. In some A.C. tube testers, the tube is given a "dynamic" test and made to act as a rectifier. If the tube is in any way deficient it will evidence itself in the slow, swinging back of the milliammeter pointer to a very low current indication. Associated with fading is the complaint of intermittent reception.

As with fading, intermittent reception may be due to a host of causes which are usually difficult to locate. Most common are broken connections, poorly soldered connections, and momentary short-circuits and open-circuits. Again, the best proceedure in trying to locate the trouble, is best determined by the individual as a result of experience.

51. Locating cause of "distortion": Contrary to the old idea of greater distance and more power, the modern set owner, on the whole demands, little more than good quality of reproduction. To meet these demands, manufacturers have designed their receivers making use of anti-overload and non-oscillating circuits, and receiving tubes capable of handling large amounts of power without distortion. Sometimes the Service Man will be assigned the task of locating the cause of distortion in some receiver which up to that time had operated satisfactorily. In most cases, distortion is caused by poor tubes, especially in the output stage. The presence of a "gassy" tube will help aggravate the condition. Should bias resistor by-pass condensers become leaky, the same result will be obtained. At other times, when the voice-coil of the dynamic reproducer is out of alignment, or if the paper or parchment cone loses its "stiffness" and "body," the receiver is not able to deliver as much sound energy in "undistorted" form. Therefore when loud signals are received, the sound program will be distorted.

In radio servicing and repair work, common sense coupled with practical experience and a good working knowledge of receiver circuits and electrical tests, will enable a Service Man to locate and repair any trouble in a radio receiver quickly and effectively. While the radio set analyzer is a great aid in speeding up this work, it can only perform its best work when its user is able to correctly interpret the readings it gives.

REVIEW QUESTIONS

1. Formulate a set of questions which the Service Man should ask the set owner upon arrival at the home. Explain just how the answer to each question will assist the Service Man to quickly diagnose the trouble.
2. Explain how to make a rapid routine test to determine if the entire antenna-ground system has developed any electrical defects. Of what value is an ohmmeter in these tests?
3. Explain how to make a rapid test on a receiver to determine whether or not a complaint of noisy reception is caused by some condition in the radio set. What results or indications will be obtained in this test if the noise is caused by the electrical contacts on an elevator motor controller located in the same building?

4. Why will a "ringing sound" be produced in the loud speaker if the detector or audio tubes in a receiver are tapped sharply with the finger, and the parts and circuits following these tubes are in proper operating condition? Why cannot this same test be applied to the tubes in the radio frequency amplifier?
5. How may the R.F. amplifier stage be tested quickly if a receiver is inoperative, and the test mentioned in question 3 shows the detector, audio amplifier and loud speaker to be operating properly?
6. Explain why it is usually best to make preliminary routine tests on a receiver before using the set analyzer on it. Explain one particular instance where a preliminary routine test would reveal the location or cause of a trouble which it would require a longer time for the analyzer to locate.
7. Make a list of the different tests which should be made on an inoperative electric receiver, by the set analyzer, if the preliminary tests fail to reveal the trouble. State these tests in their proper sequence.
8. Explain how each of the tests in question 7 are made.
9. Explain the value of each of these tests. Select any two of them, and explain in detail just what troubles might be revealed by their use.
10. Why is it important to test all the tubes in a receiver during the analysis procedure. Which tube characteristic is usually measured? How is this test made? How is a faulty tube shown up by this test?
11. What does failure to obtain voltage readings at the following points of a tube socket indicate in each case, (a) filament; (b) plate, (c) control grid?
12. Explain the effect of a shorted filter condenser in a power supply unit on the operation of the receiver. How would this trouble be revealed by the set analyzer?
13. If the condenser in question 12 is one of the sections in a condenser block, how could it be tested, isolated, and replaced?
14. What indications would be obtained on a set analyzer in each case, if the following troubles occurred in an R.F. stage of a receiver in which a separate heater screen grid type tube was employed: (a) an open grid bias resistor; (b) a shorted grid bias by-pass condenser; (c) an open secondary winding in the tuning coil; (d) an open circuit in the primary of the following tuning coil; (e) a tube with low emission; (f) a shorted by-pass condenser from screen-grid to cathode; (g) a shorted tuning condenser?
15. How could you find out if a low resistance primary winding of an R.F. transformer, or a low-resistance voice-coil if a dynamic speaker, were shorted, if you had no testing instruments available and the set could be played weakly?

CHAPTER 6.

THE SERVICE TEST OSCILLATOR

SINGLE TUNING CONTROL — EQUALIZING THE TUNED CIRCUITS — NEED FOR THE TEST OSCILLATOR — PRINCIPLE OF THE OSCILLATOR — A SIMPLE BATTERY OPERATED TEST OSCILLATOR — SIMPLE ELECTRICALLY OPERATED TEST OSCILLATOR — A SIMPLE DYNATRON TEST OSCILLATOR — COMMERCIAL FORMS OF TEST OSCILLATORS — GENERATING "HARMONIC" FREQUENCIES — READRITE SERVICE TEST OSCILLATOR NO. 550 — SUPREME TEST OSCILLATOR MODEL 60 — JEWELL PATTERN 563 TEST OSCILLATOR — WESTON MODEL 590 TEST OSCILLATOR — ALIGNING THE TUNED STAGES IN T.R.F. RECEIVERS — ALIGNING THE TUNED STAGES IN SUPERHETERODYNES — A SUBSTITUTE FOR THE OUTPUT METER — SETS WITH AUTOMATIC VOLUME CONTROL — NEUTRALIZING A RECEIVER.

52. Single tuning control: In modern radio receivers, in which from two, to as many as six variably tuned circuits are employed to provide the necessary amount of selectivity, it is common practice to build the rotor plate sections of all of the individual tuning condenser sections on a common shaft, and mount all of the stator plate sections at the proper positions along the stator frame. Each stator section is independently insulated from the others and from the frame. All of the rotor sections form a common circuit with the shaft and frame. This is known as a "gang" condenser, because turning of the single shaft varies the capacitances of all the sections simultaneously, and this makes single tuning control of the receiver possible. A 5-gang condenser, (having 5 individual sections) of this type is shown in Fig. 61. The typical connections of the secondary windings of five R.F. transformers to the individual sections of a 5-gang condenser are shown in Fig. 62. The primaries are omitted, for simplicity. The connection of each tuned stage to the control-grip cap of a

screen grid amplifier tube is also shown. Note that the rotor and frame of the condenser form the common grid return circuit for all the tuned circuits. All the circuits are tuned simultaneously by merely turning a single knob or dial fastened to the condenser shaft.

53. Equalizing the tuned circuits: In order to obtain maximum selectivity and sensitivity in modern T.R.F. re-

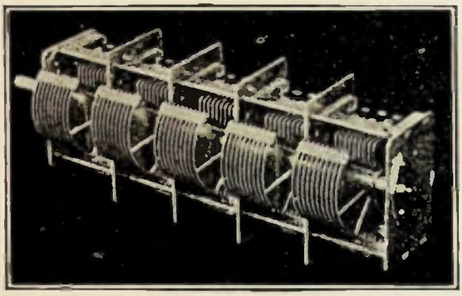


Fig. 61—A 5-gang condenser. Five sets of rotor plates are rotated together by a single shaft. Notice the slotted rotor plate at the end of each section.

ceivers employing this gang control of the tuning circuits, it is absolutely essential that each of the tuned stages be tuned to exactly same frequency for any one setting of the dial. This means that when once the tuned stages are adjusted to tune in step with each other, they should continue to "track" together over the entire tuning range of the receiver. If one or more of the stages tunes to a higher or lower frequency than the rest, that stage will not be tuned to exact resonance with the incoming signal when the others are, and therefore it produces less amplification and selectivity than it otherwise would. This results in a decrease in volume and selectivity of the receiver. Small "compensating condensers" or other means of capacity adjustments are provided on each gang condenser section for adjusting its capacity value for proper "tracking."

Many receivers do not hold the adjustments made on their tuning condensers to line them up; in many, the adjustments must be checked up when new R.F. tubes are inserted in the receiver. When the receiver has been in use for some time, the small compensating condensers that are shunted across each section of the condenser gang, may be shaken out of exact alignment due to vibration set up by the loud speaker, or other causes. Even in new receivers, the adjustments may have been disturbed by accidental shocks or jarring during shipment. When this happens, it is often necessary to re-align these tuned circuits so that maximum sensitivity and selectivity are obtained. In superheterodyne receivers, it is necessary to line up not only the variably tuned R.F. and oscillator circuits, but it is also important to adjust the tuning of each of the band-pass intermediate frequency tuned circuits in order to "peak" and "flat top" their tuning curves at the correct intermediate frequency.

54. Need for the test oscillator: One way to align the tuned circuits in a receiver, is to tune in a distant or weak station, and adjust the *trimming* or *compensating* condensers (or other adjustment provided in each section of the tuning condenser), until the maximum volume is obtained as judged by the ear. This method is tedious, inaccurate and unsatisfactory, as the ear is not sensitive enough to be able to distinguish between small changes in intensity of the output sound produced by the receiver. Furthermore, the input signal strength or loudness of the program is likely to vary during the period of adjustment, thus leading to incorrect alignment. The use of a special miniature broadcasting station or "oscillator" emit-

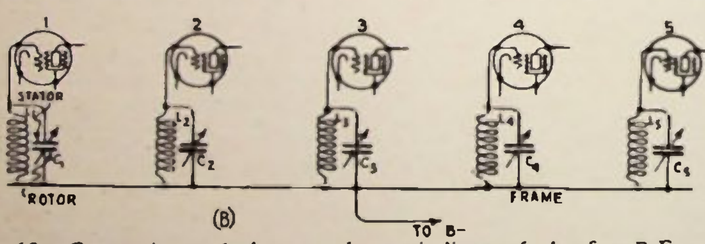


Fig. 62—Connections of the secondary windings of the five R.F. tuning coils to the tubes and to the five sections of a 5-gang condenser in a single dial receiver.

ting a steady signal of constant strength for this work, permits of much more rapid and accurate adjustments. When an oscillator is employed, the coupling to the receiver, strength of the signal, etc., may be easily adjusted for best conditions. The modulation or "note" of the generated signal may be easily adjusted to any particular value desired by the use of a "modulated oscillator." Instead of judging when the correct aligning adjustment is obtained, by noting the loudness of the oscillator note issuing from the loud speaker, a much more accurate determination of the output of the receiver may be obtained by using a copper-oxide rectifier type output meter, (see Figs. 16, 17), connected to the receiver output terminals. When this is used, the tuning condenser adjustments can be varied until the maximum output is indicated on the output meter. The output meter and test oscillator are very important devices for this work. They may also be used for locating troubles such as short-circuits, open-circuits, etc.

55. **Principle of the oscillator:** The service test oscillator depends for its operation upon the principle that a vacuum tube can be made to produce oscillations of almost any frequency by connecting it in a circuit arranged to continuously feed a proper amount of the energy of the plate circuit back to the grid circuit.

In an oscillating circuit, part of the energy of the varying plate current is continually being fed back to the grid circuit, inducing an alternating voltage in the grid circuit. This is being amplified by the tube, and the extra energy produced by the amplification, (at the expense of the energy from the batteries or other power supply), may be used outside of the oscillator circuits for any useful purpose. Giant oscillator tubes generate the radio frequency currents used at the radio broadcasting stations for transmitting. Likewise, oscillators of low power, using common receiving type tubes, may be used to generate the weaker radio frequency signals required for some receiver tests, and tuning condenser line-up work.

The grid and plate circuits of an amplifier tube can be arranged in several ways to produce oscillations, each arrangement having certain desirable characteristics which make it most suitable for a particular application—but they all operate on the principle of feeding energy back from the plate circuit to the grid circuit. The frequency of the oscillations produced, is governed mainly by the value of inductance and capacitance in the tuned circuit in either the plate or grid circuits. If a fixed inductance and variable tuning condenser of proper value are employed, the frequency of the oscillator signals may be varied over any desired frequency range. Thus it becomes a miniature radio broadcasting station of variable frequency.

Fortunately the more simple oscillator circuits are perfectly satisfactory for radio servicing work. Some of these will now be described before taking up the actual procedure followed in using them.

56. A simple battery operated test oscillator: A circuit diagram of a simple, portable, self-modulated R.F. test oscillator which any Service Man can construct for himself, is shown in Fig. 63.

A '30 type tube may be employed in it, in which case the single 22½ volt small size "B" battery, and 2-cell flashlight "A" battery required, may be placed inside the oscillator carrying case. Three volts from a tapped 4½ volt "C" battery may also be used for the filament. To cover the broadcast frequency range from 550 to 1500 K.c., coils L_1 and L_2 consist of a continuous winding of 60 turns of No. 20 or 22 double cotton or silk

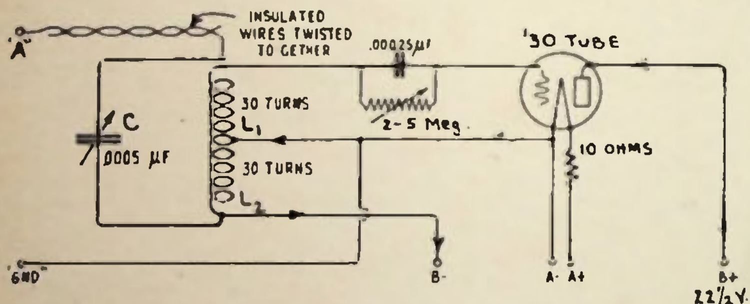


Fig. 63—A simple portable battery operated test oscillator which is easy to construct. This is designed to cover the broadcast range of frequencies from 550 to 1500 k.c. but may also be constructed to cover superheterodyne intermediate frequencies (see text).

covered wire wound on a 2 inch diameter form, and tapped at the center. A .0005 mf. tuning condenser is employed. The plate current of the tube flows from plate to filament in the direction of the arrows shown, and thence through the feedback coil L_2 to the B— terminal. This pulsating direct current produces a magnetic field which links with grid coil L_1, and induces corresponding voltages in it which are impressed on the grid circuit and are amplified. The process of feedback and amplification go on continuously, the entire unit really comprise a regenerative detector operating with sufficient feedback from the plate to the grid circuit to cause continuous "oscillation." The frequency of the oscillations produced is governed by the inductance and capacitance of the tuned circuit L_1 L_2—C and may be calculated by the usual formula for resonance.

$$f = \frac{159.000}{\sqrt{L \text{ (microhenries)} \times C \text{ (microfarads)}}}$$

Where f is the frequency of the oscillations in cycles per second.

By means of this formula, the inductance required for producing oscillations of any frequency may be quickly calculated when a given size tuning condenser is to be employed.

Under no conditions should the B— terminal be connected to either of the "A" terminals, for this would short circuit the feed-back coil L_2 and the oscillator would cease to function. The grid leak and .00025 mf. condenser cause the regular blocking action in the grid circuit, which modulates the generated signal so it is audible when tuned in on the receiver under test. The frequency of this modulation depends on the values of the condenser and leak employed. With a variable grid leak, such as can be purchased on the open market, the "note" of the generated signal may be varied to suit the individual.

The wire from the terminal marked "A" is an insulated wire, twisted together with the other insulated wire that is connected to the tuning circuit, for a distance of 1 or 2 inches. This provides enough capacity coupling between them to transfer energy from the oscillator to the receiver under test. A small midget condenser of about 10 mf. capacity between these two wires will also serve the same purpose, with the advantage that the coupling and signal strength may be easily varied. Terminal "A" is to be connected to the "antenna" terminal of the receiver, and terminal "GND" connects to the "ground" terminal of the receiver, (see Art. 61 and (a) of Art. 65). The regular antenna and ground should be disconnected from the receiver during all tests to prevent interference from any regular broadcast signals that may be received. This oscillator could be designed to produce the 175 or 180 k.c. frequency required in adjusting the band-pass i.f. circuits of superheterodynes, by using a honeycomb or duo-lateral type tuning coil of proper inductance value to tune to the frequency range desired, with the particular size of tuning condenser employed, (see the formula above). The intermediate coils used in superheterodynes make good coils for oscillators of this kind, if they have the proper inductance value. The detailed procedure for using test oscillators is explained in Arts. 55 and 56. The subject of harmonics is explained in Art. 60.

57. A simple electrically operated test oscillator: The circuit diagram of a simple, portable, self-modulated test oscillator which may be operated directly from either an A.C. or D.C. electric light circuit of 110 volts, is shown in Fig. 64.

This is of identically the same type as the battery operated oscillator described in Art. 56, and the same tuning coil and condenser data apply to it. The 25 watt 110 volt incandescent lamp bulb shown in series with the tube filament circuit merely acts as a cheap, convenient resistor to reduce the 110 volts to the proper 5 volts for the filament. Any other 450 ohm—25 watt resistor may be used here. The arrows show the direction of the plate current flow.

The .5 mf. condenser acts as a protector against a short-circuit which might occur if the electric light line terminal at the left happened to be the "ungrounded" side and that at the right were the "grounded" side. Connecting the left hand side, to the "ground" terminal of the radio receiver would also ground this side (if no blocking condenser were used) if the ground wire were left on the receiver—this causing a dead short-circuit across the electric light current. This should be remembered. In the case of a D.C. line, the line plug may have to be reversed in order to have a "positive" potential applied to the plate. This is essential for proper operation of the tube.

58. A simple dynatron test oscillator: An electrically operated R.F. test oscillator somewhat simpler in general con-

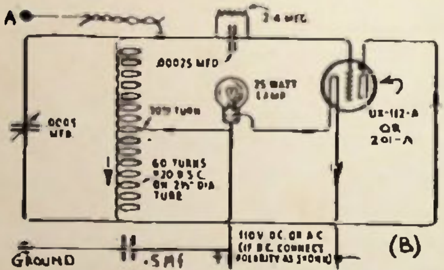


Fig. 64—A simple portable modulated test oscillator circuit of the same type as that shown in Fig. 63 excepting that it may be operated from either an A.C. or a D.C. electric light circuit of 110 volts.

struction, and which will maintain its calibration quite accurately, can be built using the "dynatron" oscillator circuit shown in Fig. 65.

The *dynatron oscillator* uses a screen grid tube to produce the generated radio frequency signal. By using the proper voltages, oscillations are produced if a tuned circuit is connected in series with the plate, the frequency of these oscillations being determined by the frequency to which the circuit is tuned. While oscillators using 3-element tubes, require coils in both the plate and grid circuits to make them oscillate, the dynatron requires only a single coil. This simplifies the circuit of course, and also makes it easier to use a plug-in coil arrangement if desired for producing oscillations over a wide range of frequencies.

The circuit diagram in Fig. 65 is that of a practical dynatron oscillator arranged to operate directly from the 110 volt line: the voltage may be either A.C. or D.C. In the case of a D.C. line, the oscillator line-plug may have to be reversed to secure proper operation. The necessary potentials for the filament, screen grid and plate (it will be noted in this circuit that the control grid is tied directly to the filament) are obtained by means of four resistors connected in series across the 110 volt line. Resistance R_4 (50 ohms) serves to reduce the line voltage to about 60 volts for application to the screen grid; R_3 (300 ohms) further reduces the voltage for the plate circuit. R_1 (1000 ohms), and R_2 (150 ohms) function to supply about 3.3 volts to the filament of the tube. The screen and plate circuits are by-passed to the filament by 1 mf. condensers C_2 and C_3.

