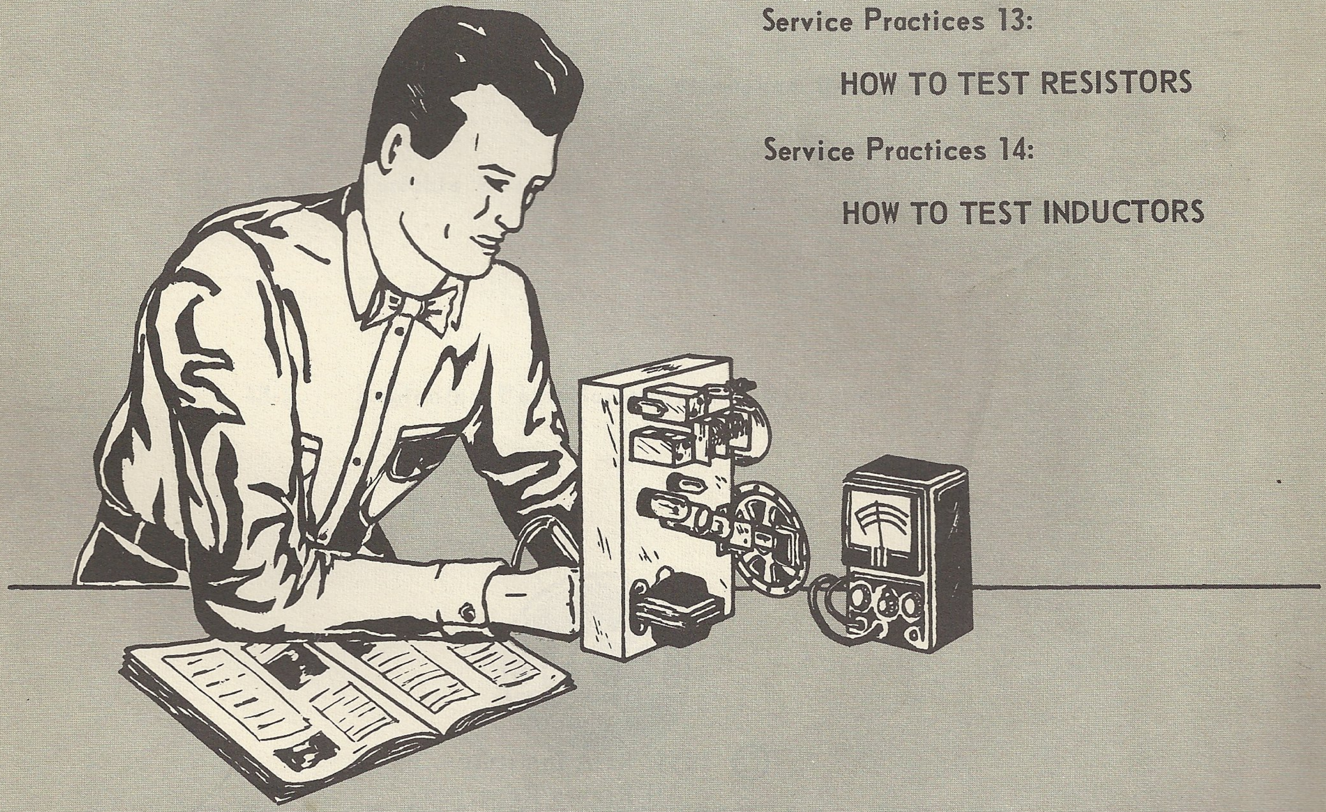
Study Group 7

ELECTRONIC FUNDAMENTALS



Service Practices 13:

HOW TO TEST RESISTORS

Service Practices 14:

HOW TO TEST INDUCTORS

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York, N. Y.

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 13

HOW TO TEST RESISTORS

13-1. Fixed Resistors

13-2. Slider-Type Adjustable Wirewound Resistors

13-3. Variable Resistors

13-4. Taper

13-5. Replacing Potentiometers and Rheostats

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Service Practices 13

INTRODUCTION

In earlier lessons, you learned about the materials that are used to produce resistance effects and how to use an ohmmeter to measure the amount of resistance. All radio and electronic equipment contains resistors that have been purposely placed in the circuit to control the flow of current. Most of these resistors are *fixed* and cannot have their resistance values changed. Some can be *varied*, or adjusted, to obtain the desired amount of resistance. Fixed resistors are usually made of carbon composition material, a metallic surface film, or resistance wire. Variable resistors are made either of materials that contain amounts of carbon or graphite, or of wound resistance wire. Variable-resistor units are called potentiometers (pots) or rheostats, depending upon how they are constructed or how they are used.

When resistors, potentiometers, and rheostats become defective, they cause radio and television receivers to stop operating entirely, become noisy, or operate improperly in one way or another. In this lesson, you will learn how to use the ohmmeter section of your multimeter to test, select, and replace both fixed and variable resistors.

13-1. FIXED RESISTORS

Insulated Composition Resistors. The most common type of fixed resistor used in radio and television receivers is made of a carbon composition in the form of a solid inserted in in an insulated pressed or molded rod as shown in Fig. 13-1.

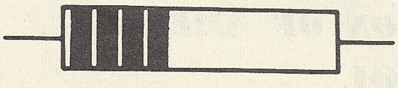


Fig. 13-1

Electrical connection to this type of resistor is made to the two tinned copper leads extending from the ends of the resistor.

Some of the common faults found with carbon or metallic film resistors are:

1. Resistance value too much above normal

2. Resistance value too much below normal

3. Open resistor

4. Noisy resistor (A noisy resistor causes a grinding, crashing, crackling, or hissing type of noise in the loud speaker.)

5. Abnormal change in resistance value when resistor heats up (An ohmmeter can be used to locate the first three faults and *sometimes* the fourth, but not the fifth.)

Testing the Resistor With an Ohmmeter. Fig. 13-2 shows part of a radio circuit. It contains resistor R_1, which we will consider to be defective. Let's consider how to test this resistor with an ohmmeter to find out what is wrong with it.

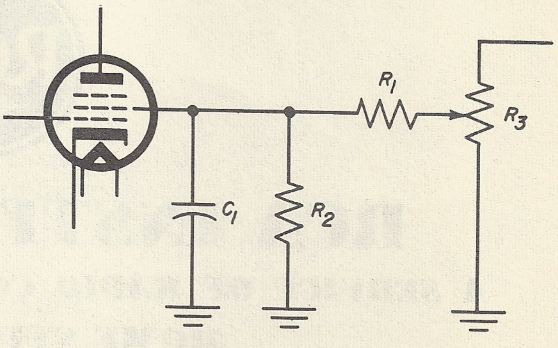


Fig. 13-2

Caution: Before using an ohmmeter to test any portion of a radio receiver, always follow these rules:

1. Turn the on-off switch of the radio receiver to off.

2. Remove the power-line plug from the wall socket to avoid personal injury and damage to meter and parts.

3. If the radio receiver is a portable-type set, disconnect the batteries to avoid damage to ohmmeter and tubes.

4. When testing a resistor in a radio or television receiver, always disconnect one lead of the resistor from any other part or parts to which it is connected in order to avoid wrong readings, unless you are sure that these other parts do not form circuits that are in parallel with the resistor being tested. Resistor R_1 in Fig. 13-2 should be disconnected from the circuit to avoid incorrect ohmmeter readings. If the resistor is not disconnected and the two ohmmeter leads are placed across R_1, the ohmmeter will also read the circuit consisting of resistors R_2 and R_3 in parallel with R_1. This means that, due to the shunting effect of resistors R_2 and R_3, you may think that R_1 is normal even if R_1 is open or has a very high incorrect value of resistance.

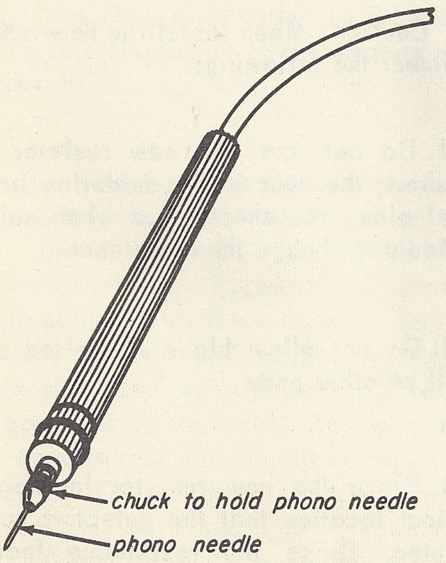


Fig. 13-3

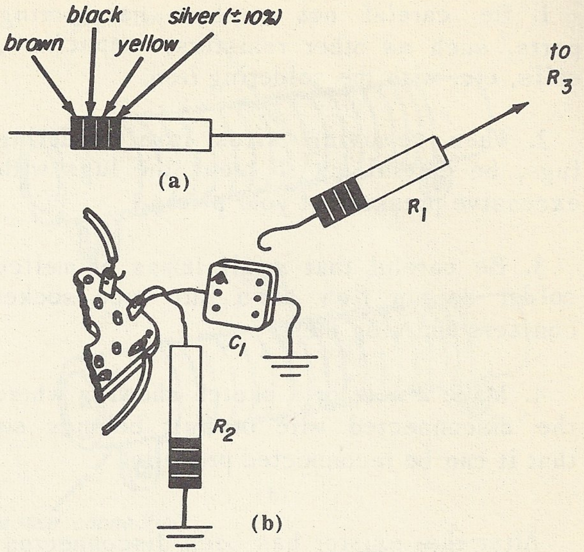


Fig. 13-4

When the ohmmeter is used to test a resistor, the test prods should be pressed firmly against the resistor leads. Figure 13-3 shows a special type of test prod that has a chuck to hold a phono needle. Because of the sharp point of the needle, such a prod makes a good positive contact. (In addition, it may be used to pierce through the insulation of rubber, plastic, or other covered leads when necessary for testing.) The metal tips of the prods should not touch the terminals or wires of other parts that do not connect to the resistor.

The resistor, color-coded as shown in Fig. 13-4*a*, is supposed to be 100,000 ohms and have a tolerance of ± 10%. As you learned in an earlier lesson, a tolerance of ± 10% means that the resistor can measure between 110,000 and 90,000 ohms, as read on an ohmmeter. This resistance range is acceptable for use in this circuit in the radio receiver.

Now that you know what precautions to take before testing a resistor and what value the resistor is supposed to have, let's go through the procedure for testing resistor R_1 to see if its value is actually what the color code says it is. First, one end of R_1 should be unsoldered and disconnected from the circuit, as shown in Fig. 13-4*b*, in order to free it from the shunting effect of R_2 and and R_3. Remember the following rules for disconnecting resistors (or other parts) in a radio receiver:

1. Be careful not to burn neighboring parts, such as other resistors, capacitors, coils, etc. with the soldering iron.

2. When removing wires from soldering lugs, be careful not to break the lugs with excessive pressure of your pliers.

3. Be careful that small lumps of melted solder do not flow down into tube socket contacts and clog them.

4. Make a note or a sketch showing where the disconnected wire or part belongs so that it can be reconnected properly.

After the resistor has been disconnected at one end, the ohmmeter should be placed across it and a resistance reading should be taken. (Fingers should be kept off the test prod tips; otherwise your body will act as a shunt across the ohmmeter and will make the resistance lower than its true value.) Let's say that the meter reads 220,000 ohms. This is too high a value. The resistor is faulty and should be replaced.

Resistor R_1 might have had one of the other four possible faults. For instance, it might have had too low a resistance, and you would have learned this by using the ohmmeter. It might have been an open resistor. Open resistors register at the calibration for infinity (∞) at the extreme end of the ohmmeter scale. However, the ohmmeter would not have been so reliable a test instrument for a noisy resistor. When an ohmmeter is placed across a noisy resistor, the indicating pointer sometimes, but not always, wavers or sways back and forth. Loose or dirty contacts can also result in a wavering pointer, even when the resistor being tested is not open; when testing any resistor, make certain that the ohmmeter leads are firmly connected to the ohmmeter pin jacks and the resistor being tested.

If the carbon resistor had an abnormal change in resistance value when it became hot due to current flow, there would have been no indication of this on the ohmmeter. When the resistor cools down after shutting off the radio receiver, its resistance value will probably return to normal. You will learn how to find this trouble in a later lesson.

Replacing Resistors. A faulty resistor should be replaced with another resistor having the correct resistance, wattage, and tolerance. A resistor with a greater wattage rating may be used if space permits. A resistor with a closer tolerance value may be used if the original value is not obtainable. It is possible to replace a resistor made of one material with a resistor made of another material. If d-c or low frequency a-c current (60 cps) flows through the resistor, a carbon, metallic-film, or wirewound resistor can be used as a replacement. If r-f current (signal) flows through the resistor, only carbon, metallic-film, or special types of wirewound resistors should be used as replacements. However, until you have had considerable experience in repairing receivers, replace a faulty resistor with one made of the same material as the original.

It is almost impossible for a resistor to become short-circuited (shorted). Of course it is possible for the leads to touch each other, or for both leads to touch some common point. Except for these conditions, an ohmmeter placed across a resistor may show that the resistance is correct, too high, or too low, but should never show that it is zero.

Caution: When installing new resistors, remember the following:

1. Do not cut the new resistor wires too short; the heat of the soldering iron will travel along the short wires when solder is applied and change the resistance.

2. Do not allow blobs of melted solder to fall on other parts.

3. Place the new resistor in the same physical location that the defective resistor occupied. Dress the resistance leads by keeping them in the clear, and cut off excess wire at the solder joints.

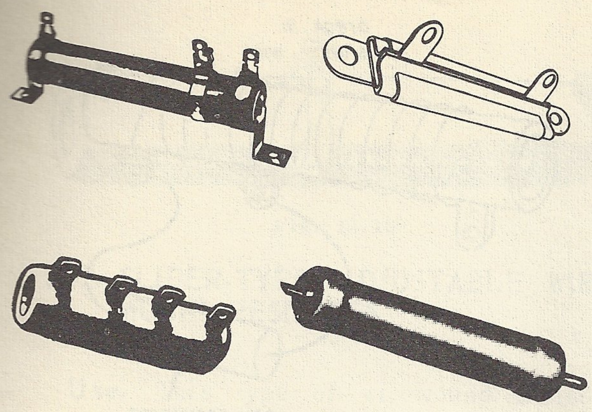


Fig. 13-5

Fixed Wirewound Resistors. When the current flow through certain portions of a radio receiver is too large to be handled by the ordinary carbon resistor, a wirewound resistor is used. This type of resistor can safely give off more heat than a carbon resistor or metal-film resistor of the same dimensions. The most common types of fixed wirewound resistors are those shown in Fig. 13-5.

Wirewound resistors do not have color-code markings. Their resistance values, in numbers, are printed directly on them. Sometimes the markings disappear, due to heating of the resistors. Sometimes there may be no value printed on a new resistor. If in doubt about the normal-resistance value of an open wirewound resistor, refer either to the radio receiver circuit diagram or to the service and repair data.