If the oscillator is to cover the broadcast band then L and C_1 can be an ordinary coil and tuning condenser designed for use in a broadcast re-

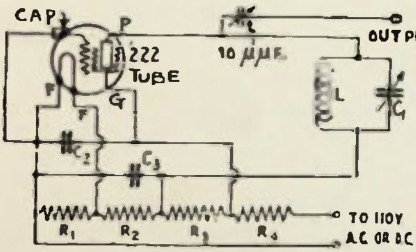


Fig. 65—A simple "dynatron" oscillator circuit suitable for use in a portable test oscillator. The constants of the parts are given in the text.

ceiver. An old radio frequency transformer with its primary removed, can be used. When the oscillator is to be used for working into the intermediate frequency amplifier of superheterodyne receivers, L can be replaced by a honeycomb or duo-lateral wound coil that will tune to the desired frequency with the condenser C_1. Harmonics of the fundamental frequencies may be used for the broadcast bands. (see Art. 60). For example, when the oscillator is tuned to 175 k.c. a signal of 700 and 1400 k.c. may also be obtained, being respectively the fourth and eighth harmonic. If good coils are used, the frequency generated by the oscillator will be found to be unusually stable. Audio frequencies may be generated by this device by connecting the primary of an audio transformer in the plate circuit of the tube, instead of the tuned circuit shown.

The Service Man may find it necessary to try several screen grid tubes in the dynatron oscillator in order to obtain one that will oscillate properly. Whether or not, a tube will oscillate in it will depend upon the value of its negative resistance, and some screen grid tubes will be found to have a higher negative resistance than others and therefore, prove to be poor oscillators in the dynatron circuit.

59. Commercial forms of test oscillators: A numbet of excellent calibrated test oscillators manufactured by radio service equipment manufacturers, are now available for radio service work. In general, these are all designed to produce test signals at both broadcast band and superheterodyne intermediate frequencies. In many models, a copper-oxide rectifier type output meter, for measuring or indicating the output of the receiver under test, is included as standard equipment with the oscillator. Of course if this is not built in with the oscillator, a separate output meter can always be employed. Several of these typical oscillators will now be described. A study of these, will give the student a good working knowledge of the circuit arrangements used in most test oscillators. Since most of these employ "harmonic frequencies" for obtaining a wide frequency range, we will study this feature first.

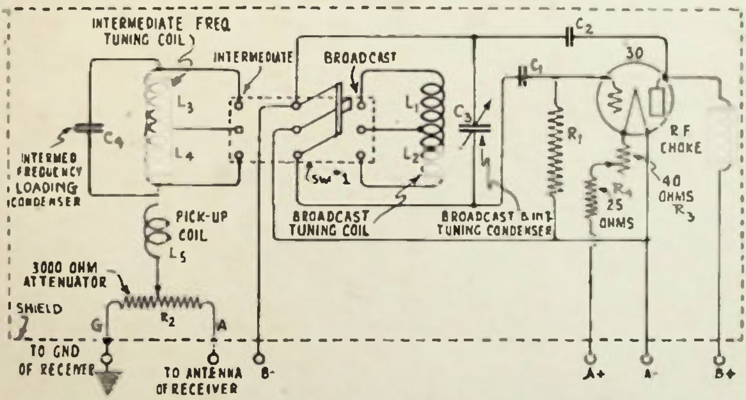
60. Generating "harmonic" frequencies: If a vacuum tube has quite a large grid bias voltage applied to it, any sine-wave voltage impressed across its grid circuit does not cause equal changes of plate current during each half cycle, due to the fact that the tube will be operating over the curved portion of the grid voltage plate current characteristic of the vacuum tube. This causes the wave-form of the plate current to depart somewhat from the sine wave grid impulses and become distorted, resulting in a generation of multiple frequencies in addition to that to which the oscillating circuit is tuned.

Let us assume that the tuned circuit is oscillating at a fundamental frequency of 500 k.c. If a radio receiver is coupled to the coil, and tuned to 1000 k.c. the oscillator signal will be heard. This frequency, which is twice that of the fundamental, (one-half the wave length), is the "second harmonic." Likewise there will be found other frequencies at three and four times the fundamental. (one-third and one-fourth wave lengths), and upward. It is impossible to obtain a reading on a current indicating device such as used in a wavemeter at these higher frequencies, but with an oscillating receiver capable of tuning over a wide band it is possible to identify them. The 2nd, 4th, 6th, 8th, etc., are even harmonics. The 3rd, 5th, 7th, etc., are the odd harmonics. Harmonics are not generated by such an oscillator at frequencies below the fundamental.

This action of an oscillator tube, of generating in addition to the "fundamental frequency," "harmonic frequencies" which are multiples of the fundamental frequency to which its oscillating circuits are tuned, is made use of in most test oscillators, for it enables a cheaper and simpler oscillator to be built for covering the wide frequency band required for adjustment and test work on both broadcast and superheterodyne intermediate frequencies.

We are now prepared to study the circuit arrangements of a few representative test oscillators designed especially for radio service work.

61. Readrite Service Test Oscillator No. 550: A circuit diagram of this battery-operated, self-modulated, R.F. test os-



Courtesy Readrite Meter Works

Fig. 66—The circuit employed in the Readrite No. 550 test oscillator. Notice the switch employed for changing over to broadcast or intermediate frequencies. The actual unit is shown in Fig. 67.

cillator is shown in Fig. 66. The oscillator mounted in its carrying case with the output meter on the panel at the right is shown in Fig. 67. The calibration chart is conveniently fastened on the inside of the cover.

This oscillator is completely shielded to prevent the radiation of energy directly to the set under test. A special shielded cable is used to convey the output signal to the "ANT" terminals of the radio receiver under test. The use of a shielded cable is advisable for two reasons. First, it prevents radiation of the oscillator signal energy into the surrounding space, and thus conserves all of it for application to the input terminals of the receiver under test. Secondly, the use of a grounded shield around the cable eliminates any annoying "body-capacity" de-tuning effects which would otherwise result whenever the operator moved his hand or body near the cable. In some cases the grounded shield around the cable is made to serve also as the connecting circuit between the GND terminal of the oscillator and that of the receiver.

This oscillator covers the entire broadcast range from 550 to 1500 k.c. The intermediate band is also read directly from 120 to 185 k.c. For superheterodyne receivers using intermediate frequencies higher than 185 k.c., ample signal response is obtained by the use of the harmonic frequencies which are also generated. This includes those recent sets employing 260 and 260 k.c. intermediate frequencies. A 2-cell flashlight battery for fila-

Courtesy Readrite Meter Works

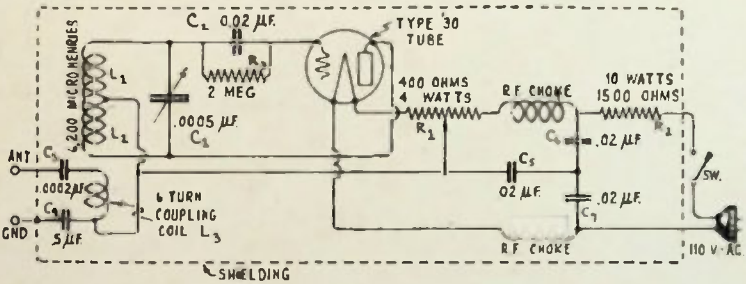
Fig. 67—A typical portable test oscillator with built-in output meter at the right. The schematic circuit diagram is shown in Fig. 66.

ment supply and a small 2½ volt B battery supply all power, and are mounted inside the carrying case.

A study of the circuit diagram in Fig. 66 shows the interesting circuit arrangement employed. The broadcast frequency tuning coil L_1 L_2 and the intermediate frequency tuning coil L_3 L_4 are separate. A pick-up coil L_5 is mounted so it will pick up energy for either one. A single tuning condenser C_3 is used, it being switched across either the broadcast or intermediate frequency tuning coils at will, by the knob-controlled switch shown in the diagram as a T. P. D. T. knife switch. Throwing this switch one way or the other also connects the tuning coil into the tube circuit. The loading condenser C_4 acts as part of the tuning capacity across L_3 L_4. Grid leaks R_1 and condenser C_1 provide the modulation. The output signal voltage available between the A and G output terminals may be varied at will by means of the potentiometer type "attenuator" resistor R_2.

62. Supreme test oscillator Model 60: A circuit diagram of this A.C. operated oscillator is shown in Fig. 68. The oscillator, mounted in its carrying case, is shown in Fig. 69. The metal tube shield is visible directly behind the tuning dial.

This oscillator is designed to operate from the 110 volt A.C. electric light circuit. The modulation of the R.F. signals is automatically accom-



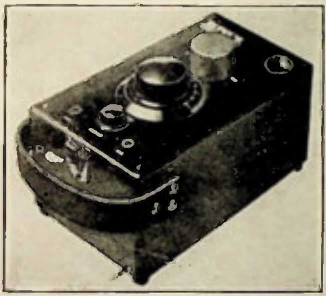
Courtesy Supreme Instr. Corp.

Fig. 68—The circuit arrangement employed in the Supreme Model 60 test oscillator. Harmonic frequencies are employed to obtain a wide frequency range with a single set of coils.

plished by the 60 cycle plate current ripple produced by the A.C. power supply employed as the plate voltage source. Consequently, the output signals of a radio receiver coupled to the oscillator will have an audio frequency "pitch" corresponding to the frequency of the power supply system. The resistor and capacitor values of the oscillator are such that practically no grid leak modulating action results, modulation being accomplished as explained above by the A.C. power supply. 100% modulation is obtained in this way. It is the purpose of the grid resistor and capacitor combination (1) to provide the proper grid bias for the oscillator tube so as to maintain the proper impedance relations between the grid and plate circuits, and (2) to provide protection to the oscillator circuits against possible short circuits between the grid and plate elements of the oscillator tube.

The fact that the modulation of an A.C. operated oscillator is practically 100%, makes this oscillator very adaptable for adjustments of modern radios in which the blasting effect of strong signals is minimized by volume level circuits which are most efficient when operating with signals from a 100% modulated broadcast station. If strong R.F. signals are applied to a sensitive radio of this type by a weakly modulated oscillator, it is possible to overload the detector with R.F. energy without having any appreciable loudspeaker output of A.F. energy. In some receivers, an overloading of the above mentioned circuits with R.F. energy may result in two maxima or peaks of the radio output and in broad tuning when the modulation is

Fig. 69—The test oscillator whose circuit diagram is shown in Fig. 68. The tube is enclosed by the shield shown behind the dial. The output control knob is at the left. The entire unit is enclosed in a portable carrying box (cover not shown).

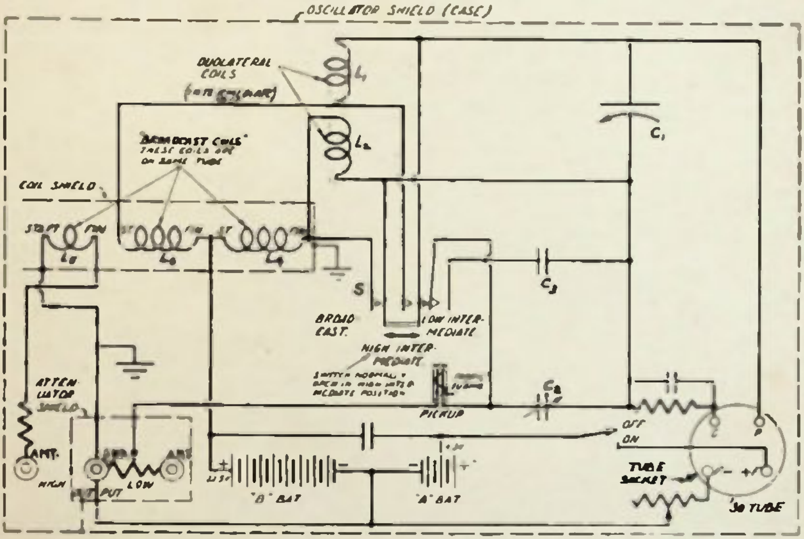


Courtesy Supreme Instr. Corp.

considerably less than 100%. It is, therefore, obvious that the loudspeaker output is greatly dependent upon the percentage of the modulation of the input R.F. signals.

It will be seen from Fig. 68 that a type '30 tube is employed. The tuning unit consists of a 6200 microhenry inductance coil tuned by a .0005 mf. variable condenser operated by a vernier dial. The output signal strength is adjusted by means of potentiometer R_1. This varies the plate voltage applied to the tube, and so varies the output directly. The full resistance of R_1 as well as resistance R_2 are always in the circuit in order to reduce the 110 volts of the line down to the 2 volts required for the tube filament. A 6 turn coupling coil L_3 picks up the energy from the tuning coil, and connects to the output circuit. A rather elaborate filter system consisting of two R.F. chokes and by-pass condensers C_5. C_6 and C_7 prevent any of the R.F. energy from feeding back into the electric light circuit.

The oscillator is completely shielded by being enclosed in a cast aluminum tray connected to ground. A Bakelite panel is over this, on top. This oscillator is designed and calibrated for universal application for all intermediate and broadcast frequency requirements with multiple tuning of all



Courtesy *Jewell Elect. Instr.* Co.

Fig. 70—The circuit arrangement employed in the Jewell Pattern 563 test oscillator shown in Fig. 71. Note the common tuning condenser C_1 which may be connected across either the broadcast coils L_3 L_4 or the intermediate frequency coils L_1 L_2 by means of switch S.

frequencies between approximately 90 and 1500 kilocycles. It is, therefore, adaptable to all present commercial intermediate frequencies as well as such frquencies between 90 and 550 kilocycles as may be designed into future radios, thereby greatly lessening the probabilities of obsolescence. This unusual tuning adaptability is accomplished by tuning over a fundamental range of approximately 90 to 250 kilocycles, all higher frequencies of this fundamental range being provided by "harmonics" for the tuning and balancing re-adjustments of tuned-radio-frequency receivers which operate within the American broadcast range of 550 to 1500 kilocycles. A frequency—dial reading calibration curve is supplied with each oscillator.

63. Jewell Pattern 563 test oscillator: The circuit diagram of this battery operated oscillator is shown in Fig. 70. The oscillator, mounted in its carrying case, is shown in Fig 71.

As will be seen from Fig. 70, this oscillator is battery operated. The batteries are fastened to the underside of the panel. The B battery is a 22½ volt portable type block. For the A battery, two flashlight cells, or 3 volts of a standard 4.5 volt "C" battery, are used. A type '30 tube is employed.

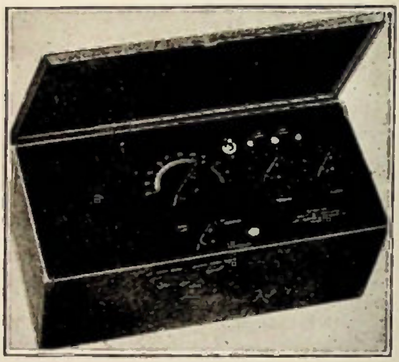


Fig. 71—The test oscillator whose circuit diagram is shown in Fig. 70. The complete oscillator with all batteries required for its operation is contained in the metal carrying case shown.

Courtesy Jewell Elect. Instr. Co.

It will be seen that the main tuning condenser C_1 may be connected across the intermediate frequency coils L_1 L_2 or across the broadcast band coils L_3 L_4 by means of the switch S. The calibration of the intermediate frequency band is controlled by a trimmer condenser C_2 which is automatically connected in parallel with tuning condenser C_1 when the switch S is thrown to either the "low" or "high" intermediate frequency positions. This condenser is adjusted at the factory to give 175 k.c. at the main division on the calibration chart. Should any other intermediate frequency calibration be desired at a main division on the tuning scale, such as 200 cycles at 60 or 65, this trimmer condenser must be adjusted until this new calibration is obtained. The trimmer condenser allows any much used intermediate frequency value to be instantly "spotted" at a convenient point on the scale.

Coil L_5 is a pickup coil which picks up the energy from the tuning coils and feeds it to the output circuit. Two "Ant" terminals are provided, one for high output and the other for low output. The entire carrying case and panel are of metal and form an effective shield.

The "low intermediate" position of switch S covers the band from approximately 130 to 180 k.c. The "high intermediate" position covers the band from approximately 175 to 275 k.c. Calibration curves for all ranges are provided. The broadcast band range is from 550 to 1500 k.c.

The oscillator is connected to the radio set under test by means of a special shielded lead, consisting of an insulated conductor to connect the "Ant" tip jack of the oscillator to the "Ant" terminal of the radio receiver under test, and a metal braid around the conductor, serving both as a shield and also to connect the "Gnd" tip jack of the oscillator to the "Gnd" terminal of the receiver. An attenuator is provided for the "low" output

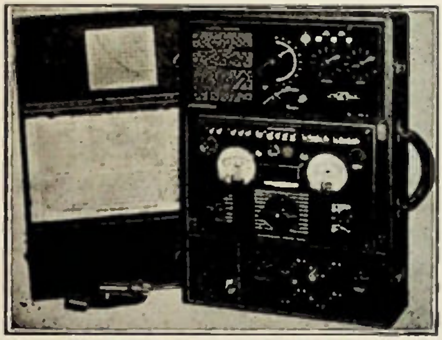


Fig. 72—A professional service combination consisting of a test oscillator at the top, a set analyzer at the center, and a power supply unit for tube tests at the bottom. The entire combination fits into a portable carrying case.

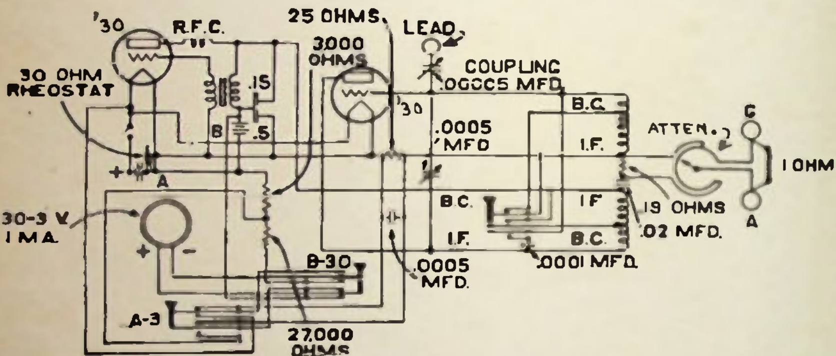
Courtesy Jewell Elect. Instr. Co.

terminals to control the strength of the output signal. The signal available for the "high" output terminals is about 1/10 volt, and is useful for neutralizing condenser adjustments in neutrodyne receivers only. Space is provided at the left of the oscillator (see Fig. 71) for an output meter if one is desired.

Fig. 72 shows a professional service combination, in which is combined in a single unit in all the testing equipment required for service work. This consists of a test oscillator, (same as shown in Fig. 71), at the top; a set analyzer, (same as shown in Fig. 32) in the center; and a power unit that supplies all necessary power for testing tubes in the analyzer. No separate output meter is needed, as receiver output measuring ranges are available in the set analyzer. The entire outfit is assembled in a portable carrying case, or may be installed permanently in a radio service shop.

64. **Weston Model 590 test oscillator:** The circuit diagram of this battery operated oscillator is shown in Fig. 73. The oscillator, mounted with the output meter, in a portable carrying case, is shown in Fig. 74.