The most common faults found in wirewound resistors are an open resistor (or open section of a tapped resistor) and an intermittent resistor. Figure 13-6 shows some typical defects. When an ohmmeter is used to test a wirewound resistor, the procedure is the same as when testing for a carbon composition resistor. An open resistor is easy to test and should be replaced when located. On the other hand, an intermittent resistor may test *normal* when the ohmmeter is applied to it. At another time it may test *open* or seem to have a resistance that is much higher than normal. At still

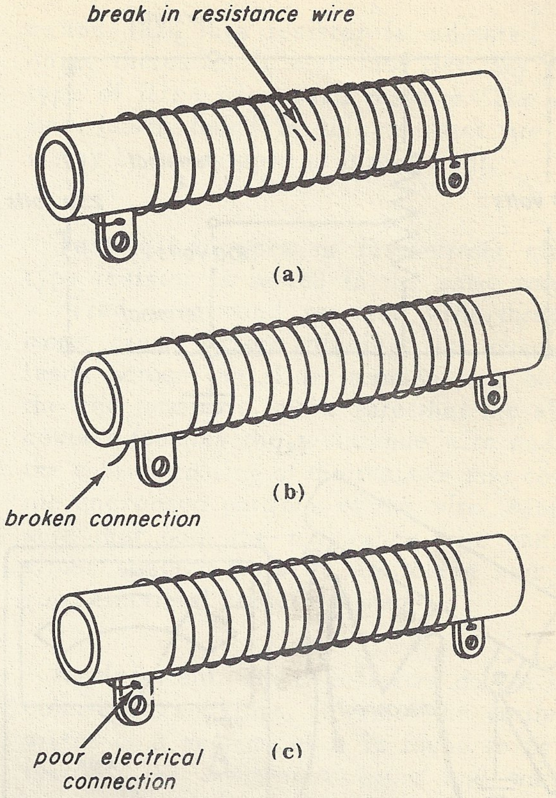
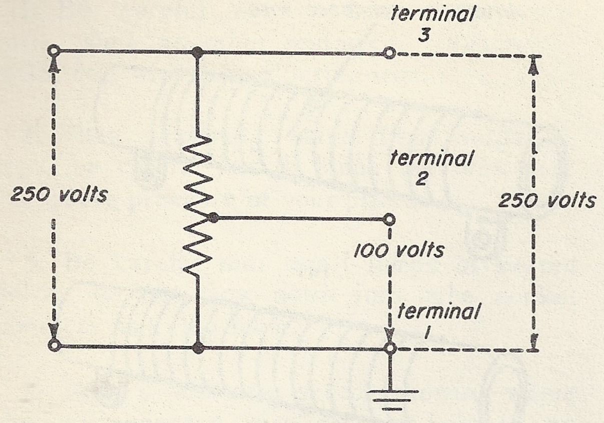


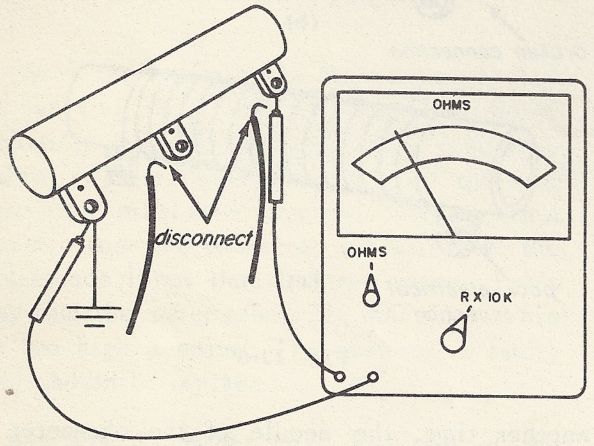
Fig. 13-6

another time, the needle of the ohmmeter may waver back and forth, indicating that the resistor is intermittent. Once you know that a resistor is intermittent, you should replace it.

When testing a tapped wirewound resistor with an ohmmeter, we must consider it as two resistors connected in series. Such a resistor, as shown in Fig. 13-7*a*, may be used in a voltage-divider circuit to provide different voltages. (The schematic shows that the voltage between the tap (terminal 2) and ground (terminal 1) is less than that between the top (terminal 3) and ground. The tap (terminal 2) is the common connection or joining-point of the two resistor sections. This means that before the ohmmeter leads are applied, at least two terminals or lugs should be disconnected, as in Fig. 13-7*b*, to avoid parallel-circuit effects and wrong readings. The ohmmeter leads then can be placed across terminals 1 and 2 and one resistance reading can be taken. Another reading can be taken with the ohmmeter connected to terminals 2 and 3.



(a)



(b)

Fig. 13-7

Each of the two sections may be open, intermittent, or perfect. The meter indications for each condition are the same as for untapped resistors.

If one section of a tapped resistor tests *defective*, it is best to replace the entire resistor. Of course, it is possible to replace the defective section by shunting it with a new resistor of the proper resistance value, as shown in Fig. 13-8. This shunt resistor does not necessarily have to be wirewound. If the power dissipated in the section does not exceed the capacity of a carbon composition resistor of the required resistance, there is no reason why such a resistor may not be used except in some very unusual cases. However, such a repair should be considered only temporary. The entire resistor should be replaced as soon as one is available.

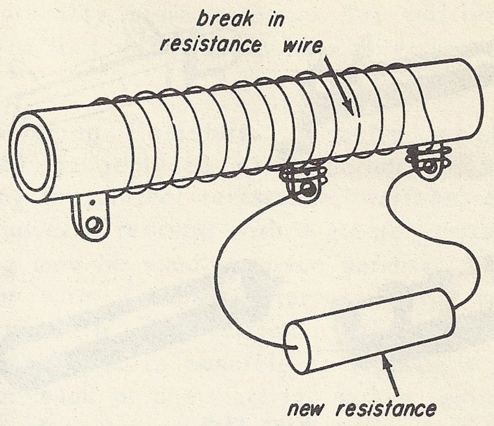


Fig. 13-8

Of course, you probably want to know why you should not shunt a section of a tapped wirewound resistor and consider it a permanent repair. Here's why: an open or intermittent section of a wirewound resistor may receive quite a bit of heat from the good section (or sections) of the resistor. This heat may cause the wire in the defective section to expand enough so that the open wire ends come together again and remain together just so long as the resistor is hot. When this happens, the resistance of the defective section will be in parallel with the shunt resistor, as shown in Fig. 13-9, and the resistance of the section will be about one-half what it should be. This will change the operating conditions of the equipment and cause it to operate improperly. It pays to play safe and change the entire resistor. When the resistor is replaced, each section between terminals or lugs should have the same resistance value and wattage rating as the original section.

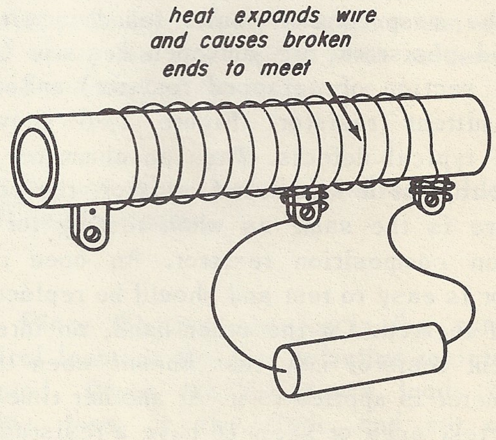


Fig. 13-9

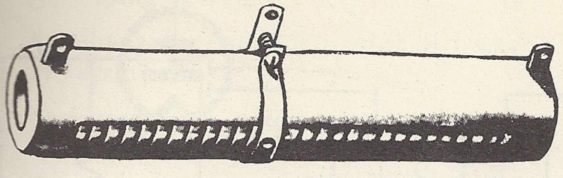


Fig. 13-10

13-2. SLIDER-TYPE ADJUSTABLE WIRE-WOUND RESISTORS

Use. This type of wirewound resistor, shown in Fig. 13-10, is neither a fixed nor a variable resistor, but half-way between these two types. It has one or more adjustable sliding contacts, in the form of a sliding sleeve that make contact with the exposed resistance wire of the resistor. This contact can be slid down the resistance wire until the desired amount of resistance is obtained. Then the sliding contact can be fixed in place by tightening a screw that causes the sleeve contact to grip the body of the resistor firmly and make firm contact with the resistance wire.