This oscillator has been designed to have a continuously variable range from 110 to 200 k.c., and from 550 to 1500 k.c. The 110-200 k.c. range

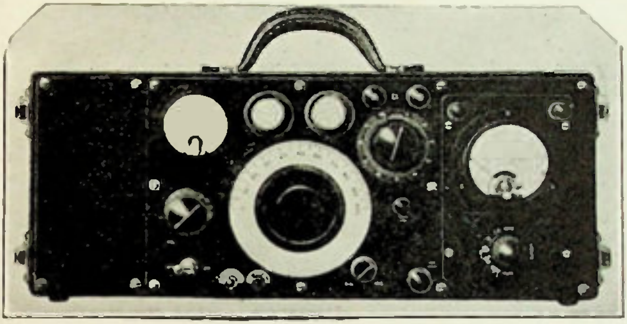


Courtesy Weston Elect. Inst. Corp.

Fig. 73—The circuit arrangement employed in the Weston Model 590 test oscillator shown in Fig. 74. A feature of this oscillator is the separate modulator tube at the right. The grid-dip milliammeter provided in the grid circuit of the oscillator to indicate when the tuned circuit being adjusted is tuned exactly to the frequency of the oscillator is a very helpful feature.

is intended for use when servicing long wave receivers, and superheterodynes whose intermediate frequency stages are tuned to a frequency within these limits. The 550-1500 k.c. range is intended for use when servicing the regular broadcast receivers such as the well-known "tuned-radio-frequency" sets. Frequencies between 200 and 500 k.c. and above 1500 k.c. may be obtained by utilizing harmonics. This increases the utility of the instrument considerably, and makes it invaluable when servicing receivers having an intermediate frequency higher than 200 k.c. and in servicing all types of short-wave receivers and converters.

As will be seen from Fig. 73, the usual coil and tuning condenser is employed. Broadcast or intermediate frequency ranges are obtained by means of a push-button switch which alters the coil connections. Modulation is obtained by the separate modulator tube and circuit at the left. A grid-dip milliammeter may be connected at will into the grid circuit of the oscillator tube to indicate when the tuned circuits of the radio receiver are exactly in tune with the oscillator signal. When this happens the reading of the grid-dip meter will drop sharply. This is very useful in some tests. A copper-oxide rectifier type output meter is also provided for all ordinary work. This is shown at the right in Fig. 74. A specially designed "attenuator," or signal strength control, enables the output signal voltage to be adjusted.



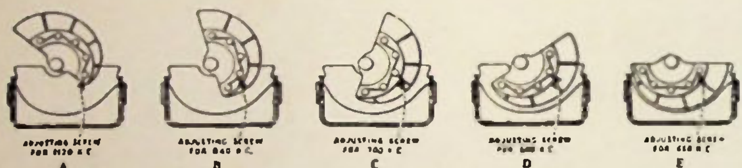
Courtesy Weston Elect. Instr. Corp.

Fig. 74—The portable test oscillator whose circuit arrangement is shown in Fig. 73. The output meter is shown at the right. The grid dip milliammeter is in the upper left-hand corner and the tuning dial is at the center.

It may be varied smoothly and gradually from zero to approximately 5000 microvolts.

65. Aligning the tuned stages in T.R.F. receivers: The use of modulated radio frequency test oscillators, such as have been described in the preceding pages, for adjusting the tuned circuits of single dial tuned radio frequency receivers, so that each tuned circuit is exactly in "resonance" or "tune" with all of the others (see Art. 52), will now be considered. This proceedure is commonly called "ganging", "lining up", "aligning", or "synchronizing." The aligning is usually done by adjusting either the small variable compensating condenser connected in parallel with each of the main tuning sections, or else by bending the fan-shaped segments of the end rotor plate of each condenser section in the gang in or out slightly, when such sections are provided. The fan-slotted plates on each section of a modern gang condenser are clearly shown in Fig. 61.

Mention must be made at this point of the fact that the older broadcast receivers do not have slotted end plates for the purpose of condenser alignment. In this case, where only separate compensating condensers are provided for each section of the gang condenser, the tuning can be lined up *exactly*, only at one point on the dial. This is usually done at a frequency



Courtesy R. C. A. Victor Corp.

Fig. 75—The slotted end-plate on each section of a gang tuning condenser. Set-screw adjustments are provided on this particular one for accurately adjusting the position of each segment. The rotor plates are shown in the 5 different positions at which the adjustments are made.

which the receiver is tuned to, when the tuning dial is set at about 50. In these sets, if the volume or tuning is off at each end of the dial, nothing much can be done about it. When several desired stations that come in at either end of the dial, are received poorly the receiver may be balanced so that these stations are received. Then stations at other points on the dial will come in with less volume.

When a fan-cut rotor plate is provided on each section of the gang tuning condenser, the tuning may be aligned exactly over the entire tuning range. We will consider the method of adjusting such condensers, in detail.

In some of these condensers, adjustment must be accomplished by simple bending of the fan-plate sections in or out, with the fingers. As it is rather difficult to bend the segments delicately and accurately by hand, one form of gang condenser employs a set-screw arrangement as shown in Fig. 75. The set-screws go through a solid plate fastened to the rotor shaft. They are arranged so the end of one screw presses against each section of the slit plate. By turning the screw, the segment it rests against can be pushed in or out from the adjacent stator plate, by a very small amount if necessary. Adjustment is usually made with the receiver tuned to 550, 600, 700, 840 and 1120 kilocycles. The five positions of the rotor for these adjustments are shown in the illustration.

The exact procedure to follow in aligning the tuned circuits of a single dial control tuned radio frequency receiver, by means

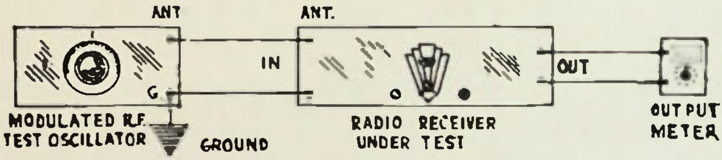


Fig. 76—The oscillator, receiver and output meter setup for aligning the tuning circuits in a single control receiver. The oscillator feeds signals of the desired frequency to the receiver. The capacity adjustment provided on each section of the gang tuning condenser is varied until the output meter indicates that maximum output is being produced. When this is obtained, it indicates that the tuning circuits are properly aligned.

of a test oscillator and an output meter, is as follows: (It is assumed that the receiver is in an operating condition.)

(a) Connecting the oscillator: Disconnect the antenna wire from the "Ant" terminal on the receiver chassis, so that broadcast signals will not interfere with the signal of the oscillator. Connect the "Ant" terminal of the oscillator to the "Ant." terminal of the receiver (or to a special contact point specified by the receiver manufacturer). Connect the "Gnd." terminal of the oscillator to the "Gnd." terminal of the receiver. (Most oscillators are provided with a shielded lead for this purpose. In this case, the inside wire connects the "Ant." terminals of both the receiver and oscillator together. The outside metal shielding connects the "Gnd." terminals of both the receiver and oscillator together.) In most cases the usual ground wire should be left connected to the ground terminal of the receiver. The entire testing setup is shown in Fig. 76.

(b) Adjusting receiver and oscillator: Turn the power supply switch of the radio to the "ON" position. Turn the oscillator power supply switch "ON." Set the oscillator for operation on the broadcast frequency range. As the radio tubes attain their normal operating temperature, turn the oscillator output or "attenuator" control part way up, then set the oscillator tuning dial at whatever frequency it is desired to start the aligning. (preferably at the high frequency end of the broadcast range). Now tune the receiver until the oscillator signal is heard loudest. The volume control of the receiver should be set at "maximum" position. If the signal is too loud, it should be reduced by adjusting the "attenuator" knob on the oscillator.

(c) Connecting the output meter: If it is desired to make the adjustments by output meter indications, turn the radio power supply switch "off." The output meter may be connected to the receiver in several ways, depending upon the receiver output stage, and loud speaker arrangements. If the receiver uses an electro-dynamic type of loud speaker, perhaps the most convenient way of connecting the output meter, is directly across the terminals of the voice-coil, or across the secondary terminals of the output transformer.

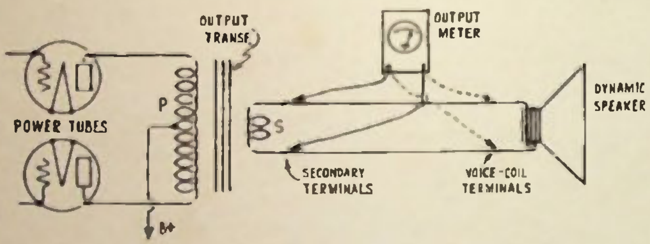


Fig. 77—The output meter may be connected either across the secondary terminals of the output transformer, or across the voice coil, if an electro-dynamic loud speaker is used in the receiver.

as shown in Fig. 77. If these terminals are not easily accessible, or if a magnetic cone or horn type speaker is employed, the output meter should be connected to the plate circuit of the power output tubes in the receiver.

Here again there are two possible cases—either the receiver uses a single output tube or uses two tubes in push-pull. Also, most receivers use an output transformer, or output choke-and-condenser filter between the plate of the power tube and the speaker terminals. Instead of opening up the connections to these inside the receiver, "plate lead output" adapters may be employed to break into the plate circuit of the power tube without disturbing any connections.

In the case of receivers using a single power tube, this tube is removed from its socket. The plate lead output adapter is inserted in the tube socket, then the tube is placed into this adapter. The plate lead on the adapter is then connected to one terminal of the output meter. The other side of the output meter goes to a 1 mf. condenser, the other side of which is connected to the grounded chassis of the receiver. At (A) of Fig. 78, are shown the output tube, output transformer, and speaker connections before the output meter is connected into the circuit. At (B) the connections after the adapter, output meter and condenser are connected, are shown.

In the case of receivers employing a push pull output stage, one of these adapters should be inserted in each of the push-pull tube sockets, and the output meter connected to the plate terminals of these adapters as shown at (B) of Fig. 79.

If an output meter is not available, a 0-5 milliammeter connected in the detector plate circuit as shown in Fig. 81 may be used for the same purpose, (see Art. 67).

(d) Aligning the tuned circuits: After the output meter is properly connected, the radio receiver power supply switch is turned "on" again

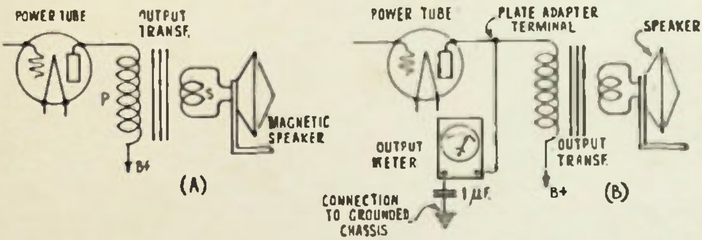


Fig. 78—Using a plate lead output adapter for connecting one terminal of the output meter directly to the plate terminal when the receiver employs a single power output tube and a magnetic type loud speaker.

and the tubes allowed to warm up. Adjust the output meter range control for a meter deflection at or below two-thirds of the full-scale deflection. The meter deflections are arbitrary and are watched merely to find out when "maximum" output is being produced.

With the oscillator operating at a definite frequency,—preferably at the high frequency end of the broadcast range—, adjust the receiver tuning dial until maximum reading is obtained on the output meter. Now vary whatever adjustments are provided on each section of the gang tuning condenser, until maximum output is indicated on the meter, the attenuator being adjusted for less output from the oscillator as the output of the set increases. During the meter indications, the oscillator signals should be audible from the loud speaker; failure to hear the signals which are indicated by the meter would be an indication of defective output transformer or speaker circuits.

If slotted rotor plate adjustments are provided on the tuning condenser, the adjustment of the segment which is just entering into mesh with the stator plates, should be varied in each condenser section. In most cases receiver manufacturers supply information as to the exact frequency at which each segment should be adjusted. Usually these fan-shaped rotor end-plates are made with 5 or 6 segments. One prominent manufacturer uses condenser gangs (see Fig. 75) which have each end rotor plate cut into 5 segments, and recommends the following frequencies for adjustment: 1120 k.c., 840 k.c., 700 k.c., 600 k.c., and 500 k.c. Where no information is at hand, the adjustments should be made at such oscillator frequencies, that *in each case* when the receiver is tuned to the oscillator frequency, the split segment is about half way in mesh with the stator plates. If receivers possessing this desirable construction feature are aligned carefully the tuning will be lined up properly over the entire scale or tuning range.

(e) End of the aligning: After completing the adjustments, turn the radio receiver "off" disconnect the oscillator; re-connect the antenna

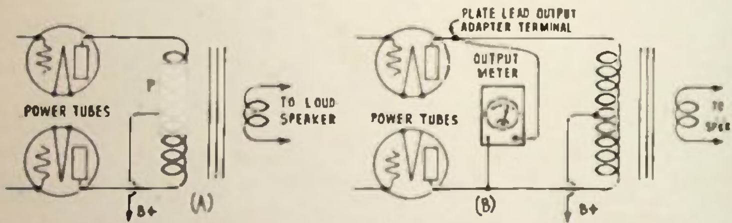


Fig. 79—Using a plate lead output adapter for connecting the output meter to the plate terminal of two power output tubes in push-pull.

wire to the ANT. terminal of the receiver; remove the output adapters (if any have been used); and return the power tubes to their own sockets; disconnect the output meter.

Now turn the radio receiver "on" again and test its ability to bring in stations all over the dial, without oscillation and with sharp tuning. This completes the aligning proceedure.

66. **Aligning the tuned stages in superheterodynes:** In modern single-dial, superheterodyne receivers, the tuning of the tuned radio frequency circuits and the oscillator circuits is usually accomplished with a gang tuning condenser. These tuned circuits must be "lined up," but this is usually done after the intermediate stages have first been aligned.

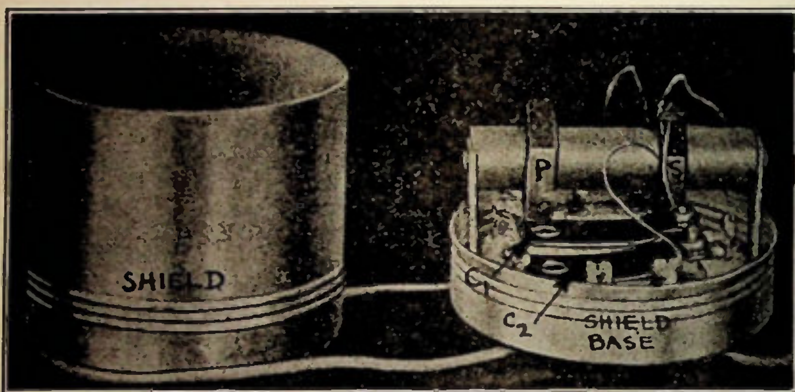
In these sets, the tuned circuits of the primary and secondary windings of the tuned intermediate transformers must first be aligned at whatever intermediate frequency the receiver is designed for. Intermediate frequencies of 170 to 180 k.c. are in common use, although in one make of receiver, a frequency as high as 260 k.c. is used. These stages are adjusted to tune to a definite frequency before leaving the factory, and if for any reason the alignment becomes changed the set will not function properly. The general symptoms are weak reception, broad tuning, and in some cases, poor fidelity. The detailed procedure to be followed in aligning the intermediate amplifier tuned circuits will now be considered. It should be remembered that it is not only necessary to align the intermediate stages with each other, but the combined I.F. amplifier must be tuned accurately to the intermediate frequency for which it was designed.

(a) The oscillator tube in the *receiver* should be removed from its socket and the receiver turned on. The "output meter" or other output indicating device to be used should be properly connected to the receiver as outlined in Art. 65.

(b) Now adjust the test oscillator so it is operating at the intermediate frequency specified by the receiver manufacturer (let us assume this is 175 k.c.). Connect the "Ant" terminal of the oscillator to the control grid terminal (cap) of the *last* I.F. tube. Connect the "Gnd" terminal of the test oscillator (usually the "shield" on the previous wire), to the cathode terminal of this tube. All the late superheterodyne receivers use screen grid tubes in the intermediate stages. Where 227 type tubes are employed in the I.F. stages, as in some of the earlier models, instead of coupling the oscillator to the control grid cap of the screen grid tube as mentioned, it should be connected to the "grid" terminal of the 227. This may be done conveniently by removing the tube from its socket, wrapping the bared end of the wire around its "grid" prong, and then replacing the tube in its socket, (with the wire still on its grid prong).

Usually there are two I.F. stages though in many sets only one stage is used. The primary and secondary coil of each stage is tuned by means of a small semi-variable 2 plate condenser of the "postage stamp" type. The interior of a typical intermediate tuning unit with its shield removed is shown in Fig. 80. The primary and secondary coils P-S are of the duolateral type mounted on a wooden spacing bar. The adjustable tuning condensers C_1 C_2 in the base of the unit, are those which must be adjusted. They are usually constructed so that a screwdriver is all that is required in order to turn the adjusting screw on each one. Therfore in a two stage I.F. superheterodyne receiver there will be 6 adjustments, and where only one stage is employed, 4 adjustments will be found. The secondary tuning condenser and then the primary condenser of the last I.F. transformer should be adjusted for maximum output. Next, the oscillator coupling lead should be connected to the control grid cap of the 1st I.F. tube, where the receiver has two I.F. stages, and adjustment of the condensers in that stage made for maximum output. To tune the 1st I.F. transformer, the test oscillator "Ant" lead is coupled to the control grid of the 1st detector tube, and the ground lead is coupled to the cathode of this tube. The secondary and the primary are now adjusted for maximum output at the intermediate frequency.

Some manufacturers have designed the intermediate stages of their superheterodyne receivers so their tuning curve is flat-



Courtesy Pilot Radio & Tube Corp.

Fig. 80—A typical intermediate frequency tuner arrangement employed in superheterodynes. The primary and secondary coils P and S are tuned by the adjustable condensers S_1 and S_2. The entire unit is enclosed in the shielding can shown. C_1 and C_2 must be adjusted with an insulated screw driver during the aligning proceedure.

topped in order to minimize the suppression of side band frequencies with resultant poor high note reproduction. With these I.F. amplifiers no appreciable change in output reading is obtained when the test oscillator frequency is shifted from 172 k.c. to 175 k.c.. In other words the drop in output should be the same when the 175 k.c. oscillator frequency is shifted to 171 k.c. and to 179 k.c. This will indicate that the flat portion of the intermediate tuning curve is centered at 175 k.c.

After aligning the I.F. stages, the adjustment provided on the receiver oscillator stage tuning condenser section should be adjusted next. This is one of the most important operations in the entire proceedure, and it determines the dial settings at which stations are received.

The test oscillator should be connected to the "Ant" and "Gnd" terminals of the receiver exactly as specified for aligning T.R.F. receivers, (see Art. 65). The oscillator tube should be in its proper socket in the receiver. Adjust the test oscillator to a frequency near the high frequency end of the broadcast band. Now vary whatever capacity adjustment is provided on the set oscillator stage tuning condenser section, until maximum output is obtained, as indicated by the output meter. Repeat this at several other frequencies in the broadcast range. This insures that the frequency of the receiver oscillator wil always differ from that to which the R.F. and first detector tuning circuits are tuned, by a fixed frequency equal to that for which the I.F. amplifier is designed,—for any setting of the receiver tuning dial.

In some cases, the receiver pointer dial may have shifted in relation to the condenser shaft. This can be checked and adjusted by noting whether the kilocycle marking on the set dial corresponds with the frequency of the oscillator when the adjustments on the set oscillator condenser are being made.

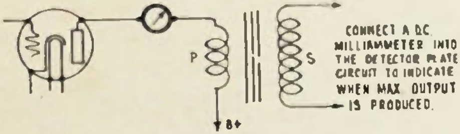


Fig. 81—A 0.5 D.C. milliammeter connected in the plate circuit of the detector of a T.R.F. receiver, or the second detector of a superheterodyne receiver, may be used to indicate when the tuned circuits are aligned properly. The indication to be watched for depends on the type of detector employed. (see Art. 67).

The tuned circuits of the radio frequency stages, (if any are employed), and the first detector stage, are aligned next. With the oscillator still connected as before, those sections of the gang condenser which tune these stages, are aligned in exactly the same way as explained for T.R.F. receivers in Art. 65. The test oscillator is operated at several broadcast frequencies,—preferably starting at the high frequency end of the dial. Proper adjustment is made until maximum output is obtained, in each case. This completes the proceedure for aligning the tuned circuits of superheterodyne receivers.

A non-metallic screw driver about ¼ inch in diameter is always employed for adjusting the line-up of the condensers. If a metal screw driver were used, very disturbing hand-capacity effects would prevent the proper adjustment of these circuits.

67. A substitute for the output meter: If an output meter is not available for indicating when the maximum output is obtained from a receiver during the aligning proceedure, a 0-5 range milliammeter may be connected in series with the plate circuit of the second detector, as shown in Fig. 81. If it is necessary, this may be done by inserting the plug of the set analyzer into the detector socket, and pressing the proper switches to read the detector plate current.

With sets using grid bias or power detection, the receiver should be aligned so that *maximum plate* current reading is obtained on the meter With sets using grid leak-condenser detection, the receiver should be aligned so that *minimum* detector plate current reading is obtained, since in this form of detector, the plate current is reduced by increased signal voltage applied to the grid.

Another simple output indicator, which can be applied to superheterodyne receivers, is a low-range high-resistance voltmeter connected from the cathode of the second detector to the chassis, (B minus). The readings will be affected by the carrier wave only, and are practically independent of the modulation.

68. Sets with automatic volume control: The Service Man must observe a special precaution when using an output meter during the aligning of receivers which employ an automatic volume control tube to keep the set output constant even though the input varies—thus defeating the use of the output meter.

This tube should be removed from the receiver when making any adjustments, for it may disturb the normal characteristics of the receiver. To permit the use of an output meter with sets of this kind, a "dummy" tube, (one that has one of its heater prongs cut off so that its filament does not light up—but is otherwise in normal condition), should be substituted for the tube in the automatic volume control stage.

69. Neutralizing a receiver: Few of the receivers being constructed today make use of the neutralizing systems employed in the older neutrodyne and T.R.F. receivers—simply because the use of modern shielded tuning coils and the screen grid tube, has removed the main causes of feedback in R.F. amplifiers. However, there are still many of these old receivers in use, and it is necessary that the Serviceman know how to *balance* or *neutralize* a receiver.

The tools required for this operation are an insulated screw driver, a test oscillator, and a "dummy" tube (filament prong cut off) of the same type as those used in the R.F. stages of the receiver. Instead of a "dummy" tube, adapters, which have one filament leg "open," may be used. These "neutralizing adapters" are really preferable, since they remove the possibility of incomplete neutralizing through the use of a "dummy tube" whose inter-electrode capacities may not match those of the tube which is to normally be used in the stage being neutralized.

The receiver should be placed in operation, and the test oscillator, which has been tuned to a frequency of about 1400 k.c., should be coupled to the ANT. and GND. terminals of the receiver in the regular way (see (A) of Art. 65). The receiver should then be tuned to resonance with the oscillator, so that the oscillator note is heard loudly in the loud speaker. The last radio frequency tube should be removed and the dummy tube placed in its socket. If the oscillator signal is now inaudible, it indicates that this stage is not off-balance, i.e., it is neutralized. However, should the signal be heard to any degree, the neutralizing condenser for that stage should be adjusted so that the signal is very weak or not audible at all. When this stage has been properly adjusted the dummy tube should be withdrawn and the regular tube replaced. The same proccedure should be repeated with the other radio frequency stages. If far better neutralization is desired, the neutralizing should be checked at one or more other frequencies, preferably 800 k.c. and 600 k.c.

To better accomplish this result, an electrical output indicating device such as a milliammeter placed in the plate circuit of the detector tube, (see Fig. 81) or an output meter connected properly (see Figs. 77, 78 and 79) should be used to determine when the receiver is in the best neutralization or balance. The neutralizing condensers should be adjusted so that a minimum reading is obtained upon the output meter. For a grid leak condenser detector the plate milliammeter reading (if a plate milliammeter is used), will be *maximum*, and for a grid bias or power detector, it will be *minimum* when the stage is completely neutralized.

REVIEW QUESTIONS

1. What is a 4-gang tuning condenser? What is the object of using "gang" condensers in modern radio receivers.
2. Four sections of a 5-gang condenser in a T.R.F. receiver are set at such capacity that they tune their respective tuning coils to 1000 k.c. The fifth section has been jarred out of alignment so that it tunes its tuning coil to 990 k.c. at this setting. Explain in detail just what effect this will have on the operation of the receiver.
3. Describe two different forms of compensating adjustments provided on the individual sections of gang condensers. Which is best? Why?
4. Of what value is a modulated R.F. test oscillator in service work? What frequency ranges should it cover? Why is it not satisfactory to use the regular broadcast signals for this work?
5. Draw the complete circuit diagram for a simple battery operated test oscillator which may be used for testing and lining up the R.F. or intermediate tuned stages of either a T.R.F. or superheterodyne receiver. Explain its operation.

6. Repeat question 5. for an A.C. operated oscillator. What are the relative advantages and disadvantages of the battery operated and electrically operated forms of test oscillators?
7. What is meant by the term "tuning to the harmonics of the oscillator"? Explain the value of the harmonic frequencies generated by a vacuum tube oscillator.
8. A .0005 mfd. tuning condenser is to be used in an oscillator which is to tune down to 400 k.c. What must be the inductance of the tuning coil used with it?
9. Draw the connection diagrams for, and explain, two ways of obtaining an indication of when the output of the receiver under test is a maximum.
10. What is meant by "aligning" the tuned circuits in a receiver? What is its purpose?
11. Draw a diagram showing the complete setup of apparatus for aligning the 5 tuned circuits of a single dial T.R.F. receiver. All connections between the receiver and the other main pieces of apparatus used for this work must be clearly shown. Assume the receiver contains a single output power tube with a choke coil-condenser filter between it and the loud speaker.
12. Explain, step by step, the complete proceedure for aligning the tuned stages of the receiver in question 11.
13. Repeat question 11 for the case of a single dial superheterodyne receiver employing 1 stage of T.R.F. amplification ahead of the first detector, and 2 stages of 180 k.c. intermediate frequency amplification. A push-pull output stage feeding into an output transformer and electro-dynamic loud speaker is employed. The voice coil terminals on the speaker are accessible.
14. Explain, step by step, the complete proceedure for aligning the tuned stages in the entire receiver of question 12.
15. Why is the signal generated by an R.F. test oscillator purposely modulated?
16. Explain two ways of producing a modulated signal in an A.C. operated R.F. test oscillator. In which type can the frequency or "note" of the modulation be varied at will? How is this done? What determines the frequency of the modulation in the other type?
17. Why is the connecting lead from the "Ant" terminal of the oscillator to the "Ant" terminal of the receiver under test, usually shielded by a grounded shield covering?
18. Why must the regular antenna wire be disconnected from the receiver when it is being aligned?
19. What symptom will be noticed when a neutrodyne type of receiver needs to be re-neutralized?
20. Explain in detail the proceedure to be followed in re-neutralizing a neutrodyne receiver having three tuned R.F. stages.

CHAPTER 7.

INTERFERENCE, NOISE AND ITS ELIMINATION

NOISY RECEPTION — CLASSIFICATION OF INTERFERENCE — HOW INTERFERENCE REACHES THE RECEIVER — PRELIMINARY TEST FOR NOISE — INTERFERENCE PICKUP BY ANTENNA-GROUND — INTERFERENCE THROUGH ELECTRIC LIGHT CIRCUIT — CHARACTERISTIC NOISES PRODUCED BY ELECTRICAL DEVICES — LINE FILTERS AND NOISE SUPPRESSORS — NOISE ORIGINATING IN THE RECEIVER — REVIEW QUESTIONS.

70. Noisy reception: Reception of radio programs is often accompanied by disturbing noises which are not part of the program. These may be in the form of crackles, clicks, buzzes, sharp grinding or clashing noises, etc. The term "interference" is commonly applied to include under one heading, all of the various classes of disturbing noises of this kind. Noisy reception occurring in radio receivers is one of the most serious and troublesome problems the Radio Service Man is called upon to solve. It is especially common in conjested city districts where many electrical appliances and devices are operated from the same power lines as are the electric radio receivers, and often within short distances of the receiving antennas.

The set analyzer is useless for this sort of work, excepting in some cases where the interference is caused by one of the parts in the receiver itself. As a result of considerable experimental work on this problem, it is now possible to follow definite plans of attack in order to locate and suppress trouble of this nature, and in most cases, to actually identify the type of device which is causing the interference simply by listening to the character of the interference noise being produced. The various methods for doing this quickly and effectively will now be considered.

71. Classification of interference: In general, it may be said that interference of any type is caused by abrupt changes

of current being set up in an electrical circuit in some manner. General interference may be classified into the following three following divisions:

Class 1: Interference caused by atmospheric disturbances and conditions considered beyond man's control.

Class 2: Interference caused by some part in the receiving equipment.

Class 3: Interference caused by external electrical and mechanical devices controlled by man.

72. How interference reaches the receiver: Interference of "Class 1" is generally termed "atmospheric" or "natural" *static*. It is caused by a series of electrical discharges taking place between clouds alone, or between clouds and the earth, as shown in Fig. 82. These discharges create electromagnetic

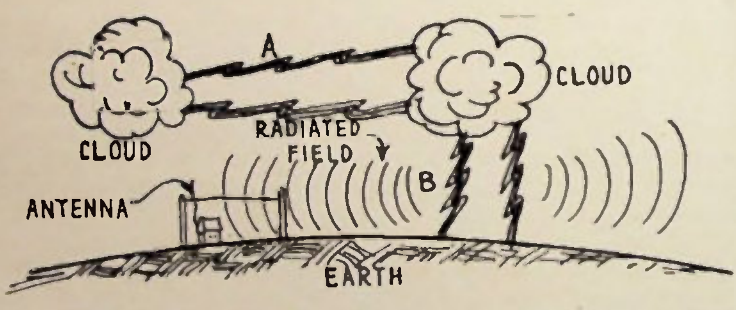


Fig. 82—Atmospheric static is usually caused by electrical discharges taking place between clouds as at "A," or between clouds and the earth as at "B." In many cases continuous electrical leakage is taking place in either of these ways without being seen. Often the discharge is violent and sudden, being accompanied by the familiar lightning streak.

radiations which are of exactly the same nature as are those of the radio signals, so they affect the receiving antenna and receiving equipment similarly, and are heard along with the radio program. Atmospheric static is usually most annoying during times of disturbances in the atmosphere—such as thunderstorms, northern lights, heat lightning, dust storms, etc. Regardless of the fact that many devices have been offered on the market for eliminating or reducing the effects of atmospheric

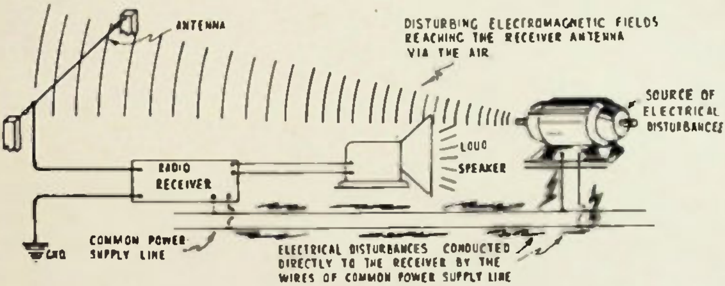


Fig. 83—Electrical disturbances may reach an electrically operated receiver installation either by the radiated field which affects some part of the antenna-ground system, or by being conducted directly to the power supply unit and plate circuits of the tubes by means of the common power supply line.

static, the truth is that all of them reduce the static effects simply by reducing the sensitivity of the receiver, so that both the *signals* and *static* are heard more weakly. It is the opinion of responsible investigators that "Class 1" interference *cannot be eliminated* successfully, although under some circumstances it can be reduced in intensity. Since this class of interference is beyond man's immediate control, it will be eliminated from our discussion.

"Class 2" interference may be caused by a loose contact in a vacuum tube or other part in the receiver, a broken connecting wire, old "B" batteries—in fact anything which will cause abrupt variations of the current in one of the circuits of the receiver. This class of interference can be eliminated in all cases, although at times it may be difficult to locate the exact part in which the trouble lies. The proceedure to be followed in locating and eliminating trouble of this kind will be considered in detal in Art. 79.

"Class 3" interference is produced by abrupt changes in the current flowing in a circuit, and is caused by the operation of certain types of electrical apparatus or appliances. Certain types of electric motors, electrical "make-and-break" contacts, X-ray and violet ray machines, electrical ignition systems, loose

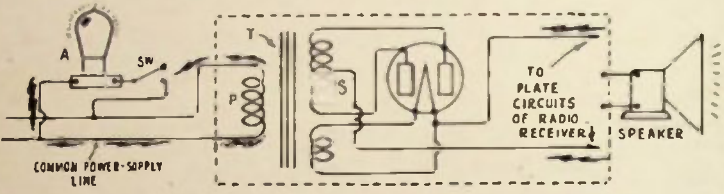


Fig. 84—A simple experiment showing how interruptions of the lamp circuit "A" are conducted along the common power supply circuit and affect the plate circuits of the receiver through the inductive action taking place between the primary and secondary windings of the power transformer T in the electrically operated receiver. This is an illustration of the transfer of disturbances by "conduction."

or dirty contacts, etc., are responsible for this trouble. The apparatus not only produces electrical disturbances in the power supply circuit to which it is connected, but where sparking occurs, electromagnetic fields or radiations are also set up. These travel outward into space in all directions, and are capable of affecting radio receiving antennas or ground wires located in the vicinity, in exactly the same way as the signal radiations from the broadcasting stations do. These are the two main paths by which all disturbing impulses of this class may reach the receiving equipment. Both methods of propagation are shown in Fig. 83. Usually they reach the receiver by both paths, if it is of the electrically operated type. If it is battery operated, interference will only reach it via the antenna-ground system of course.

Perhaps the following simple but effective experiments will help to clarify and fix these two important points in the mind of the reader. When they are understood clearly, the entire problem of noise elimination becomes more simple.

Experiment: Put an electrically operated receiver, (one which does not already contain a line filter built into its power supply unit), into operation. Tune a station in loudly, and turn the volume control up to maximum volume position to make sure the set is working properly. Now leaving the volume control at "max," detune the set so that no station is heard. In this way the interference to be produced will be more easily heard. Now rapidly switch on-and-off any lights or electrical appliance connected directly

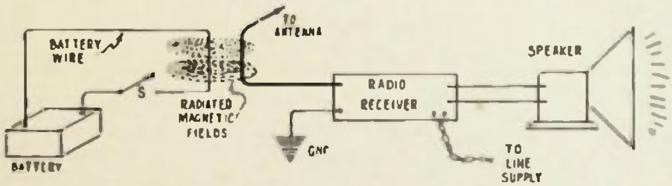


Fig. 85—A simple experiment showing how interference may reach the antenna-ground circuit by the radiated field from the disturbing source.

to the lighting circuit which supplies the receiver. A loud click will be heard in the loud speaker each time, caused by the electrical disturbance produced in the lighting circuit by the makes and breaks of this circuit.

The circuit condition is shown in Fig. 84. The electrical disturbances caused by opening and closing the lamp circuit A, affect the primary winding P of the power transformer T in the radio receiver. This causes larger impulses to be induced in the high voltage secondary winding S. These are communicated through the rectifier to the plate circuits of the receiver where they cause abrupt variatioins in the plate voltages and currents. These are amplified by the amplifier stages and appear as "noises" in the loud speaker. This illustrates the first way in which interference may be picked up by electric receivers. In D.C. electric receivers, disturbances in the power supply line are communicated directly to the plate circuits, since no power transformer is used.

A simple experiment to illustrate the effects of the radiated electromagnetic fields can be performed with the apparatus setup shown in Fig. 85. An "A" or "B" battery is connected to a piece of insulated wire about 6 ft. long, through a switch S. The radio receiver is put into operation as before, and the battery wire is held *parallel* to the antenna lead-in or ground wire of the receiver and about 1 foot away, as shown. When switch S is rapidly opened and closed, the radiated magnetic field from the battery wire will cut across the antenna circuit wire and induce voltage impulses in it. These will be amplified by the receiver, and appear as noises in the loud speaker. Note that in this case, there is no actual *direct* electrical connection between the source of the interference and the radio receiver. The impulses are transmitted only by the field radiated from the source of interference. If a sensitive receiver is used, the interference will be heard even if the battery wire is held some distance away (always *parallel*) from the antenna circuit. This illustrates the second way in which interference can be picked up by radio equipment of both battery operated and electrically operated types.

Interference of "Class 3" can be eliminated, or at least reduced, in all cases, provided the source and cause can be determined. The method of doing this will be studied in detail.

Now that we have some idea of what causes interference, and how it may reach the receiving equipment, we are prepared to proceed to study the methods to follow in locating and suppressing or eliminating interference in actual practice. Let us assume the Service Man is called in on a complaint of "noisy reception" from a particular receiver.

73. Preliminary test for noise: The first step in trouble-shooting a radio receiver for noise, is to determine whether the electrical disturbance is reaching it by way of the antenna-ground circuit or not. This will narrow down the possible causes of the noise. To do this the following proceedure is followed.

If the receiver is of the type which uses an aerial and ground, the set should be operated with the volume control full on and with the *noise* coming in as loudly as possible. If possible adjust the tuning so no broadcasting station is heard—although this is not absolutely essential. Now disconnect both the *antenna* and *ground* wires from the receiver. Take a very short piece of wire, or a nail, and connect the antenna and ground posts on the set together with it, as shown in Fig. 86. The antenna system or energy collector has now been removed, so that any interference which was being picked up by the antenna-ground system will now have no effect on the receiver. Therefore, if the noise diminishes or stops altogether when this is done, it indicates that it was reaching the receiver from an outside source by way of the antenna-ground circuit, and attention must be directed toward tracing down the source outside.

If the noise does not stop, and the receiver is battery operated, (having no connection to the electric light circuit) the trouble is undoubtedly due to some part or connection in the receiver or batteries.

If it is an electric set, the noise may be due either to this cause or to electrical disturbances reaching the set by way of the electric light circuit. In this case, in order to definitely narrow down the trouble to the receiver or to the electric light circuit, a good line filter (any of the types shown on the following pages), should be plugged in or connected between the receiver and the electric light circuit. The filter will prevent the line disturbances from entering the set. If the filter stops the noise it may be assumed that it is coming in by way of the electric light circuit. In this case, it is merely necessary to permanently connect a filter of this kind in the circuit. If the filter has not stopped the noise, (with the antenna and ground wires still disconnected), it may be assumed that the noise originates somewhere in the receiver, and attention should be concentrated on this.