Caution: The slider pressure screw should not be tightened too much; excessive pressure of the slider contact against the resistance wire may cause the wire to break off at the point of contact or cause the ceramic form that it is wound on to crack.

Soldering lugs are provided for terminal connections. The sliding contact is usually left in its tightened position after the correct resistance point has been obtained. This means that this resistor is adjusted only once; thereafter it acts just like any other type of fixed wirewound resistor. The common faults found in this resistor are that it may be either open or intermittent.

Testing. An open or intermittent slider-type resistor is tested in the same way as a fixed wirewound resistor with three or more taps. Before placing the ohmmeter leads across the slider terminal and one of the end terminals, make sure that the slider contact touches the resistance wire and not the enamel coating of the resistor that covers the unexposed portions of the wire. Also be sure that both the resistance wire and the slider contact surfaces are clean and that good electrical contact is made.

Replacement. These resistors do not have color-code markings. If either the entire resistor or a section of it is found to be defective, the resistance value and wattage rating should be determined. After a little experience, you will be able to judge the wattage rating of most wirewound resistors. The complete resistor can be replaced, or the open section can be shunted with a section of another slider-type adjustable wire-wound resistor. A fixed resistor cannot, as a rule, be used for a shunt because fixed resistors do not come in the odd resistance values that are common in sections of slider-type resistors. The new section should have the same resistance value as the open section and have the same, or greater, wattage rating.

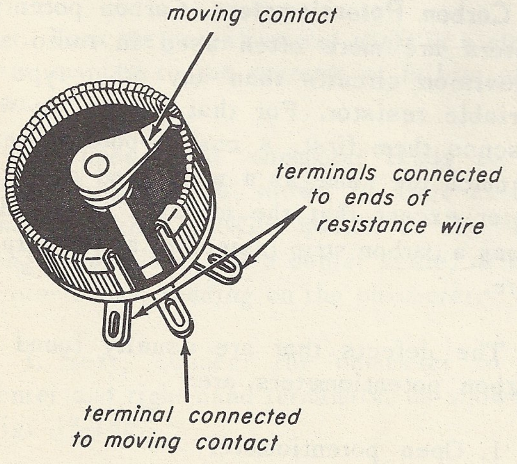


Fig. 13-11

13-3. VARIABLE RESISTORS

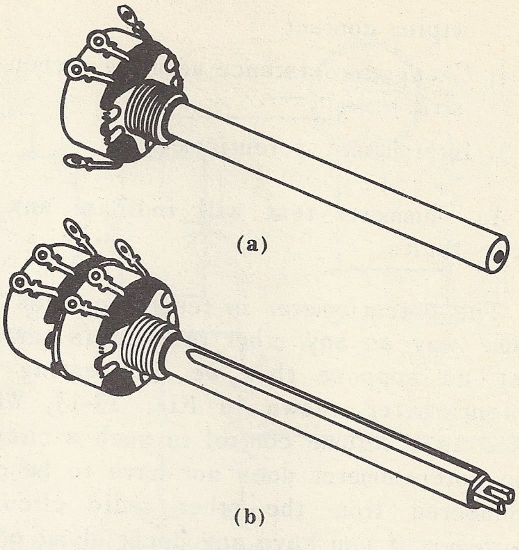
A variable resistor, as shown in Fig. 13-11, is one in which a movable arm or slider makes contact with any point between the end terminals of a carbon composition or wirewound resistor. Such a resistor may be used as a rheostat or as a potentiometer. When used as a rheostat, the sliding arm and only one of the end terminals are used. As shown in Fig. 13-12*a*, a rheostat is actually a variable resistor. When the movable arm is near the left terminal of the rheostat, there is very little resistance in the circuit (more current flows) and the light glows brightly; while the farther it moves toward the would keep changing – making the sound jumpy. Dirty potentiometers do not necessarily have to be replaced. There are various cleaning fluids and compounds on the market that have been specially prepared to clean a potentiometer so that it will operate as smoothly and quietly as when it was new. Instructions for applying them come with each type.

A potentiometer having a changed or incorrect value of resistance is tested by connecting the ohmmeter as shown in Fig. 13-14*a*. An ohmmeter reading is taken and the value obtained is compared with the resistance stamped on the case of the pot or obtained from servicing notes. If the resistance of the pot has changed so far from its normal value so that it actually affects the operation or tone quality of the radio receiver, it should be replaced. If the pot operates smoothly, and the radio receiver operates normally, no harm is done if the pot is not replaced, even though its resistance may be somewhat off the 20% maximum tolerance usually allowed resistors in radio receivers.

An intermittent carbon potentiometer is one that, due to a poor electrical connection within the pot, causes the circuit between two of the three lugs to either open or change its resistance at different times. To test for an intermittent potentiometer, proceed as follows:

1. Test the pot for any of the four previously mentioned defects. If everything is normal, proceed with the next step.

2. Connect the ohmmeter as shown in Fig. 13-14*a*. Place a piece of insulating tape between the two jaws of a pair of long-nose pliers. Grip one terminal of the potentiometer with the insulated pliers and force the lug slightly from side-to-side, at the same time holding the case of the potentiometer with the other hand. Watch the ohmmeter to see if the reading suddenly goes to infinity. If it does, the lug is loosely connected within the potentiometer. Release the pliers and then grip the other end terminal with the pliers, repeating the same procedure.



(a)

(b)

Fig. 13-15

3. Connect the ohmmeter leads to the center lug and the right-hand lug, as shown in Fig. 13-14*b*. Grip the center lug with the insulated pliers and check for a loose lug connection as before. If the potentiometer is intermittent, it should be replaced.

Some types of potentiometers have four erminal lugs, like the one shown in Fig. 13-15*a*. The same procedure is used for testing a pot of this type as is used for testing the three-lug type, except that the resistance between the fourth lug and the closest end lug is also determined by an ohmmeter check.

Another type of control, known as the *dual potentiometer* is shown in Fig. 13-5*b*. Each potentiometer of a dual potentiometer is tested separately.

13-4. TAPER

One test that must be made whenever a potentiometer becomes defective is that for *taper*. Taper is the term used to describe the way the resistance of the potentiometer's resistance strip varies from one end terminal to the other. We might expect that the resistance would increase evenly along the resistance strip. For example, we might expect that each quarter turn of the movable arm would cause it to slide across an equal amount of the resistance of the resistor strip, as in Fig. 13-16. Some potentiometers act just this way. When they do, we say that they have a *linear taper* – because the

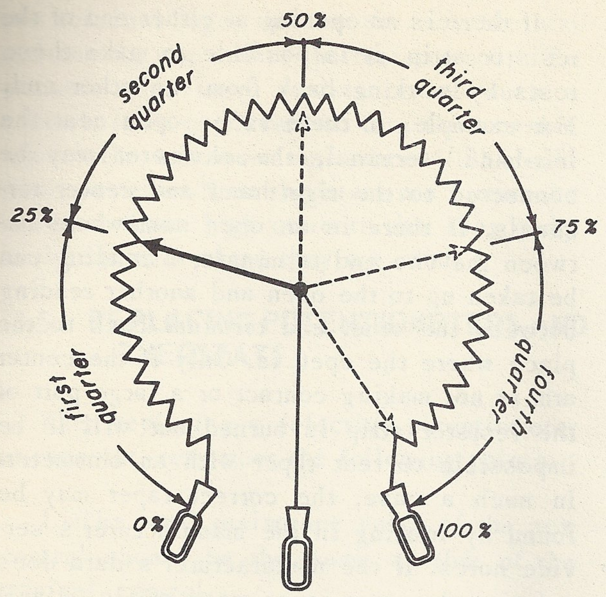


Fig. 13-16

resistance increases in a straight line, evenly. However, the greater number of the potentiometers used in volume, tone, and other control circuits in radio and television do not have a linear taper. Most tapers are determined by comparing the resistance of the second half-rotation. In some cases the resistance in one half-rotation of the movable arm may be much greater or much smaller than in the next half-rotation. Why this should be so is discussed in later theory lessons. At this time it is necessary only that you know how to identify the more common tapers used in potentiometers.