By these simple tests, the source of the interference may be narrowed down to either the antenna-ground circuit, the receiver or the power supply line within a few minutes. Where the receiver is of the fully shielded type with all R.F. coils and wir-

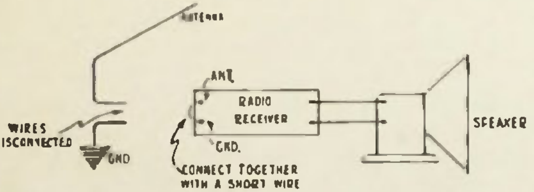


Fig. 86—Preliminary noise test on a radio receiver. The antenna or energy collector system is disconnected from the receiver, in order to determine if the electrical disturbances are reaching the receiver by its path.

ing enclosed in metal shields, this test is conclusive. Some receivers, however, are not fully shielded, and in exceptional cases of strong radiated interference from a nearby source, enough energy may be picked up by the wiring or coils of the set to cause the noises to continue to be heard in the speaker. However, there will be some decrease in the loudness of the noises when the antenna and ground wires are disconnected from the receiver.

74. Interference pickup by antenna-ground: Let us assume that the preliminary test described in Art. 73 shows that the interference is reaching the set via the antenna-ground circuit. The proceedure to follow in this case will now be outlined:

The nature of the disturbance must first be determined. It may be atmospheric "static" or "man-made" interference. If it is atmospheric static, its intensity should change with the time of day and the weather, being especially strong during stormy weather. Information concerning this can be obtained from the owner of the receiver, or the Service Man may observe the intensity of the noises himself over a period of several days when the weather differs. As already stated in Art. 72, interference due to atmospheric static cannot be eliminated since it is beyond man's control. If the receiver is sensitive enough so it will bring the stations in with sufficient volume when its volume control setting is reduced, the "static" perhaps may be reduced somewhat by employing a short antenna. Of course this will result in a decrease in loudness of the desired signals.

If the symptoms are such that atmospheric static is not suspected, a thorough inspection of the entire antenna-ground system should first be made. Failures in this system, such as shorts or grounds in the aerial or lead-in wires, a loose or corroded splice in the lead-in, poor contacts at the window lead-in strip, loose, dirty, or corroded contact between the ground clamp and water pipe, leaky lightning arrester, etc., will all cause noisy reception. Practically all of these conditions may be determined by visual inspection, and are easy to correct, (see Fig. 41).

Where noise in a receiver appears to result from a faulty aerial system and this is found to be intact, it must be remembered that another aerial, nearby, that is grounding or shorting at times, may also cause the trouble. The interference may be picked up by induction, and it will be necessary to repair the other aerial before satisfactory reception may be secured. Numerous cases have been known, where more than three other aerials had to be repaired in order to entirely eliminate interference in a receiver connected to a separate aerial.

Several large service organizations have adopted a special method of installing antenna systems, that has many merits. The advantages of this system are readily understood. Instead of using bare copper wire for the aerial wire, separate rubber-covered lead-in wire, and a window lead-in strip: kits composed of insulators, a ground clamp and a 150 ft. roll of rubber-covered wire, about 16 gauge are furnished for every installation. This wire is used for both the aerial and lead-in, and is brought directly to the receiver all in one piece without using a window strip. This does away with the possibility of several loose and corroded connections. The aerial wire, being insulated, will not cause any disturbance in the receiver upon coming in contact with any grounded object or another aerial, unless so much rubbing takes place, due to swaying by the wind, etc., that the rubber insulation wears through at the point of contact.

If the entire antenna-ground installation seems O.K., the Service Man should determine whether the antenna-ground system is located in a building near a power house, trolley line, or electrified railroad line; and whether there are any electrical devices such as electric motors, elevators, X-ray machines, violet-ray machines, oil burner or electric refrigerator installations, etc., located in or near the building. The owner should also be questioned as to whether the interference appears at all times, or only at certain times of the day, etc. He may be able to furnish considerable valuable information in this connection. This part of the trouble-shooting proceedure is a tedious one and may take some time but in many cases it leads on directly to the source of the trouble.

Fortunately the Service Man is aided greatly in this phase of the work by the fact that most types of radio interference have a characteristic sound by which they may be instantly identified. These sounds have been classified in Art. 77 to aid in this work. Opposite each class of noise, is a list of the kinds of common electrical apparatus which are most likely to cause this noise. The Service Man can then hunt for a similar piece of electrical apparatus in the neighborhood of the receivers. Questioning of a few persons will usually reveal its location.

Interference caused by some source external to the building presents a special problem. It is usually necessary to experiment with different forms of aerials, and their direction in relation to the interfering source. Where noise is caused by a traffic light control line, a train or trolley line, etc., the aerial wire should be erected so it points at right-angles to the electric rail or overhead trolley wire, with the lead-in taken from the furthest end. On numerous occasions, two aerial wires have been successfully used, diverging at an angle from the single lead-in so as to form a "V" as shown in Fig. 87.

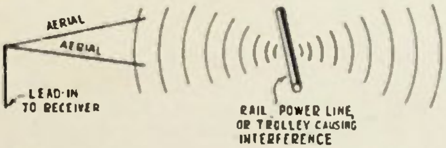


Fig. 87—A horizontal "V" antenna erected at right angles to an interfering power line, trolley line, etc., will help to reduce interference caused by direct induction. The lead-in is taken from the "V" end, as shown.

The best position, in which noise pickup is balanced out, must be found by trial.

Where hum is picked up by electromagnetic induction directly from nearby A.C. power lines, the "phased" aerial shown in Fig. 88 is usually very effective in reducing the interference. The insulators divide the aerial into four sections. The directions of the induced voltages due to this induction will be as shown by the arrows. Note that the direction of the voltage induced in A-B is opposite from that in C-D due to the phase difference which occurs in the induction field during the time it travels from the plane of A-B to that of C-D. By connecting the four sections as shown these voltages are made to oppose and cancel each other, since all sections are of equal length.

If inquiry reveals that large motors, such as those employed to run elevators in the building, or X-ray equipment, etc., are definitely in use in the building, an antenna with a very long horizontal aerial portion erected as high above the building as possible should be employed. This will increase the signal—noise ratio by removing the aerial wire as far from the source of the interference as possible, and using a long wire to provide greater radio signal pickup. In stubborn cases, a shielded lead-in wire must be employed to prevent the radiated fields which are set up by the interfering device from acting on the lead-in wire running through the building—possibly close to the source of disturbance. Shielded lead-in wire is similar to ordinary rubber covered wire, except that it has an additional braided metal

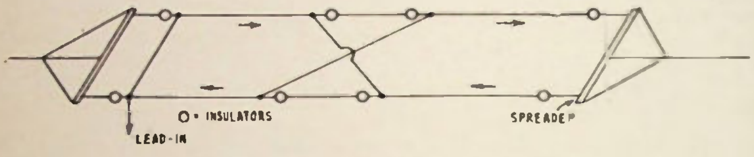


Fig. 88—A "phased" antenna. The instantaneous voltages induced in the four sections of the antenna by electromagnetic induction from a nearby interfering power line will be in the directions shown by the arrows, and will tend to cancel each other out,—thus reducing or eliminating the interference.

(usually copper) sheathing on the outside, as shown in Fig. 89. Ordinary lead-sheathed rubber insulated copper wire is also used extensively for this purpose. The wire inside should be connected to the aerial and receiver in the usual way. The shield should be grounded—preferably at several intervals along its length. In some cases, better results will be obtained where the shield is not grounded. The shielded lead-in should be tried both ways and the method used which proves most satisfactory. Of course shielded wire should not be used for the horizontal aerial portion of the

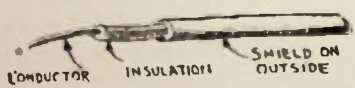


Fig. 89—Shielded lead-in wire. The central lead-in conductor is insulated by the surrounding rubber insulation and electrically shielded by the enclosing metal shield.

antenna system, for this would prevent it from picking up the radio signals. In some cases the interference is so intense that it is not possible to eliminate it by any practical means.

75. Interference through electric light circuit: In the case of receivers which obtain their power from either A.C. or D.C. electric light lines, interference is often caused by direct conduction of the electrical disturbances through the line wires to the receiver, as shown at the lower part of Fig. 83, and in Fig. 84. Of course, this trouble does not occur in battery operated receivers. This complaint is often caused by small electric motors, or electrical household appliances, operated somewhere in the building, (or in the vicinity), from the same power line as that which supplies the radio receiver. Here, when once the interfering device is located, the interference may be eliminated directly at the source (preferably), or at the receiver, by a suitable filter.

Portable, sensitive, noise-hunting receivers with directional "loop aerials" have been developed especially for tracking down the exact sources of such disturbances, by simply carrying them in the direction in which the noise comes in louder and louder, until the source is located. The average Service Man does not have one of these outfits available however, so he must rely on questioning the set owner, and possibly the neighbors, about the ownership of motors, electrical devices etc., until he locates the offending device.

As each type of electrical device produces a distinctive characteristic interference sound, its location can be very much simplified if the Service Man learns to recognize these sounds. These will now be identified.

76. Characteristic noises produced by electrical devices: The following table contains a list of the common interference noises which are encountered, together with the corresponding type of electrical devices which produce them.

1. **Crackling** **Scraping** **Short buzzes** **Sputtering**	loose or corroded connections in electric light sockets, floor lamps, electrical appliances and cords, broken heating elements, wet outside power insulators, leaky power transformer insulators, power line grounded on branches of a tree, elevator control contacts, high tension lines, leaky cables.
2. **Clicks**	telephone dialing systems, switches of any kind as in sign flashers, elevator controls, heaters with thermostats, heating pads, electric irons with thermostats, telegraph relays, etc.
3. **Steady** **Hum**	poor ground on set, antenna or ground wires run close to or parallel to power line.

4. **Buzzing or Rushing**	automobile ignition, moving picture machine, arc lights, street car switches, oil burner ignition, battery chargers, diathermy machines, high frequency apparatus, X-ray or violet ray machines.
5. **Rattles, Machine-gun fire**	telephone dial systems, automobile ignition systems, buzzers, vibrating rectifiers, sewing machine motors, dental laboratory motors, annunciators, doorbells.
6. **Whistles, Squeals**	Defect in the receiver, heterodyning broadcast station signals, picking up radiations of an oscillating radio receiver nearby.
7. **Buzzing, Humming, Whining, Droning, Whirring**	electric motor noise. May be on vacuum cleaner, electric fan, electric dryer, massage machine, hair dryer, motor generator set, small blower, farm lighting plant, electric refrigerator, oil burner, dental apparatus, cash register, dishwasher, sewing machine, etc.

Many manufacturers of high grade electrical appliances, such as vacuum cleaners, electric irons and heating pads having heat control thermostats, etc., equip their products with small by-pass condensers built right into the unit. These effectively prevent any interference with radio receivers operated in the vicinity, and the manufacturers make this a sales feature.

77. Line filters and noise suppressors: When the offending electrical device can be located, the interference may usually be effectively suppressed at its origin by connecting a suitably designed electrical filter directly into the power line which supplies current to it. If the interference originates outside of the building and is conducted to the radio receiver by the electric light circuits, but the offending device cannot be located, it can be effectively reduced or eliminated only by connecting a filter at the service switch near the house meter,—not at the radio receiver. By connecting the filter at the incoming service switch, the disturbances are prevented from circulating through the electric wiring of the building and setting up fields which might also affect the receiving antenna-ground system employed.

Suitable line filters are, in general, of the low-pass type, that is, they will readily pass the 60 cycle current and block the flow of all higher radio frequency impulses which constitute the "noise" disturbances. The electrical disturbances created by small motors and other electrical appliances may be prevented from feeding back into the electric supply line in many

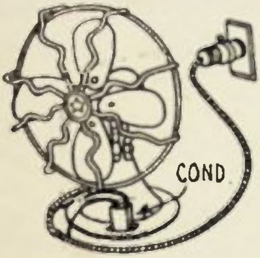


Fig. 90—A simple, effective way of eliminating interference caused by small motors and electrical appliances. A 1 mf. condenser is connected directly across the terminals ser is connected directly across the terminals of the device, as near to the brushes or place where sparking occurs, as possible.

cases, by connecting a 1 mf. condenser *directly* across the motor terminals, as shown in Fig. 90. In some cases, one condenser is not sufficient, and it may be necessary to use two condensers of similar capacity, connected as shown in Fig. 91. The common connection is connected to a good ground located as near to the motor as possible.

In many cases, it will be found to be better to connect this common connection to a carefully cleaned metal part of the motor frame instead of

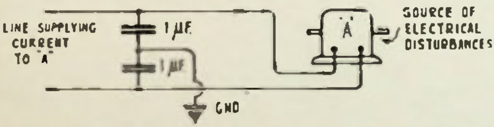
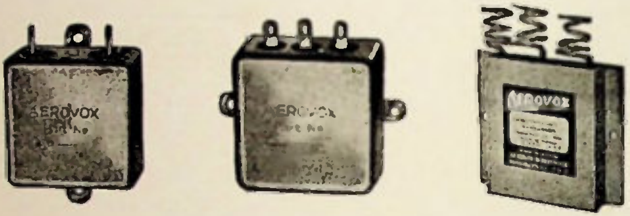


Fig. 91—A simple 1-1 mf. condenser filter for preventing any electrical disturbances caused by an electrical device from feeding back into the power supply line.

to a ground. The reason for this, is that a considerable difference of radio frequency potential may exist between the frame of the motor and the so-called "ground connection," and interference may be radiated from all points which are at a different potential from that at which the interference is originating.

Several typical forms of by-pass condensers for this purpose are shown in Fig. 92. That at the left is a simple 1 mf. by-pass condenser with metal-tab terminals. The middle one contains the two 1-mf. condensers with the common connection already made and brought out to the center tab. This is ideal for the filter system in Fig. 91. That at the right is a double 1-1 mf. condenser with pig-tail leads for connection.



Courtesy Aerovox Wireless Corp.

Fig. 92—*Left*: A single 1-mf. by-pass condenser with metal-tab terminals. *Center*: Two 1-mf. condensers in a single case with a common center terminal. *Right*: A condenser unit with flexible pig-tail lead terminals.

In more obstinate cases it is necessary to connect a radio frequency choke coil in series with each side of the line, in conjunction with two by-pass condensers as shown in Fig. 93. The chokes block the high frequency impulses from the line,

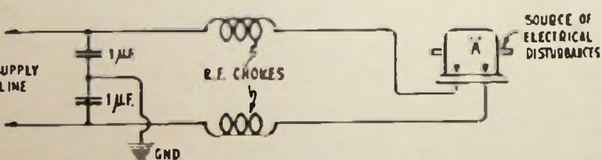


Fig. 93—A two-condenser filter with the common terminal connected to ground or to the frame of the interfering device. An R. F. choke coil is also connected in series with each side of the line. This filter prevents the disturbances from feeding back into the common power supply line.

and the condensers by-pass them across to ground. If 1-mf. condensers are used for the filter in Fig. 93 the R.F. choke coils may be constructed as follows:

Each choke consists of 100 turns of double cotton covered wire, bank-wound on a cylindrical wooden or fibre form one or two inches in diameter. The size of the wire must be adequate for carrying the current flowing in the circuit. No. 14 wire may be used for 9 amperes. A layer of Empire cloth should be placed between each two layers. The condensers should be rated at at least 500 volts.

The entire filter unit should be enclosed in a metal cut-out box. It is particularly successful in eliminating interference from motor-driven devices

Fig. 94—A simple filter consisting of two R. F. choke coils alone. This is usually effective in mild cases of interference.

such as electric refrigerators, vacuum cleaners, vibrators, washing machines, oil burners, etc.

Sometimes two R.F. choke coils alone, connected in series with the power supply line as shown in Fig. 94, are sufficient to prevent electrical disturbances from feeding back into the power supply line. These may be constructed as explained above.

There are many commercial line filter units available today. In some cases the construction has been specialized, so that a certain type of filter unit is specified for eliminating electrical interference from each particular type of electrical device. Two convenient forms of these units are shown in Fig. 95. Each one employs the circuit arrangement of Fig. 91.

The filter unit at the left contains two 1mfd. condensers, and is of the type designed to plug into the lighting socket between the electrical device causing disturbances and the power supply line. The binding post at the right, is for the connection to ground, or to the metal frame of the disturbing device. This is adapted particularly for use in average cases of interference.

The filter on the right employs condensers of larger capacity, but is of the same type. This is designed for use where the interference is very bad. Like the one on the left, it can be used either between the apparatus which is causing interference and the line, in order to prevent the electrical disturbances from entering the line circuits—or it may be installed between the line and the radio receiver to prevent electrical disturbances in the line from reaching the circuits of the receiver.

The following filter may easily be constructed by the Service Man at small expense in a very short time, and is very useful in eliminating most average cases of line interference:

Procure a metal coffee can, two 1-mf. condensers of proper voltage rating, and a ½ lb. roll of ordinary No. 18 bell wire. Divide the wire into two chokes. The parts are placed into the can and connected as in Fig. 93. If desired, an outlet, into which the offending apparatus is plugged, may be mounted on the cover of the can, as in many manufactured units. The chokes should be separated from one another by at least 3 in., and if possible placed at right angles to the can. The entire unit may be impregnated with paraffin after being placed in position in the can. The cover may then be soldered, or fastened by screws, into place.

It must be remembered that in all cases where line filters are applied to an electrical device causing electrical disturbances,

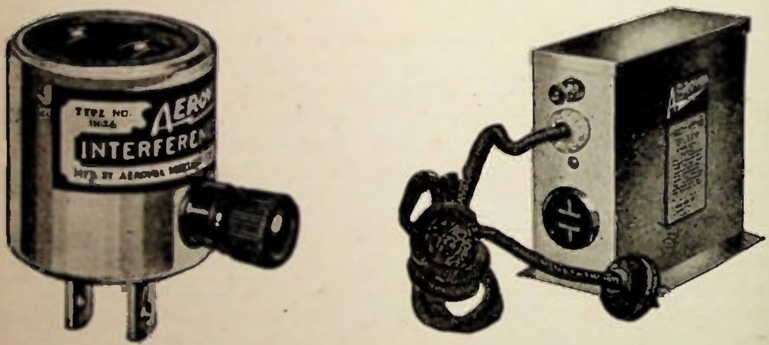


Fig. 95—*Left*: A simple interference filter designed to be plugged between the lighting socket and the electrical device causing the interference.
Right: A heavy-duty filter for the same purpose.

the filter should be mounted directly on the device if possible and its connecting leads kept as short as possible. Also in cases where sparking occurs in the device, radiation is transmitted by the spark through space, and this may affect the antenna circuit of the receiver. Such offending apparatus as X-ray, violet ray and diathermy machines used for medical purposes must often be completely shielded by an enclosing copper box or screening connected to ground, in order to prevent this radiation. Of course a suitable line filter must also be used as well.

78. Noise originating in the receiver: If the preliminary tests outlined in Art. 73 indicate that the noise is originating somewhere in the receiver itself, attention must be directed to the receiver. Generally, tubes are the most frequent offenders, and each one should be tapped sharply with the forefinger while the set is turned on. If it contains a loose element, a loud noise will be heard in the loud speaker at once, and the tube should be replaced. A quick visual examination may reveal a loose connection somewhere, and will not be amiss. Should this proceedure fail to disclose the cause, the following systematic mechanical tests are necessary.

The first R.F. tube should be removed, after the set has been placed in operating condition. Should the noise cease, then the trouble is caused by some defect in that stage and an inspection of all parts, circuits and connections of the first stage should be made at once. If the noise is still heard with that tube removed, the second R.F. tube should be withdrawn and the same tests carried out in that stage. In this way, using the same proceedure, the faulty stage may be localized, and the cause of the trouble ascertained and eliminated.

Very often, the detector plate by-pass condenser is a cause of noise. This may be checked easily by disconnecting the unit from the circuit while the set is operating. Although these condensers may check satisfactorily when a continuity or ohmmeter test is applied, they may break down and become leaky when the voltage is applied to them in the circuit. In receivers, employing power or grid bias detection, the cathode bias by-pass condenser may often be found to be at fault. Particularly is this true in some of the models of receivers where glass tubular grid leaks are used in grid lead-condenser detection. This unit is a frequent source of noisy reception.

The most common cause for noisy reception in an audio amplifier, lies in the primary of the audio transformers. The best test for a noisy primary is to substitute another transformer for the one in use, or to disconnect the primary from the circuit entirely and substitute a plate resistance R and blocking condenser C connected as shown in Fig. 96. This condition will sometimes evidence itself even with the detector or 1st audio tube removed from its socket.

Where the noisy condition continues, after all tubes but the last audio, have been withdrawn, it is probable that the power pack or the reproducer is at fault. In the power pack, there are several units that may be responsible for noisy reception. Most common is a voltage divider resistor which "sparks" across. These resistors are usually covered with an enamel coating to make them moisture-proof. When the enamel contains impurities of a metallic nature, sparking occurs at that point. This condition may be noted by a visual examination (preferably in a darkened room), and the remedy is, replacement. At times, a power transformer will be the source of interference. Many good transformers employ an electrostatic shield between the primary and secondary windings to prevent the transfer of line noises. Arcing may take place between the primary and the shield due to breakdown of the insulation, and will produce an annoying interference that is exceedingly difficult to trace. When this condition is found to exist, a new transformer must be installed.

The majority of dynamic speakers used in receivers today employ copper tinsel cord to make connection to the voice coil. This wire or cord, similar to that on head sets and magnetic reproducers, has great flexibility but after some time, becomes worn and frayed, resulting in noise. Accompanied with this noise, may often result the complaint of intermittent recep-

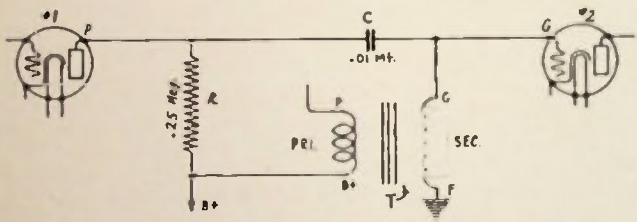


Fig. 96—Testing an audio transformer primary for noise by substituting resistance plate coupling for its primary winding.

tion. A repair of this kind may be effected easily by replacing the tinsel cord with another strip.

The off-on switch in radio sets is a frequent offender. The contacts become worn or corroded and will, upon vibration, set up a disturbing "crackle." If the switch is at fault, a flickering or lowering in the pilot light or tubes should be noticed.

The presence of dust or small foreign particles between the plates of the variable condensers will also set up noise. An ordinary pipe cleaner may be used to advantage for removing the foreign matter in such cases. The rotor friction contacts of the variable condensers may become corroded and cause a scraping sound in the reproducer as the receiver is tuned.

Any corroded or poorly soldered joint will cause unnecessary and undesirable noise. One source of this trouble, usually overlooked by many Service Men, is in corroded or dirty tube socket contacts. When engaged in the task of locating noise, originating within the receiver itself, it is the best policy to clean all contacts thoroughly and to re-solder every suspicious soldered connection, to eliminate any possibility of trouble at these points.

It must be evident to the reader, at this point, that there are so many causes which may contribute to noisy reception in a radio receiver, that trouble of this kind can only be located quickly by a most careful, systematic, proceedure as outlined here. In possibly no other branch of radio servicing is the practical experience of the Service Man, and his attention to minute details so important as in this work.

REVIEW QUESTIONS

1. What three classes of electrical interference may affect a radio receiver?
1. Describe (with the aid of sketches), two ways in which interference originating outside the receiver, may travel to the receiving equipment and affect it so as to cause noisy reception. How could you prove this?
3. Why is a set analyzer of very little value in trouble-shooting for noisy reception?
4. Why is it impossible to completely eliminate interference caused by atmospheric "static"?
5. Explain in detail, how to determine whether interference is affecting a radio receiver by way of the antenna-ground circuit or not.
6. Explain how you would proceed to locate the source of the interference, if the test in question 5 showed it to be affecting the antenna-ground circuit.
7. Of what use is a shielded lead-in wire? What effect will the increased lead-in-to-ground capacitance caused by the grounded shield, have on the antenna stage tuning condenser adjustment in a single-dial receiver?
8. How would you determine whether the noise originates in the receiver itself, or in the power supply line? In the latter case what is the remedy?
9. Describe three line-filter arrangements, and draw a diagram showing the connections of each one across an offending motor. For what particular application would each be used?
10. Describe the characteristic noises which would be produced in a radio receiver in each case, by interference from the following electrical devices: (a) a D.C. electric motor; (b) a spark coil; (c) elevator control relay contacts; (d) a nearby high tension A.C. transmission line with a leaky insulator; (e) a doorbell.
11. How would you proceed to locate the exact source of the noise, if the preliminary tests had shown it to be caused by something in the receiver itself?

Chapter 8.

VACUUM TUBE CHECKERS

NEED FOR THE TUBE-CHECKER — A SATISFACTORY TEST FOR TUBES — SIMPLE SERVICEMEN'S TUBE-CHECKERS — VARIOUS COMMERCIAL TUBE-CHCKERS — CHART OF VACUUM TUBE CHARACTERISTICS — REVIEW QUESTIONS.

79. Need for the tube-checker: In the course of his daily work, the Service Man usually has occasion to test tubes of various types in order to find out whether they are in normal operating condition. This is especially true in radio stores, where large quantities of tubes are sold daily. For this purpose, he should have at his disposal some means of making rapid, though accurate, tests of all types of tubes that are manufactured. While most set analyzers are equipped to test tubes, it is not always convenient to have to connect up a particular radio receiver which employs the type of tube to be tested and then plug the analyzer into a socket of the receiver, in order to make the test.

Note: The Supreme Model AAA-1 Diagnometer described in Art. 32 is an exception to this. In addition to providing means for tube testing during receiver socket analysis, it contains a separate tube tester which operates from the A.C. power supply line.

What is needed, is a tube tester which obtains all the necessary voltages for the tube under test, directly from the A.C. electric light socket—without need for connecting up any receiver. Testers of this kind are commonly called "counter tube-checkers," "tube-sellers," or simply, "tube-checkers." They are employed extensively in radio stores and service stations.

Many Service Men also prefer to use a portable form of tube-checker on service calls instead of depending on the tube test provided by the set analyzer. The reason for this, is that most set analyzers incorporate a small 4.5 volt battery which may be connected into the grid circuit of the tube under test, in order to change the grid voltage. In this way a rough check on the transconductance is obtained by noting the change which this produces in the plate current, and dividing its value by the change in grid voltage. Although this method is a good one for outside tube test work, it is very difficult to compute a simple chart or table that will be very exact, because of the fact that the voltages impressed upon the tube are different in different models and makes of receivers. To make fairly accurate tests with this system, the operator must be cognizant of the different voltages in the different receivers, and consider them when making his calculations.

From this explanation, it may be seen that for really accurate results, some method must be devised whereby comparative tests may be made with the same voltages always impressed upon the tubes.

80. A satisfactory test for tubes: As explained previously, the three important electrical characteristics of a vacuum tube are, its *amplification constant, plate impedance, and transconductance,* (formerly called "mutual conductance"). It would appear that all three quantities would have to be measured in order to tell whether a tube is in good condition or not. Actually, however, this is not necessary for ordinary rapid service testing. If we can measure one of these factors, we will have a check on the other two, provided we know what the normal characteristics of the particular type of tube being tested should be.

The factor usually chosen for measurement in commercial tube checkers used by Radio Service Men and dealers, is the *transconductance*, for this is the most important quantity to determine. If a test indicates a tube to have a normal value of transconductance, we can be reasonably sure that the amplification constant and plate impedance are normal, since anything which might happen in a tube to reduce its amplification constant or plate impedance would also affect its transconductance. Any change due to presence of gas, low electron emission or disarrangement of a tube's electrodes will alter the transconductance.

Now in checking the condition of tubes, we do not have to actually measure and calculate the transconductance—all we need is some indication that the tube has a normal value. The fact that the transconductance in mhos is equal to

$$G_m = \frac{\text{change in plate current (amps)}}{\text{change in grid potential (volts)}}$$

enables us to arrange a simple, rapid test for indicating whether the value of the transconductance of a particular tube being tested is the normal value for that type of tube or not.

Evidently, if we change the control-grid potential by a given amount and note the change which this produces in the plate current, we will have in effect a good indication of the transconductance, and from a suitably prepared chart showing the readings which were obtained in a preliminary test with tubes in perfect condition, we could determine whether the change in plate current that we obtained from the particular tube under test, was normal for this type of tube. This is the basis for the operation of practically all the common tube checkers. In general, the larger the plate current change produced, the better is the tube (for a certain given type).

The designer provides a switch (usually of the push-button type), which when pressed, will change the control-grid potential of the tube by 3 or 4.5 volts. A chart is usually provided with the tube-checker, showing the approximate plate current readings which should be obtained before and after pressing this "grid test" button, if the tube is normal. By using such a tube tester it is therefore possible to obtain for all practical servicing purposes, an accurate, trustworthy indication of how good a particular tube is, and whether or not it should be replaced. Tube checkers are usually arranged to supply the proper filament, plate and grid voltages to any type of tube being tested, by means of a suitable tapped transformer operated from the 110 volt A.C. electric light line. Provision is also usually made for testing *both plates* of full-wave rectifier tubes.

It should be understood when testing tubes, that a relatively large variation in the transconductance of a given type of tube will cause only a small change in tube performances as judged by the ear during a listening test under receiving conditions in a radio receiver. Therefore the allowable tolerances in the expected plate current changes obtained during tube tests is rather large. In general, it may be stated that a tube which shows *no change* in plate current when the "grid test" button is pressed, will not amplify signals, but that tubes which are within 25 *per cent* of the values of the chart, or of their calculated transconductance values, should be considered as satisfactory. When the plate current changes are less than one-half of those shown on the chart, the tubes should generally be replaced.

81. Servicemen's simple tube-checkers: A complete circuit diagram of a simple tube checker which any Serviceman can build of easily obtainable standard parts is shown in Fig. 97. This was originally devised by the E. T. Cunningham Co., but it has been further simplified by the authors in order to make possible the use of a standard filament heating transformer with a single secondary winding delivering 7.5 volts. It has also been altered to make it possible to check all standard types of tubes in use at the present time. A descriptoin of this checker follows:

Five sockets are provided for testing the various types of tubes, two being four-prong sockets, and other three being of the five-prong type. All of the filament terminals of the sockets are connected in parallel across the secondary of the transformer T, having a 110 volt primary and a 7.5 volt-3 ampere secondary winding. Filament voltage control is obtained by two series filament rheostats R_1 and R_2, and read on the two-scale A.C. voltmeter M_3. R_2 is a high resistance low-current rheostat for adjusting the current when testing a tube which does not require much filament voltage and current. R_1 is a low resistance high-current rheostat for adjusting the current when testing a tube which takes a high filament current. The proper filament voltage settings for the various types of tubes are listed in the table at the left of Fig. 97. It is very important to always set both rheostats at *maximum* resistance before inserting a tube in any socket. After the

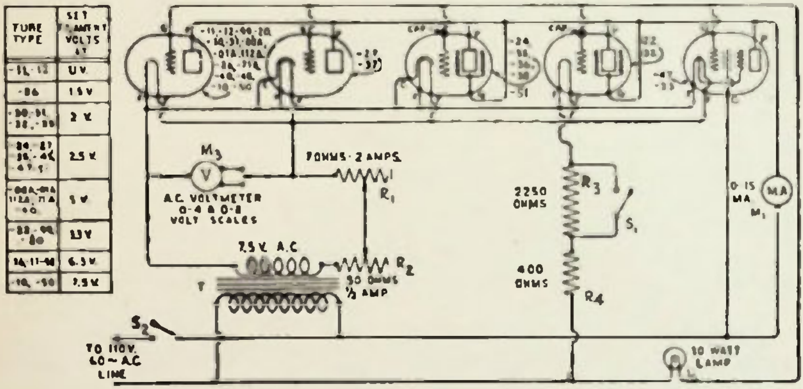


Fig. 97—An A.C. operated tube checker arranged for rapidly checking the condition of tubes by a rough check on the transconductance. It may be constructed from easily obtainable standard parts, (see Fig. 99).

tube is inserted, they may be varied, to obtain the proper filament voltage. Because of the filament current, the 50 ohm rheostat R_2 provides all regulation necessary, even for 60 m.a. tubes of the '99 type. The grid bias voltage is obtained automatically from the fall of potential caused by the flow of the plate current of the tube tested through the two resistors R_3 and R_4 connected in one side of the circuit. When S_1 is pressed, it shorts R_3 out of the circuit, reducing the grid bias voltage and causing an increase in the plate current. This is read on the milliammeter M_1, the amount of plate current change being an indication of whether the tube is good or not.

In operation the rheostats R_1 and R_2 are first set at maximum resistance value. The tube is then inserted in the proper socket and these rheostats are adjusted to give the correct filament voltage as shown on meter M_3. The plate current is then read on M_1 before and after pressing switch S_1. A table of approximate plate current changes to be expected follows.

These should not be taken as absolute standard values, since slight variations in the values of the biasing resistance, transformer voltage, meter calibration, etc., will cause some changes in the result. It would be best

Tube Type	Average Plate Current Value for Tubes	
	K_1 open	K_1 closed
11	1-1.5	1-2.5
cx-12	1-1.5	2-2.5
26	1.5	4
45	3	11
24	1	2.6
27	1.5-2	3.5-5
99	1.5	3
20	2.5-3	5.5-6
22	2	4-6
01A	1.7	4.5-5.0
40	.7	1.7
71A	3.5-4	12-13
00A	1.5	3.5
10	2	6
50	3	10.5
12A	2	6.5-7.0

to construct the checker, and determine the plate current changes to be taken as a guide, by actually testing a set of the various types of tubes which are known to be in good operating condition. When testing screen grid tubes the screen grid is connected to the plate, making it a three element tube for purposes of this test. For this reason it is necessary to use a separate socket for screen-grid tubes since they have the control-grid connection on top and the screen grid is connected to the usual grid terminal of the socket. Clips are provided for the connecting to the caps of screen grid tubes. The milliammeter used in the checker may be either an A.C. or D.C. meter. The 10 watt-110 volt lamp L used as a protective resistor, is included in the circuit to protect the meter in case a shorted tube is accidentally inserted in the socket. A plate-filament or grid-plate short in a tube inserted in this tester will cause the 10 watt lamp L to light and the needle of meter M_1 to vibrate slightly about the zero mark on the scale, the needle attempting to follow the 60 cycle current variations passing through the meter.

A simple checker for quickly checking the condition of half-wave or full-wave rectifier tubes only, is shown in Fig. 98. This may also be constructed by the Service Man. The rectifier is arranged to operate in a standard rectifier circuit, using a rectifier tube to deliver a current to a fixed load resistance. If a lower current than normal flows through this resistance during the test, it indicates that the emission is below normal and the tube should be replaced.

This circuit is arranged to use a standard power transformer delivering 600 to 700 volts from a center-tapped high voltage winding, and two 7.5 volt windings. The resistance of 1.25 ohms is connected in series with one winding so that 5 volts is applied across the filament of the type '80 rectifier. As can be seen from the circuit diagram, a double-pole double-throw switch is provided to change from one type of tube to the other. When a type '80 is being tested, it is supplied with 300 volts per plate, and

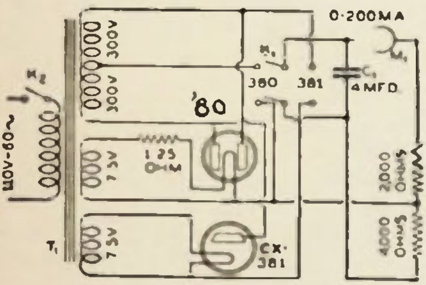


Fig. 98—An A.C. operated rectifier tube checker. This may be constructed from standard parts and will check half-wave or full-wave rectifier tubes.

it supplies current to a 4 mfd. condenser and a 2000 ohm load resistance. When a type '81 tube is being tested the switch is thrown to the proper side, and this alternates the connections so that the tube is supplied with 600 volts on the plate and it feeds into a 4 mfd. condenser and a 6000 load ohm resistance.

The test is simply made by throwing the switch to the proper position, placing the tube in the proper socket, closing the line switch and reading the milliammeter connected in series with the load resistance. The milliammeter should read 100 m.a. or more for a type '80 tube, and 60 m.a. or more for a type '81 tube. If the power transformer supplies 700 volts across the high voltage secondary both the readings will be about 10 m.a. greater. A conventional double-pole double-throw switch should be employed. The 4 mfd. condenser must be a good one, capable of working continuously at 1000 volts D.C. The load resistor must have a high current carrying capacity. This checker has been designed more or less for use in the repair shop or laboratory, although it may be constructed as a portable unit.

If desired, an A.C. operated tube checker may be constructed that is more portable and easier to handle than the one shown in Fig. 97. It is now possible to secure small filament transformers with secondary windings delivering 1.5V, 2.5V, 3.3V, and 5.0V. If one of these is employed, we may dispense with the A.C. voltmeter and both rheostats, by adding two switches, for the voltages impressed upon the filaments of the tubes will be known. The schematic diagram for this simplified checker is shown in Fig. 99. If the voltage switches are left out, a still simpler checker may be constructed by using additional sockets. Where it is not possible to secure a filament transformer supplying the voltages mentioned above, an ordin-

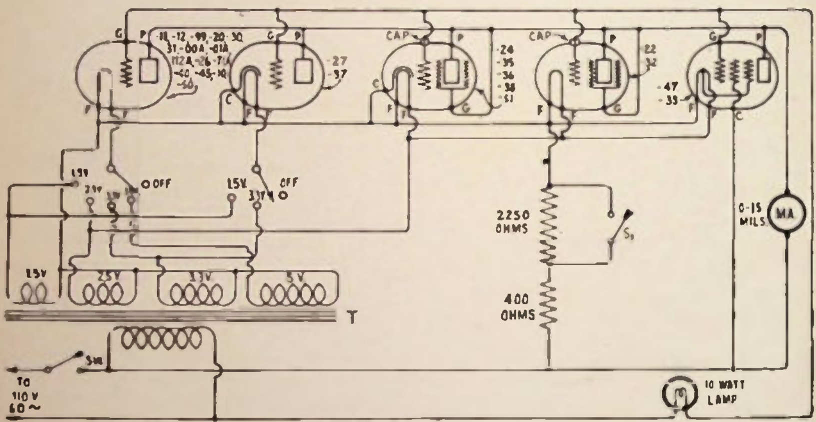


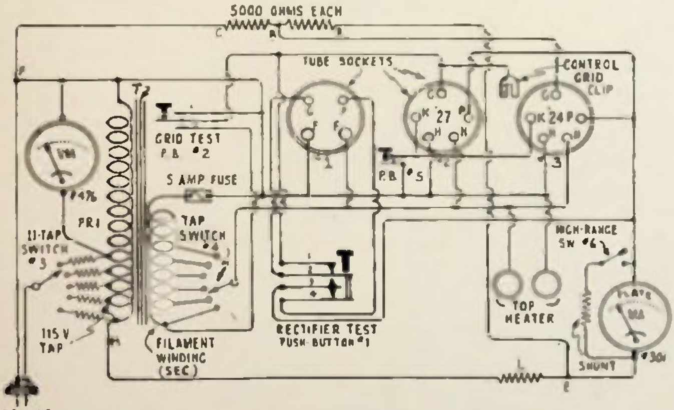
Fig. 99—The tube checker of Fig. 97 in simplified form. A filament transformer having several secondary windings is used.

ary 1.5, 2.5, 5.0 volt transformer may be used, and 3.3 volt tubes may be tested on 2.5 volts. After the checker has been assembled, a chart may be prepared for future reference, by noting the readings indicated when good tubes of each type are tested. This chart may be pasted upon the face of the tube checker. This checker is used in much the same way as the one in Fig. 97.