Unfortunately the manufacturers of potentiometers do not agree on any means of identifying the different tapers used in potentiometers, so when you look in a parts catalog, you'll find that one manufacturer calls his linear taper #4, another identifies his as an A taper, and still another marks his *C-1*. Each one means the same thing but says it differently.

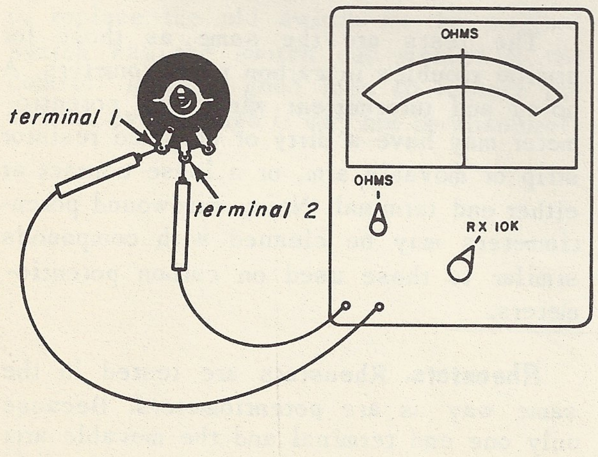


Fig. 13-17

However, it is possible to measure the taper of most potentiometers with your ohmmeter so that you may know which taper to order from your parts dealer. Here's how you do it:

1. Hold the potentiometer with the lugs down and the shaft toward you, as in Fig. 13-17.

2. Connect the leads of your ohmmeter to terminals 1 and 2, as shown.

3. Turn the shaft counter clockwise (toward terminal 1) as far as it will go. Then advance it slowly in a clockwise direction and watch the resistance increase by watching the ohmmeter needle. If the resistance measured at the halfway point is half the total resistance, as in Fig. 13-18*a*, then the potentiometer probably has a linear taper. To make sure, repeat the test even more carefully. This time notice how the resistance increases as you start turning in a clockwise direction away from terminal 1. If the resistance change is very slow at first and then speeds up and changes at an even rate until just toward the end, where the change rate slows down again, you may have what is called a *symmetrical taper.* If the first half-rotation passes 1/10 of the total resistance, with the other 9/10 in the second half, you have a potentiometer with a *left-hand logarithmic* taper, as in Fig. 13-18*b*. If the first half passes 9/10 and the second half 1/10, then you have a *right-hand, logarithmic* taper, as in Fig. 13-18*c*. If the first half-rotation passes 2/10 and the second half 8/10 of the total resistance, as in Fig. 13-8*d*, it is a *left-hand, semi-logarithmic* taper. If the first half rotation passes 8/10 and the second half 2/10 of the total resistance, as shown in Fig. 13-8*e*, it is a *right-hand, semi-logarithmic* taper.

two terminal lugs, one for the movable arm and one for one end of the resistor strip. To measure the total resistance of such a control, it is necessary to turn the movable arm to the maximum resistance (full clockwise) position. Most rheostats are wirewound because of the high currents that they carry in the circuits where they are used.

13-5. REPLACING POTENTIOMETERS AND RHEOSTATS

When replacing a defective potentiometer or rheostat, remember the following points:

1. The total resistance value of the new control should be the same as that of the original control.

2. The wattage rating of the new control should be at least the same as the wattage rating of the original. Sometimes a higher wattage control may be used, if space permits.

3. A wirewound control must be replaced with a wirewound control, and a carbon control with a carbon control.

4. The new control must have the same taper as the one being replaced.

5. If the control has some special feature, such as a tap at some point between the two end terminals, the new control must be tapped at the same point.

6. If the control has a switch attached to it, as on an ON-OFF switch and volume control combination, it is usually necessary to replace the old switch as the original switch has the switch cap riveted to the control. It is a good idea to replace the switch, even though it may not be absolutely necessary, because the switch and control are made to have about the same service life.

7. Make sure that the replacement control has a shaft similar to that which it replaces, so that the control knob may be properly attached. The new shaft may not be of the same length as the old one, so it may be necessary to remove (with a hacksaw) some of the new shaft to bring it down to the length of the old one. On the new shaft, measure off the length of the old shaft, as in Fig. 13-19. Then remove the excess with your hacksaw.

8. Before unsoldering the leads and removing the old potentiometer or rheostat from the chassis, make a drawing showing the connections to each terminal lug or mark each lead so that it may be connected to the correct terminal in the new control.

Once the potentiometer or rheostat is disconnected from the receiver circuits, it is easily removed by removing the mounting nut with an open-end or socket wrench of the correct size.

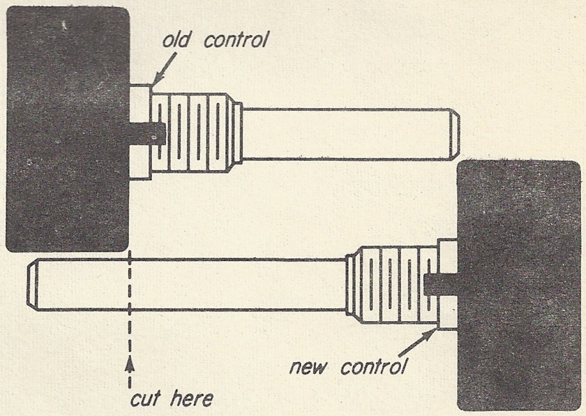


Fig. 13-19

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 14

HOW TO TEST INDUCTORS

14-1. Practical Inductors Used in Radio and Television

14-2. Inductor Defects

14-3. Basic Tests for Inductors

14-4. Radio-Frequency Inductors

14-5. Low-Frequency Inductors

14-6. Voice Coils

14-7. Output Transformers

14-8. Power Transformers

14-9. Replacement of Inductors

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Service Practices 14

INTRODUCTION

In Theory Lesson 14, you learned about an electrical property called inductance. Components that are used to introduce inductance into a circuit are called *inductors*. In radio and television receivers, inductors have many forms, from tiny radio-frequency chokes to large power transformers.

Defective inductors can cause hum, poor reception, or low output, or cause a receiver or other electronic equipment to stop working completely. It is important to know how to test inductors and how to repair or replace them.

In this booklet, you will learn how to test an inductor in order to find out whether it is defective and how to repair or replace it. We will assume that you suspect the inductor for some reason or that you have been told to test it by someone else. In latter lessons, you will learn how to troubleshoot receivers and how to localize the trouble first to a section or stage of the receiver, and then to components of that stage.

14-1. PRACTICAL INDUCTORS USED IN RADIO AND TELEVISION

Inductors used in radio and television are of two general types — air-core inductors and iron-core inductors. Air-core inductors are generally used at radio frequencies. They are constructed by winding the wire on a waxed cardboard, plastic or ceramic form. A number of typical inductors of this type are shown in Fig. 14-1. From left to right, these are an antenna coil, an r-f transformer, and an oscillator coil.

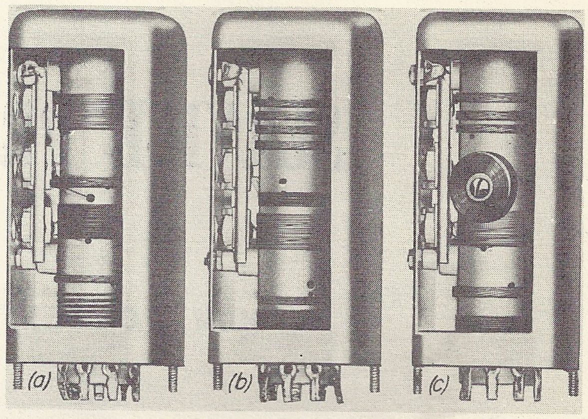


Fig. 14-1

Iron-core inductors are generally used at audio frequencies. The construction of a typical inductor of this type is shown in Fig. 14-2. The windings are wound around iron or steel stampings called laminations, which are bolted together in a stack. Such coils usually have many layers of windings, and the separate layers are insulated from each other by sheets of specially prepared paper. A number of typical iron-core inductors are shown in Fig. 14-3; *a* shows a power transformer, *b* a filter choke, *c* an audio-output transformer, and *d* an audio-interstage transformer.

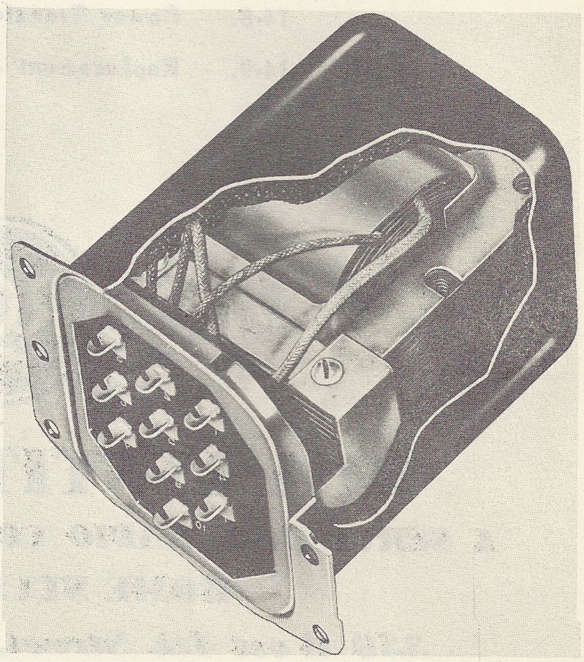


Fig. 14-2

14-2. INDUCTOR DEFECTS

An inductor may have one or more of the following defects:

1. An open winding

2. Shorted windings
   a. Completely shorted winding
   b. A partially shorted winding
   c. A winding that is shorted to another winding
   d. A winding that is shorted to the core or to the case

3. A winding that has changed its inductance value or its coupling to another winding

Open Winding. Inductors are generally wound with relatively fine wire. A short or other defect in the receiver may cause much more current than the safe current to flow through the inductor. The flow of current through a conductor produces heat, and, if the current is more than the safe current for the inductor, enough heat may be produced to melt the wire of the coil, producing an open circuit.

Open windings may result when the leads brought out from a coil are separated from the coil. These leads are generally not the same wires with which the coil is wound. Usually, heavier stranded leads are used to make connections to the circuit. These leads usually are soldered to the coil wires. If any of these connections is poorly made or breaks because of rough handling, an open winding will result. If you can reach the break, you may be able to repair the coil. It is possible that windings may open in coils that are not protected by a case. In such cases, the break can be seen by visual inspection, and a repair can usually be made. Open windings also may be produced by poor or broken connections to the leads or terminals of a winding. This may be due to either poorly soldered joints or corrosion. In air-core inductors, the ends of the winding, which is usually made of a relatively fine wire, are connected to terminals on the coil form, as shown in Fig.

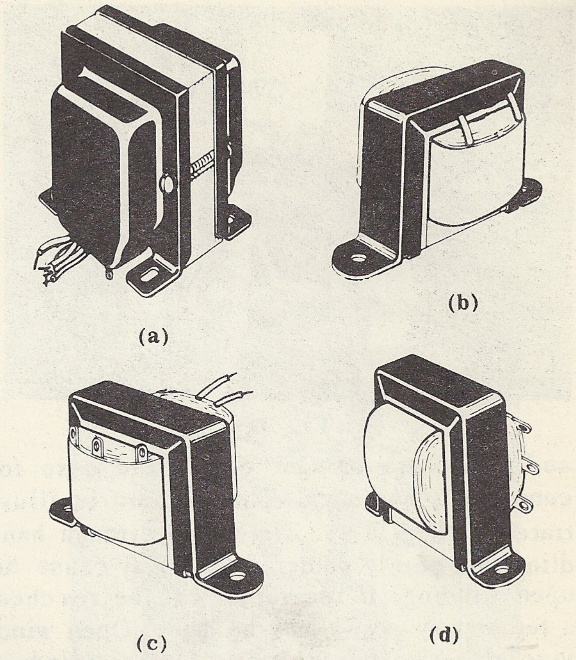


Fig. 14-3

14-4. Rough handling may cause a break at point X, as shown in the figure. This break can be seen by looking at the coil. By carefully removing a portion of a turn of wire from the coil, such breaks usually can be repaired. Extreme care must be used in handling such wires, as they are very delicate. If the broken connection is too far in the coil, it may be more expedient to have the coil replaced.

In iron-core inductors, the wire with which the coils are wound is usually not brought out of the case, but heavier insulated stranded leads are soldered to the ends of the coil

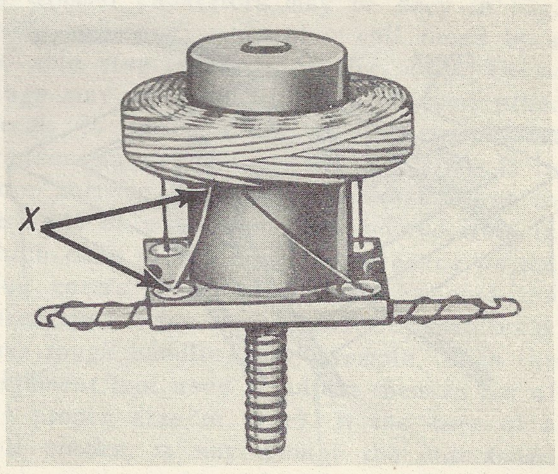


Fig. 14-4

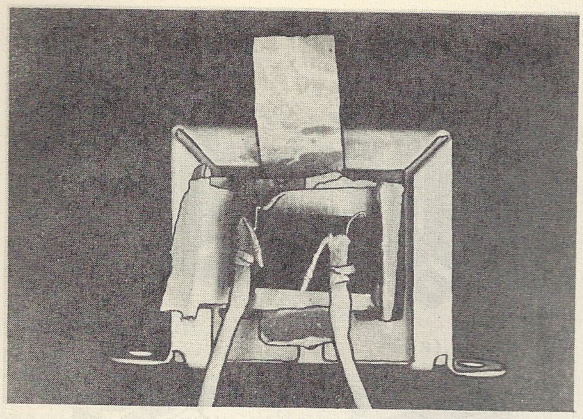
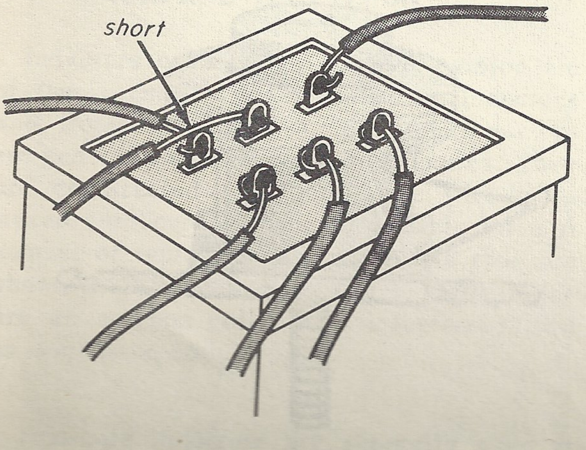