82. Commercial tube-checkers: Manufacturers of testing equipment used in Radio Servicing, have developed counter type and portable type tube checkers which are very versatile, useful, and interesting. Several typical checkers of this type will now be described.

Fig. 100 shows the circuit diagram of the Weston Model 555 counter tube-checker. The actual instrument is shown in Fig. 101. The reader is advised to trace this circuit step by step for his own benefit and knowledge.

This is a tube-checker for testing both A.C. and D.C. types of tubes, including filament type rectifier tubes. It operates from any 50 or 60 cycle A.C. lighting circuit having any voltage value from 90 to 130 volts. To operate the tester, it is necessary to adjust the line voltage regulator tap switch No. 3 until the pointer on the line voltage voltmeter is opposite the arrow. When this is done, the voltage applied to the filament is automatically adjusted exactly to the values designated on the Filament Voltage Selector, and the voltage applied to the plate is always a definite value, regardless of the line voltage.



Courtesy Weston Elect. Instr. Corp.

Fig. 100—The circuit arrangement employed in the Weston Model 555 counter type tube checker. Notice the transformer with tapped windings. The actual instrument is shown in Fig. 101.

With the "grid test" push button No. 2 in the normal position (up), the control grid of the tube being tested is connected to the upper side of the filament winding. Pressing this button connects the grid to the lower side of this filament winding, thereby changing the grid bias voltage and causing a change in plate current which may be read on the plate milliammeter. This change is a measure of the transconductance of the tube.

To test a full-wave rectifier tube, the plate current reading for one of the plates is read on the plate milliammeter when push-button No. 1 is in the "up" position. When this button is pressed, it automatically connects the other plate into the circuit for test.

Push button No. 5 is for a "cathode-to-heater short" test. If the pointer of the milliammeter does not return to zero when this push-button is pressed. (opening the connection to the cathode), it indicates that the cathode is shorted to the heater. The reader should trace the various circuits for different positions of the push-buttons. This will prove instructive.

When testing power, rectifier and other tubes whose plate current reads above 20, the milliammeter range is increased by pressing the high range button which connects a shunt across the meter. The screen grid voltage for screen-grid tubes is obtained by the fall of potential from A to B in resistor A-C. The two terminals marked "Top Heater" are for connection to the top heater tubes of the McCullough type, when these are tested. A chart

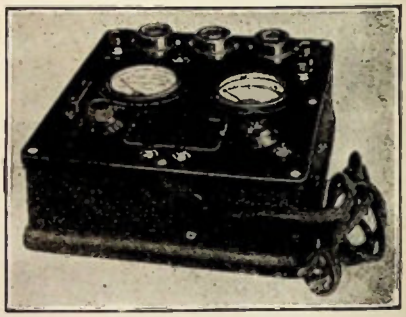


Fig. 101—The Weston Model 555 tube checker whose circuit diagram is shown in Fig. 100. Notice the socket and instrument arrangements for enabling rapid tests to be made.

Courtesy Weston Elect. Instr. Corp.

containing the average test readings of known good tubes as determined by this model of checker is furnished with each one for quick reference.

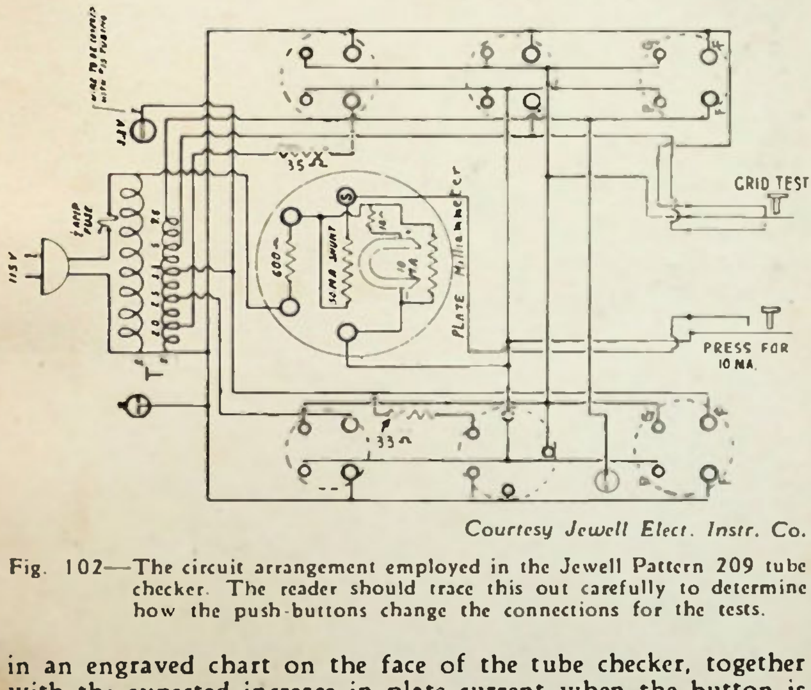
A circuit diagram of the Jewell Pattern 209 tube-checker is shown in Fig. 102. The checker itself is shown in Fig. 103. This instrument also operates from the 50 or 60 cycle 110-120 volt A.C. electric light circuit. A description of it follows:

Reference to Fig. 102 shows that a single D.C. milliammeter with ranges of 10 and 50 milliamperes is employed. The 10 M.A. range is read by a push-button switch. Six tube sockets are provided—a separate one for each type of tube requiring a different filament voltage. These filament voltages of 1.5, 2.0, 2.5, 2.8, 3.3, 5 and 7.5 volts are supplied at 4-prong sockets, and 2.5 volts to a 5-prong socket, by the tapped low voltage winding of the filament transformer T.

Two terminals giving three volts are provided for tubes, such as the older Kellogg, that have heater terminals on top. A jack and suitable lead are provided for grid control connection by means of the "grid shift test" push-button switch.

The actual grid test is accomplished by pressing the "Grid Shift Test" push-button switch. This transfers the grid connection from one side of the filament to the other (trace this on Fig. 102) thus changing the grid bias potential by the definite amount. The magnitude of the change in the plate current produced by this is a measure of the transconductance and condition of the tube.

Expected values of the first plate current reading are given



Courtesy Jewell Elect. Instr. Co.

Fig. 102—The circuit arrangement employed in the Jewell Pattern 209 tube checker. The reader should trace this out carefully to determine how the push-buttons change the connections for the tests.

in an engraved chart on the face of the tube checker, together with the expected increase in plate current when the button is pressed. A top view of this checker with a screen grid tube inserted in one of the sockets for test, is shown in Fig. 103.

A circuit diagram of the Supreme Model 40 tube-checker is shown in Fig. 105. A top view of the checker itself is shown in Fig. 104. This checker is designed to test all tubes.

without the need for adapters. This includes power and R.F. pentodes. A description of it follows:

Filament potentials of 1.5, 2.0, 2.5, 3.3, 5.0, 6.3 and 7.5 volts are supplied by the tapped filament transformer winding. One end of this

Fig. 103—The Jewell Pattern 209 tube checker whose circuit diagram is shown in Fig. 102. Notice the plate milliammeter, position of the sockets and push-buttons, plate current reading chart, and position of the clip on the cap of the screen grid tube being tested.

serves as a "common" lead to each tube socket. By means of the filament-heater selector switch, any one of these filament voltages may be applied to any of the five tube sockets on the panel—a very flexible arrangement.

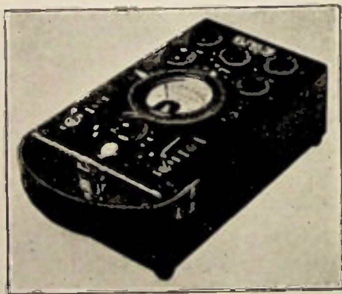
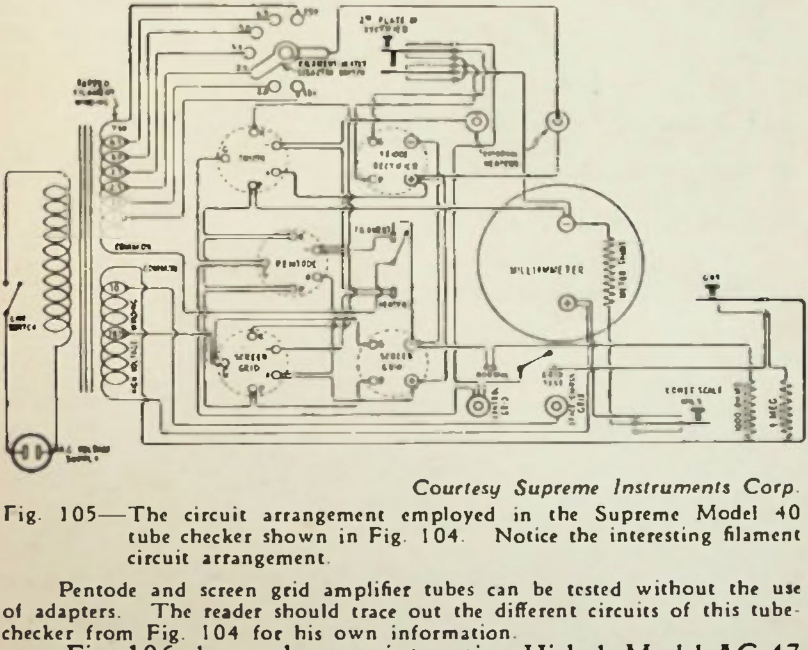


Fig. 104—The Supreme Model 40 tube checker whose circuit diagram is shown in Fig. 105. Note the compact arrangement of all the parts. The filament voltage switch knob is below the milliammeter.

The "grid test" for indicating the transconductance value of the tube is also used in this tester. A "grid test" switch is employed for this. The "grid shift" test for all amplifier tubes is provided with a biasing arrangement automatically obtained by the plate current load under test, so that the controlling grid biasing potential may be observed on the meter.

An amplifier tube which will show no change in plate current during the test, will not amplify signals. Discard limits for all tubes are tabulated on a card which is furnished with the tube-checker. A push-button switch is provided for connecting a shunt across the plate milliammeter for extending its range.

This checker also provides for making the following tests: a "gas" test for amplifiers (to reveal gassy tubes); a cathode-heater short test for heater type tubes and tests for both plates of full-wave rectifier tubes.



Courtesy Supreme Instruments Corp.

Fig. 105—The circuit arrangement employed in the Supreme Model 40 tube checker shown in Fig. 104. Notice the interesting filament circuit arrangement.

Pentode and screen grid amplifier tubes can be tested without the use of adapters. The reader should trace out the different circuits of this tube-checker from Fig. 104 for his own information.

Fig. 106 shows the very interesting Hickok Model AC-47 tube-checker, which is designed to be operated from a 110 volt A.C. line. It applies D.C. voltages to both the plate and grid, and indicates the dynamic "transconductance" and "plate current" directly on the two meters provided. All shorts between elements are also indicated. A chart of tube values is mounted directly on the tester panel as shown. The entire unit may be transported in the carrying case provided.

Fig. 106B shows the circuit arrangement employed in the Dayrad Type L tube checker. Examination of this diagram shows that six tube sockets are provided, each one being perman-

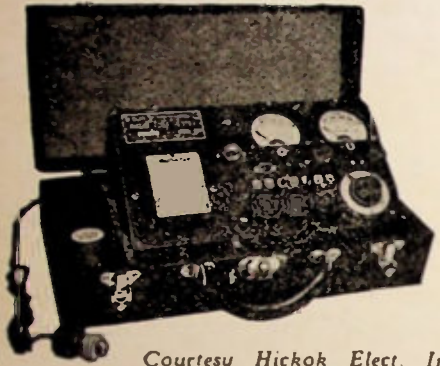


Fig. 106—A front view of the Hickok Model A.C. 47 tube checker partly removed from its carrying case. This checker is also operated from the 110 volt A.C. line.

Courtesy Hickok Elect. Instr. Co.

ently connected to receive its proper filament voltage from the tapped low-voltage secondary of the transformer. The fila

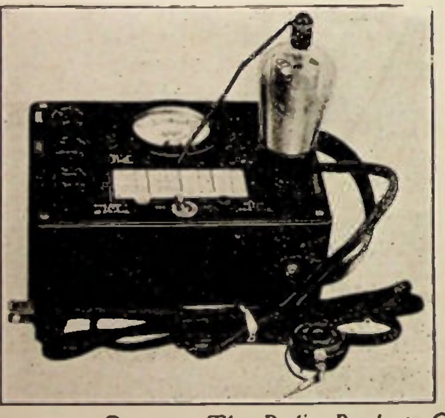
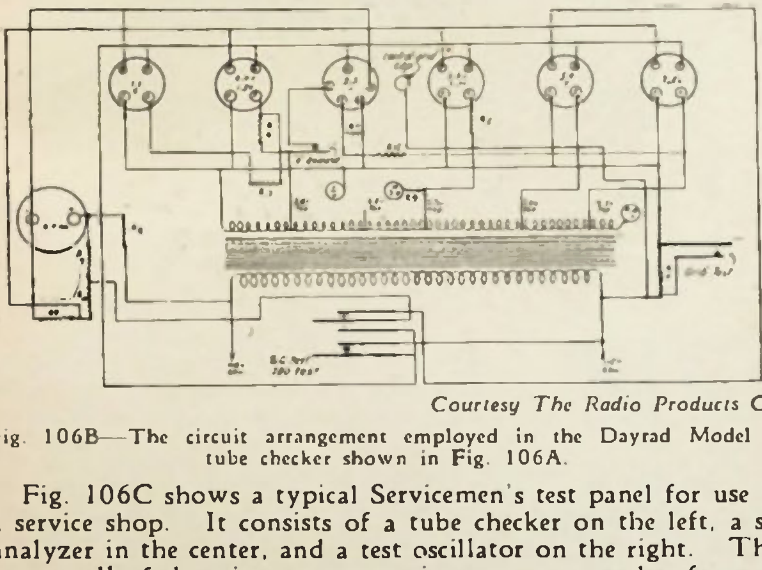


Fig. 106A—A top front view of the Dayrad Model L tube checker with a screen grid tube in place in the proper socket, ready to be tested.

Courtesy The Radio Products Co.

ment voltages are shown marked on these sockets. A single milliammeter is connected in the plate circuit. The "grid test" is performed by pressing the push-button switch shown at the lower right. This short-circuits the grid bias resistor R_3, and the resulting lowering of the grid bias voltage causes an increase in the plate current,—which is read on the plate milliammeter. The *change* in plate current produced by this test is a measure of the transconductance and the worth of the tube. The actual instrument is shown in Fig. 106A. Notice the chart giving the values of the plate current changes which should be obtained for tubes in good condition.



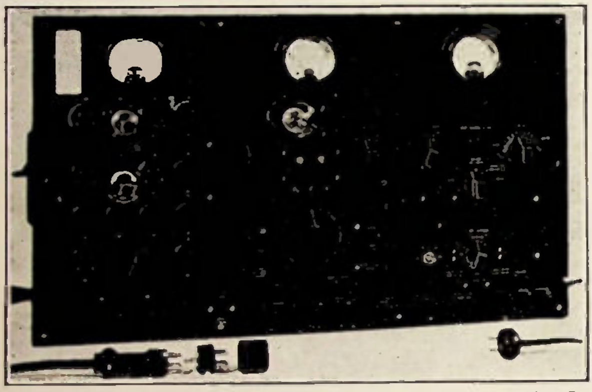
Courtesy The Radio Products Co.

Fig. 106B—The circuit arrangement employed in the Dayrad Model L tube checker shown in Fig. 106A.

Fig. 106C shows a typical Servicemen's test panel for use in a service shop. It consists of a tube checker on the left, a set analyzer in the center, and a test oscillator on the right. This groups all of these important test instruments together for convenience.

83. Chart of vacuum tube characteristics: As there are many different types of vacuum tubes manufactured and used for different operating conditions and voltages in radio equipment, it is convenient to have all of their important constants and operating characteristics arranged in a single table or chart for easy reference. A table of this kind, which gives the *average* characteristics of all standard types of tubes manufactured at the present time, is shown in Fig. 107. The reader should

familiarize himself with the general characteristics of the commonly used tubes listed in this table. A good working knowledge of the data contained in it will be of great assistance in radio work.

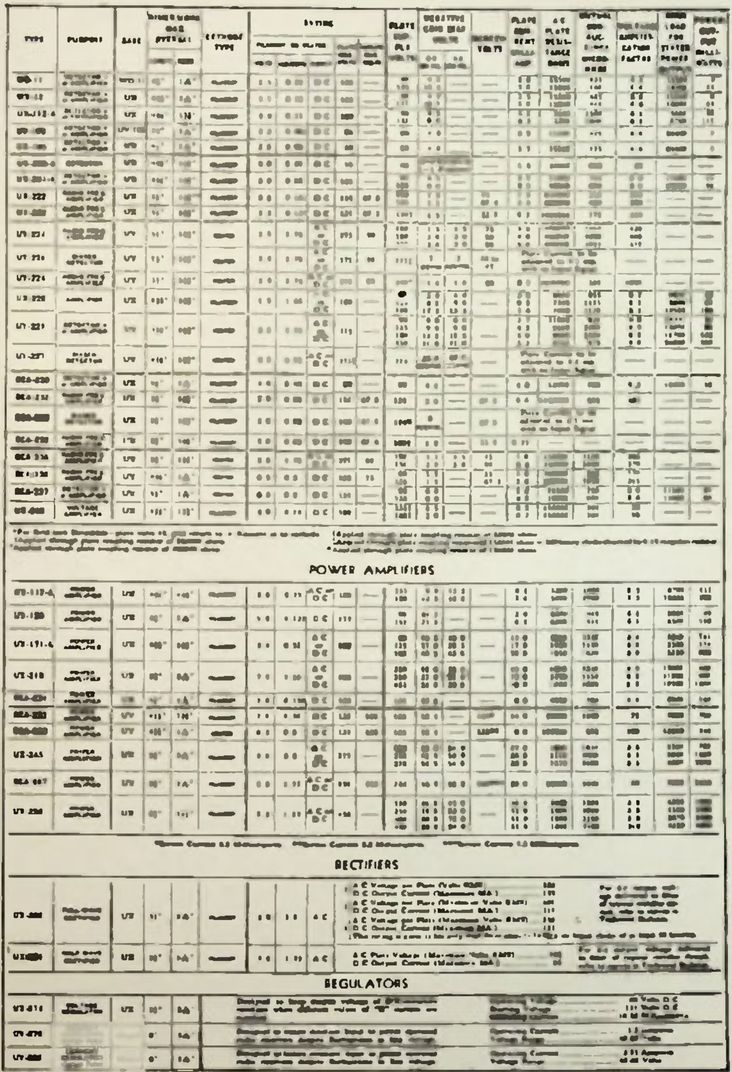


Courtesy The Radio Products Co.

Fig. 106C—A complete Servicemen's test panel consisting of a tube checker, set analyzer, and test oscillator,—from left to right.