Fig. 14-5

and wires are brought out of the case for connection purposes. This method is illustrated in Fig. 14-5. Here again, rough handling or a poorly soldered joint may cause an open winding. If the joints can be reached, a repair may sometimes be made. Open windings also may be caused in iron-core inductors by excessive current, which may melt the fine wire used in the winding; if heavy wire is used for the winding, the soldered joint may melt and open.

Shorted Windings. Shorts may occur across the leads of a winding, so that the entire winding is shorted out, or they may occur between turns that are next to each other, or they may occur between layers of windings that are next to each other. Shorts may also occur from the winding to the inductor case or core.

The shorting out of an entire winding is usually due to a short between terminal lugs that are next to each other, as shown in



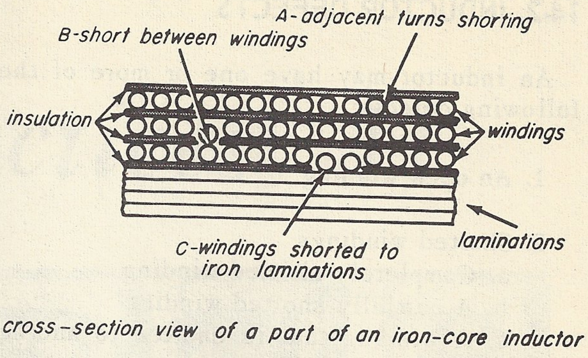


Fig. 14-7

Fig. 14-6. The exposed leads have shorted together two terminal lugs, thus shorting out an entire winding. Moving the wires to their proper positions will repair this trouble. (Moving wires to their correct positions is called *dressing the leads*).

Figure 14-7, which is a cross-section of a typical inductor, shows where the other shorts may occur. Shorts between turns may be due to excess current through a winding. This excess current burns away or damages the insulation so that turns that are next to each other can make electrical contact with each other, as shown at point A. Such shorted turns usually will not stop the inductor from operating completely; but, because the total number of active turns is reduced, the inductor will not work as it should. Sometimes shorted turns will result in so much excess current that the transformer will become very overheated. Almost always, such transformers must be replaced; repairs are not practical.

Shorts between one layer of a winding and another or shorts between two windings are usually caused by high-voltage surges that break down the insulation. Once such a breakdown occurs and chars the insulation slightly, it is easy for breakdowns to happen at the spot, and soon a hole is burned through the insulation at that point, as shown at point B of the figure. Breakdowns of this type may also take place between the winding and the case, or between the winding and the core, as shown at point C of the figure. If the point where the breakdown has occurred can be reached, a repair can sometimes be made by adding more insulation, in the form of plastic tape. Usually, however, such in-

Changed Inductance. The inductance value of an inductor does not often change; however, it is important to know when it has changed. Changed inductance values may be caused by shorted turns, as previously mentioned. Usually, this causes either a measurable change in the resistance or the voltage output of the winding, or both. Thus such changed inductance values can be located. Sometimes, a change of inductance cannot be directly detected through resistance or voltage measurements. This may happen with inductors of the type shown in Fig. 14-1*b*, which is an r-f transformer from a broadcast receiver. Proper operation of such transformers depends upon the spacing of the two windings relative to each other. The coils are held in place either by wax or by a cement called *coil dope.* Heat produced by excess current through the coil, or by a nearby component which gets very hot, may melt the wax or dry up the cement, allowing the coils to change position. Sometimes the old position of the coil may be located by the position of the old wax or cement that remains. In this case, a repair may be made by moving the coil back in position and applying fresh coil dope. Try to find out why coils were able to shift position, and take steps to prevent this from happening in the future, if possible.

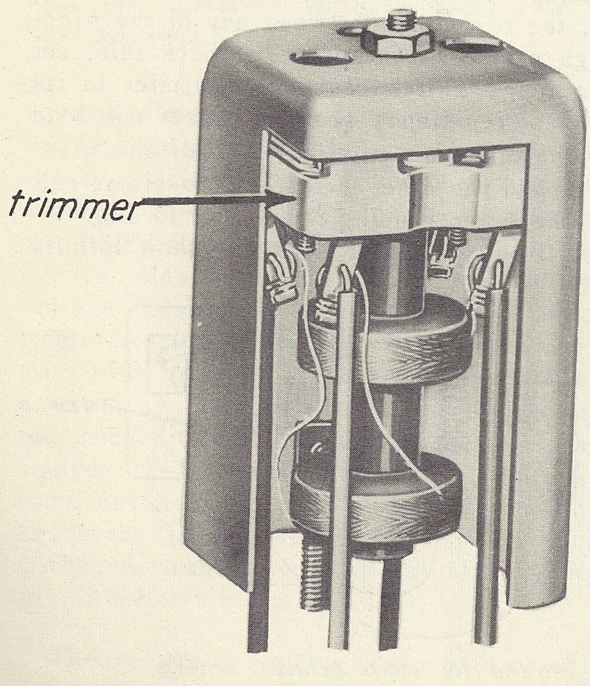


Fig. 14-8

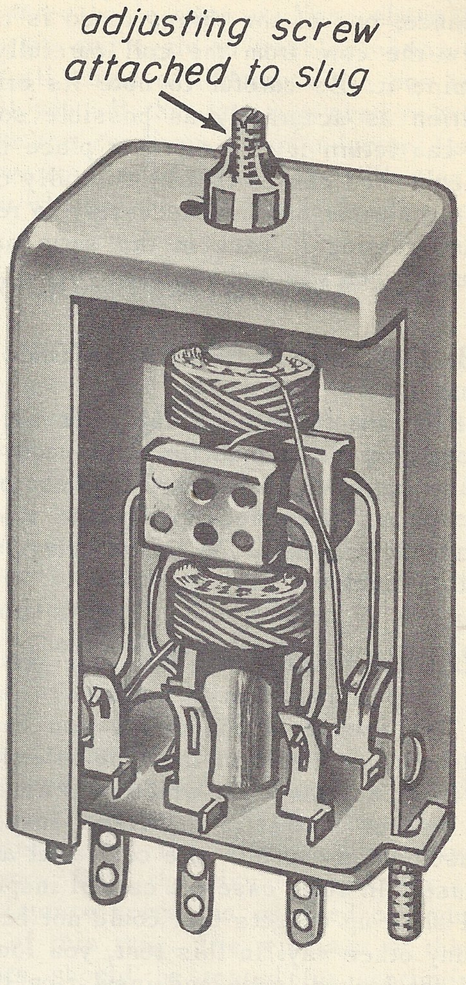


Fig. 14-9

Most air-core inductors used in broadcast receivers are tuned either by a small variable or trimmer capacitor across the coil or by a movable core or slug that may be moved in or out of the coil. An example of a coil tuned by trimmer capacitors may be seen in Fig. 14-8, and an example of a coil tuned by a movable slug is shown in Fig. 14-9. These slugs may be made of brass or some other metal, in which case the inductance decreases as the slug enters the coil. It is more common, however, for these slugs to be made of some form of powdered iron, in which case the inductance *increases* as the slug enters the coil. These powdered-iron cores are not too strong, and they may break from rough handling (for example, when the alignment tool used to adjust them is not of the proper size or type). If the core of a coil cracks, it may change the inductance of the coil considerably. If you suspect that ductance, one of the things to do is to unscrew the core from the coil carefully and examine it. Be careful to note its original position as accurately as possible so that you can return it to its proper place inside the coil. You can do this by carefully counting the number of turns necessary to remove it and turning it back in the same number of turns when you replace it.