REVIEW QUESTIONS

1. What is the difference between a counter type tube-checker, and the tube testing arrangement provided in a set analyzer?
2. What is the advantage of the former for testing tubes?
3. What is the most satisfactory test for the quick checking of vacuum tubes? Why?
4. Explain with the aid of a simple diagram, how this test may be performed on a '27 type vacuum tube.
5. What are the main parts of a tube checker. What is the function of each?
6. Draw the circuit diagram, and explain the operation of, a commercial tube checker. Tell how it is used to test amplifier tubes—rectifier tubes.
7. How are the various filament voltages required for testing all types of tubes, obtained in most A.C. operated tube checkers?
8. List in tabular form, the filament voltage, maximum plate voltage, amplification factor, plate impedance and transconductance (formerly called "mutual conductance") values for the following types of tubes: 201A, 227, 224, 235, 245, 244. (Use the chart in Fig. 107 for obtaining these values.) Discuss them.



Courtesy R. C. A. Radiotron Corp.

Fig. 107—Chart giving the main average characteristics of all standard types of vacuum tubes used in radio receivers in the United States.

CHAPTER 9.

USEFUL INFORMATION FOR SERVICE MEN

A COMPLETE TROUBLE-SHOOTING CHART — THE STANDARD RESISTOR COLOR CODE — THE STANDARD WIRE COLOR CODE — THE SERVICEMAN'S EQUIPMENT — HOW TO SOLDER.

84. A trouble-shooting chart: As an aid to the student and novice in radio servicing a rather complete trouble-shooting chart has been prepared, and is shown on pages 176 and 177. While the authors are fully aware that no trouble-shooting chart can ever cover the many diversified troubles which occur in the numerous different makes and types of receivers, it is hoped that this one will assist the student and novice in any preliminary service work he may undertake. It may also be employed as a review questionaire, the student taking each symptom and writing down as many of the possible causes and locations of the trouble as he can think of in the light of the knowledge he has gained from the previous work in the text.

The chart has been arranged as simply as possible with the main symptoms arranged in the vertical columns, and the various main parts in the receiver installation in which the trouble might lie, arranged in the horizontal sections.

Example: An A.C. electric receiver operates with very poor volume. What may be wrong with it?

Answer: Referring to the column marked "Low Volume" we find listed all of the different troubles in the various units of the receiver—which might cause this symptom.

85. Standard resistor color code: Manufacturers of radio receivers have adopted a standard resistor color code marking which has been approved by the Radio Manufacturers Association. This color code is marked on the resistors in the recent models of receivers which are manufactured by member companies of this association. The Service Man will find it to his advantage to know this code, for it enables one to tell at a glance just what the resistance value of a resistor is, by inspecting the code color markings on it.

The code identifies resistors by means of 3 colors, known as "body," "tip" and "dot" colors. The *Body Color* is the main color of the resistor, and represents the first figure of the resistance value. The *Tip Color* is the color of one end of the resistor, and represents the second figure of the resistance value. The *Dot Color* (sometimes a narrow band is used instead of a dot) indicates the number of ciphers following the first two figures.

It should be borne in mind that this code applies only to the newer model receivers that are now appearing on the market. It will be a safe practice on all older model receivers to refer to the manufacturer's service charts for the color code used on the earlier model sets.

The figures represented by the various colors are given in the following table:

1st Figure (Body Color)	2nd Figure (Tip Color)	(Dot or narrow Band Color)
0—Black	0—Black	None —Black
1—Brown	1—Brown	0 —Brown
2—Red	2—Red	00 —Red
3—Orange	3—Orange	000 —Orange
4—Yellow	4—Yellow	0000 —Yellow
5—Green	5—Green	00000 —Green
6—Blue	6—Blue	000000—Blue
7—Violet	7—Violet	
8—Gray	8—Gray	
9—White	9—White Ciphers	

Example: A resistor has a Red Body—(2); a Green Tip—(5) and an Orange Dot or Band—(000).
Answer: The resistor value is 25,000 ohms.

86. Standard wire color code: A standard color code has also been approved by the National Electrical Manufacturers Association for the wires used in wiring up receivers. As in the case with the resistor code markings, this particular wire marking code is not standard on all receivers, but is being used in the latest receivers manufactured by manufacturer members of the N. E. M. A. The standard wire color code follows:

For conductors that are individual to one circuit only: "A+," Yellow; "A—," Black with Yellow tracer; "B+" Max., Red; "B+" Int., Maroon and Red; "B+" Det., Maroon; "B—" Black with Red tracer; "C+," Green; "C— (low), Black and Green; "C—" (max.), Black with Green tracer; Loud Speaker (high side), Brown; Loud Speaker (low side), Black with Brown tracer.

87. The serviceman's equipment: In order to install or make repairs on radio receivers and associated equipment, every Service Man should possess certain test equipment and tools. The test equipment, and the methods of using it, has already been studied in detail. The number of servicing tools that should be available, depends largely upon the type or scope of work that is being done by the individual. However, there are certain testing devices and tools which should be made part of every Service Man's equipment if possible, in order to enable him to locate trouble and make repairs quickly and efficiently. The list of these follows:

(1) set analyzer
(2) *ohmmeter
(3) *test leads
(4) long-nose pliers
(5) small chisel
(6) flashlight
(7) neutralizing tool
(8) dusting cloth
(9) 2 files (fine, coarse)
(10) 1 set "Hex" wrenches
(11) off-set screw driver
(12) blunt-nose pliers
(13) *oscillator (optional)
(14) *output meter (optional)
(15) A.C. tube checker (optional)
(16) screw driver for dial set-screws
(17) small screw driver (4 in.)
(18) large screw driver (6 in.-8 in.)
(19) diagonal side-cutting pliers
(20) automobile pliers (optional)
(21) steel wool or emery cloth
(22) soldering iron and r. c. solder
(23) neutralizing adapters (UX, UY)
(24) Bakelite screw driver

*May be included as part of the set analyzer equipment.

A few of the tools included in the above list are shown in Fig. 108.

TROUBLE-SHOOTING CHART

POSSIBLE SOURCE OF TROUBLE	SYMPTOMS OF TROUBLE: NO RECEPTION	VOLUME WEAK	IRREGULAR RECEPTION	DISTORTION	NOISY RECEPTION	HUM, WHISTLES
"A" BATTERY (IF USED)	1. Battery exhausted. 2. No water in storage battery. 3. Battery terminals corroded.	1. Battery exhausted. 2. Poor connection at corroded terminals 3. Charger not equal to demand on battery. 4. Trickle charger not functioning.	1. Loose connection.	1. Battery exhausted.	1. Battery sulphated. 2. Charger operating while set is played.	2. Hum, from charger operating. 2. Whistles, from depleted battery.
"B" BATTERY (IF USED)	1. Battery exhausted. 2. Battery not properly connected.	1. Battery exhausted. Volume starts off well but quickly diminishes while set is played.	2. Defective cell. 3. Loose connection.	2. Battery exhausted.	1. Erratic noises — battery exhausted. 2. Fluttering, motorboating, high resistance of run-down battery.	1. Whistles, from run-down battery.
POWER PACK	1. Not connected to power supply socket. 2. Electric light line power off—or fuse blown. 3. Rectifier tube inoperative. 4. Choke coil open. 5. Open bias resistor. 6. Plate of rectifier tube red hot — condenser broken down or short-circuit in filter. 7. Fuses in power supply unit burned out. 8. Open voltage divider.	1. Rectifier tube worn out. 2. Transformer winding partly short circuited. 3. By-pass condenser punctured. 4. Electric light line voltage too low. 5. Open resistor.	1. Poor voltage regulation of power line. 2. Loose connection. 3. Opening voltage divider. 4. Opening choke coil.	1. Plate voltage too low or too high. 2. Shorted bias resistor. 3. Shorted bias by-pass condenser.	1. Defective resistor in voltage divider. 2. Sparking over punctured condenser. 3. Motorboating — insufficient capacity of last filter condenser. 4. Rectifier tube wearing out. 5. Sparking voltage divider. 5. Sec. winding of power transf. sparking to shield.	1. Open filter condenser. 2. Loose transformer laminations. 3. Poor ground conn. 4. Poorly designed filter. 5. Coupling between A.F. amplifier stages. Power unit placed too close to set.
TUBES	4. Defective lightning arrester. 1. Tube burned out. 2. Tube paralyzed. 3. Tube prongs not making contact with socket contacts.	1. Weak tubes. 2. Wrong type of tube used. 3. Corroded tube contacts. 4. Loose elements. 5. Gassy tubes. 6. Control-grid cap not connected.	1. Imperfect prong contacts. 2. Shorting tube (upon vibration). 3. Microphonic tube. 4. Loose elements	1. Tubes weak. 2. Wrong type of tube in last stage. 3. Gassy tubes.	1. Microphonic tubes; require cushioned sockets. 2. Gaseous rectifier tube aging. 3. Loose elements. 4. Shorting elements. 5. Corroded terminals.	1. Tube deteriorating. 2. Too high voltage on detector tube. 3. No center tap on detector tube filament circuit. 4. Gassy tube.

ANTENNA AND GROUND	1. Antenna disconnected. 2. Antenna grounded. 3. Ground connection open.	1. Antenna or ground disconnected. 2. Antenna poorly insulated, grounded or wire corroded. 3. Antenna too short. 4. Loose or corroded ground connection. 5. Antenna too near a grounded metal object.	1. Swinging antenna becoming grounded at times. 2. Loose or corroded ground connection. 3. Bad lead-in strip. 4. Loose connection.	1. Parallels, or too close to antenna of near-by oscillating receiver. 2. Antenna too long — signal input too strong for receiver.	1. Antenna too close, or parallel, to power lines. 2. Antenna too long, picks up too much stray noise. 3. Loose or corroded ground connection. 4. Antenna runs too near interfering electrical devices. 5. Another nearby antenna grounding.	1. A.C. hum or commutator ripple picked up from near-by power lines. 2. Negative side of filter circuit not grounded (B—) 3. Too near antenna of an oscillating receiver.
CIRCUIT OF SET	1. Line switch open. 2. Open R.F. coil. 3. Open A.F. transf. 4. Shorted by-pass cond. 5. Shorted R.F. coil. 6. Shorted tuning condenser section.	1. Tuned stages out of alignment. 2. Open R.F. coil. 3. Shorted R.F. coil. 4. Open A.F. transf. 5. Open resistor. 6. Open by-pass cond. 7. Insufficient regeneration (S. W. set). 8. Antenna too long (S. W. set).	1. Loose connection. 2. Open-circuiting by-pass cond. 3. Opening resistor. 4. Shorting tuning cond. section. 5. Poor soldered joint. 6. High resistance leaks.	1. Shorted bias resistor. 2. Shorted bias by-pass cond. 3. Too near oscillating point. Re-neutralize or align. 4. Plate voltage too high on R.F. tubes. 5. R.F. circuits too sharply tuned.	1. Squeals, bloops — set not neutralized. 2. Defective grid lead. 3. Broken wire or imperfect contacts. 4. Noisy audio primary. 5. Noisy volume control. 6. Leaky condenser.	1. Oscillation from overregeneration. 2. Set not properly neutralized. 3. Magnetic feed back between stages. 4. Open grid circuit (audio) 5. Center tap of transformer not correct. 6. Hum balancer out of adjustment. 7. Open section or lead of center-tapped resistor.
LOUD SPEAKER	1. Speaker disconnected. 2. Open circuit in speaker unit jack, plug or cord. 3. Speaker coil short circuited. 4. Coil in speaker unit burned out. 5. Shorted or open voice-coil.	1. Speaker out of adjustment. 2. Loose contact. 3. Leak across speaker cord. 4. Coil partially shorted. 5. Spider worn.	1. Loose connection. 2. Shorting voice-coil. 3. Opening coil.	1. Speaker overloaded. 2. Not matched to tube in last stage. 3. Moving coil rubbing on pole-piece. 4. Spider torn.	1. Sound vibrations communicated from speaker to tubes in set. 2. Scraping voice-coil. 3. Out of adjustment. 4. Broken spider. 5. Loose connection. 6. Poorly soldered joint.	1. Buzz or rattle in dynamic speaker due to moving-coil rubbing against pole pieces. 2. Worn-out rectifier. 3. Feedback from speaker circuit to amplifying stages due to sound vibrations communicated from speaker to tubes in set. 4. Shorted field coil. 5. Poor filter condenser.
GENERAL	1. Incorrectly wired homemade set. 2. Shielded location or dead spot. 3. S.O.S. on air. 4. Set not turned on. 5. Breakdown at broadcasting Station — try another station.	1. Sensitivity of set inadequate. 2. Spot poor for reception. 3. Fading of received signals.	1. Breakdown at broadcasting station, try another station.	1. Improper tuning. 2. Fading. 3. Weather condition. 4. Unsatisfactory transmission from station— try another station.	1. Static — try disconnecting aerial and ground. 2. Power unit too close to set. 3. Near-by regenerative set. 4. Sparking electrical machinery, or contacts.	1. Two stations on nearly same wavelength causing heterodyne whistle. 2. Interference from near-by oscillator. 3. Near-by regenerative or oscillating receiver.

When an automobile is used for carrying the servicing equipment around, it may be well to include the following also.

(1) assorted bits	(3) 1 "brace"	(5) hack saw
(2) extension bits	(4) hammer	(6) stone chisel, and reamer

Although the tools listed above may seem at first glance to represent a rather formidable array, it will be found that each serves a definite purpose and will often be called into use. Where aerials are to be erected on the roofs of dwellings, an extension ladder is also necessary.

Besides the tool kit, every Service Man should carry with him sufficient tubes and parts to enable him to render rapid service. The number and types of tubes to carry depends upon the models of receivers or receiver that he encounters. In addition to the tubes, the service kit should contain:

2—female plugs; 2—male plugs; 1—3-way plug; 2—.1 mfd. by-pass condensers; 1—.001 mfd. condenser; 1—.00025 mfd. condenser; 2—Plug Fuses (3A., 15A.); 2—automobile cartridge fuses (3A); 1—20 ohm center tapped resistor; 1—2 or 4 mfd. filter condenser, 400V; 1—.5 mfd. by-pass condenser, 200V; assorted screws, nuts, washers, wire; 10—carbon resistors (assorted sizes 500-500,000 ohms); 2—wire-wound resistors (750 and 200 ohms).

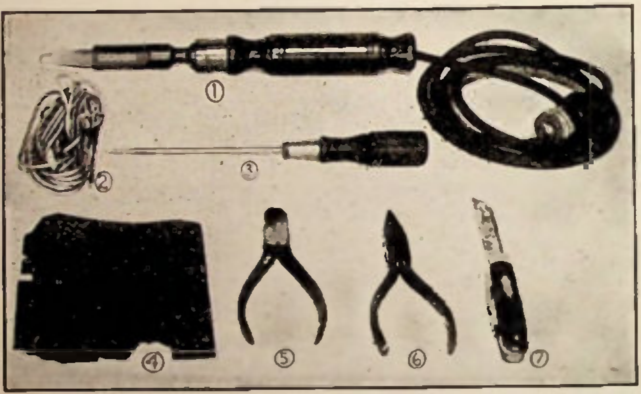


Fig. 108—A few of the common tools useful in radio service work. (1) Electric soldering iron; (2) Rosin-core solder; (3) screw driver; (4) emery cloth; (5) side-cutting pliers; (6) long nose pliers, (7) jack-knife.

88. How to solder: Every man engaged in radio service work should know how to use the soldering iron. Soldering is very simple, if the several points concerning it are known and followed. The most important element in successful soldering is *cleanliness*. Both the iron, (whether it be of the electric type or the old fashioned plain iron), and the joint to be soldered must be bright and shiny so that the solder will stick to it. It is impossible to make a good soldered joint if either the iron or the work itself has a layer of dirt or grease over it. The first step is to prepare the iron by "tinning" it, as follows:

Turn on the current, and when the iron has warmed up so it is hot enough to melt solder, rub the faces of its tip on a piece of emery cloth, so that the surface becomes clean and bright. Now quickly apply the end of a piece of "rosin-core" solder to these surfaces, until a clean bright coating of solder entirely covers them. Apply only enough solder to form this coating. This completes the "tinning" process. Never try to use an iron whose "tinning" has been burned off.

Preparing the objects to be soldered together is a simple matter. Let us suppose we are to connect the ends of two wires and solder the joint.

First remove the insulation from the ends of the wires by squeezing it between the jaws or back of a pair of square nose pliers, or with a knife. Scrape both wires *clean*, either with the back of a knife, or with a piece of emery cloth. Be sure that all traces of the rubber insulation are removed. If the wire is stranded, separate the strands so that as many of them as possible are cleaned. Twist the ends of the wire together. Take the soldering iron in one hand and the solder in the other and apply both to the wire as shown in Fig. 109. Hold the flat face of the iron against the joint, so as to allow the heat to flow easily from the iron to it. The solder should be applied at the place where the joint and the iron meet. Melt down the solder so that both the solder and the rosin run on to the wire. Keep the iron in place long enough to allow the *molten mixture* to penetrate the joint. Let the solder simmer a little and then remove the iron, being careful not to disturb the wire until the solder solidifies.

That is all there is to the whole operation, but for success *everything must be "clean."* Even a superficial layer of dirt that appears harmless will cause trouble. Also, the soldering iron used must be large enough to be able to thoroughly heat the joint to the temperature of molten solder.

The purpose of the rosin in rosin-core solder should be thoroughly understood. If plain solder were employed without any flux, it would not be possible to make it stick to the metal easily—regardless of how clean it was.

The application of the hot iron causes the formation of an oxide of the metal on its surface, and this film, although it is only of microscopic thickness, prevents the molten solder from adhering to the metal. The molten rosin absorbs this oxide coating just as quickly as it forms and floats it off. (This allows the solder to flow into the "pores" of the metal, thus making a secure joint both electrically and mechanically. The rosin is known as a "flux," and is used greatly in radio work because it does not cause after-corrosion of the metal.

There are also other fluxes in both liquid and paste form, which may be applied to the work to be soldered by means of a small brush or piece of wood. Rosin core solder is particularly convenient because the flux flows on to the joint at the same time that the solder does, and therefore saves an extra manipulation of the hands for the person who is soldering. Most soldering pastes are objectionable in radio work because they smear and sputter when the work is heated with the iron, and

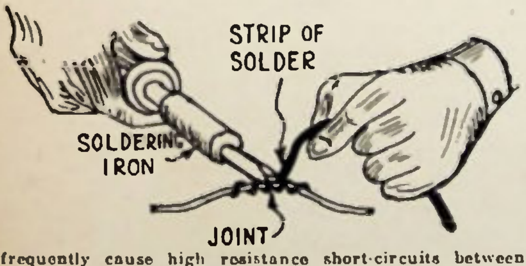


Fig. 109—How the soldering iron and the strip of solder are applied to the joint.

frequently cause high resistance short-circuits between two or more otherwise insulated circuits. This is often a cause of rasping or frying noises in a radio receiver, and is extremely difficult to trace down.

As a soldering iron is used, the tinning will gradually burn off, and the copper itself may become black or corroded. After a particularly long stretch of service, small pits will develop in the tip.

Never neglect to clean off the corroded surface, using nothing more than a rag, or if necessary, a piece of emery cloth. Keep a thick wad of cotton or flannel sheeting on hand and use it frequently. Of course, it will be necessary to use a file to smooth down the pitted surface occasionally. Do not remove any more of the metal than necessary. After finishing a particular soldering job, always wipe off the iron point before it coils off completely. It should always be left *clean and bright*.

(The figures refer to page numbers)