14-3. BASIC TESTS FOR INDUCTORS

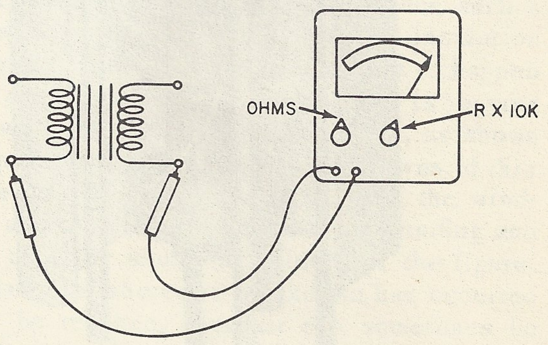
There are three practical tests that you can perform on an inductor. Many more tests can be made with laboratory-type equipment, but we are interested now in the types of tests that will help you locate defective inductors quickly.

External Inspection. The first test that you can perform on an inductor is to inspect it. The amount of inspecting you can do, of course, depends on the type of inductor, the frequency range for which it is used, and the type of case it is in. Visual inspection is used mostly for air-core coils that are not encased. In some cases, a careful inspection will show up defects that could not be found in any other way. In this test, you look and feel for broken leads and insulation that is frayed, burned, or otherwise damaged. Check to see that terminals are not bent too close to each other so that they may touch and short and that there are no pieces of solder or bits of wire between terminal slugs.

Smell the inductor. If the inductor was overheated to the point of burning the insulation, even if it was some time ago, you will know it because the odor of burnt insulation stays on for some time. Look for signs of melted wax or pitch on or near the inductor, or for discolored or scorched enamel on the inductor shield can or case.

Resistance Checks. With an ohmmeter, you can check an inductor for continuity and for shorts or leakage to the case or to the core. If the inductor has several windings, you can check for shorts or leakage between windings. By comparing the measured resistance of the winding to the value given in the manufacturer's service data, you may sometimes tell whether the winding has shorted turns. However, if the winding consists of just a few turns of heavy wire and the total resistance is less than one ohm, the change in resistance due to shorted turns cannot be detected by a service-type ohmmeter. Also, if the winding consists of many turns of fine wire, a large number of turns may short out without causing a measurable change in the resistance of the winding. In these cases, it is necessary to use other tests that will be described later in this booklet. In general, if the measured resistance of the inductor agrees with the value given in the service data, the inductor winding is probably good. The resistance values of inductor windings given in the service data are average values; the values you measure on your meter can differ somewhat from the values given without indicating that the inductor is defective. The amount by which an inductor may vary from the value given without being considered defective depends upon the type of inductor. We will talk more about this when we discuss testing different types of inductors later in this booklet.

If the inductor has more than one winding, there should not be any short or leakage between any of the winding. That is, the resistance between any of the windings should be infinite. To check this, set the range switch of your multimeter to its highest resistance scale. Connect one lead of the ohmmeter to either lead of one winding, and the other meter lead to either end of the other winding, as shown in Fig. 14-10. If the ohmmeter does not show infinite



testing for shorts between windings

Fig. 14-10

resistance, there is leakage or a short between the windings. This will probably interfere with the operation of the transformer. Make this test between *each* pair of windings of the inductor.

There should be no short or leakage between the winding and the core on which it is wound nor between the winding and the case or shield in which the winding is enclosed. To test for such a short or leakage, set your ohmmeter to its highest-resistance range. Connect one lead of the ohmmeter to one end of the winding and connect the other lead from the ohmmeter to the case of the inductor. In iron-core inductors, the core is either bolted or otherwise attached to the case. Therefore, this test will show shorts or leakage to either the core or the case. Since the case of the inductor is almost always attached to the chassis, such leakage grounds the inductor to the chassis and will almost always interfere with the proper operation of the circuit. Make this test from *each* winding to the case.

Sometimes such shorts or leakages will occur only when voltage is applied to the inductor and cannot be detected when the low voltage from the ohmmeter battery is applied. We will discuss how to make checks with the operating voltages applied in a later section.

Voltage Measurements. Another test that can be used with many inductors is the voltage test. In this test, you use your multimeter as an a-c or d-c voltmeter to measure the voltage that appears at the inductor terminals. Most service notes give average voltage values for different parts of electronic circuits. In many cases, these values may differ from the values you measure by as much as 10 to 20 percent without making too much difference in the operation of the equipment. In some circuits, the voltages must be close to the given value if the equipment is to perform properly. In such cases, the manufacturer will usually specify this in the service notes.

The manner of making voltage tests will be described when we discuss the specific inductors in the next section.

The three basic tests outlined above are used again and again in troubleshooting for testing all kinds of inductors. No one test can tell you all that you may need to know to judge the condition of an inductor. However, two or more of these tests will usually tell you whether the inductor is good or bad.

14-4. RADIO-FREQUENCY INDUCTORS

Radio-frequency inductors are coils that usually are wound upon either waxed cardboard tubes or plastic coil forms. These coils may sometimes have small powdered-iron threaded cores that extend part way into the coil for tuning purposes and for improving the performance of the coil. Typical inductors of this type are antenna coils, i-f transformers, radio-frequency chokes, filament chokes, loop antennas, interference filters, etc.

The voltages developed across inductors of this type in broadcast receivers usually are too small and of too high a frequency to be measured by the average service-type multimeter. Only the visual inspection and the resistance tests can be used on inductances of this type. The windings of these inductors should be tested for continuity, correct resistance, and shorts between windings. It is almost impossible for a short to occur from the winding to the core or the case in an inductor of this type. However, in i-f or similar transformers, the *terminals* coming out of the case may bend over and touch the edges of the case, shorting the winding to ground, as shown, in Fig. 14-11. This type of short is common but may be easily seen by careful inspection.

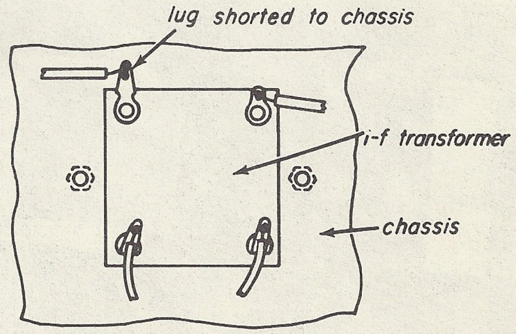
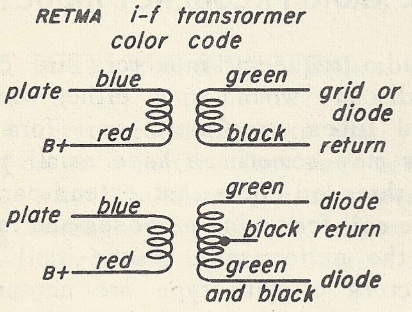


Fig. 14-11

Identification of Leads. Usually, there is no problem in identifying the leads of radio-frequency inductors; either the leads can be traced visually or they are color-coded. The color code for intermediate-frequency transformers is shown in Table A.

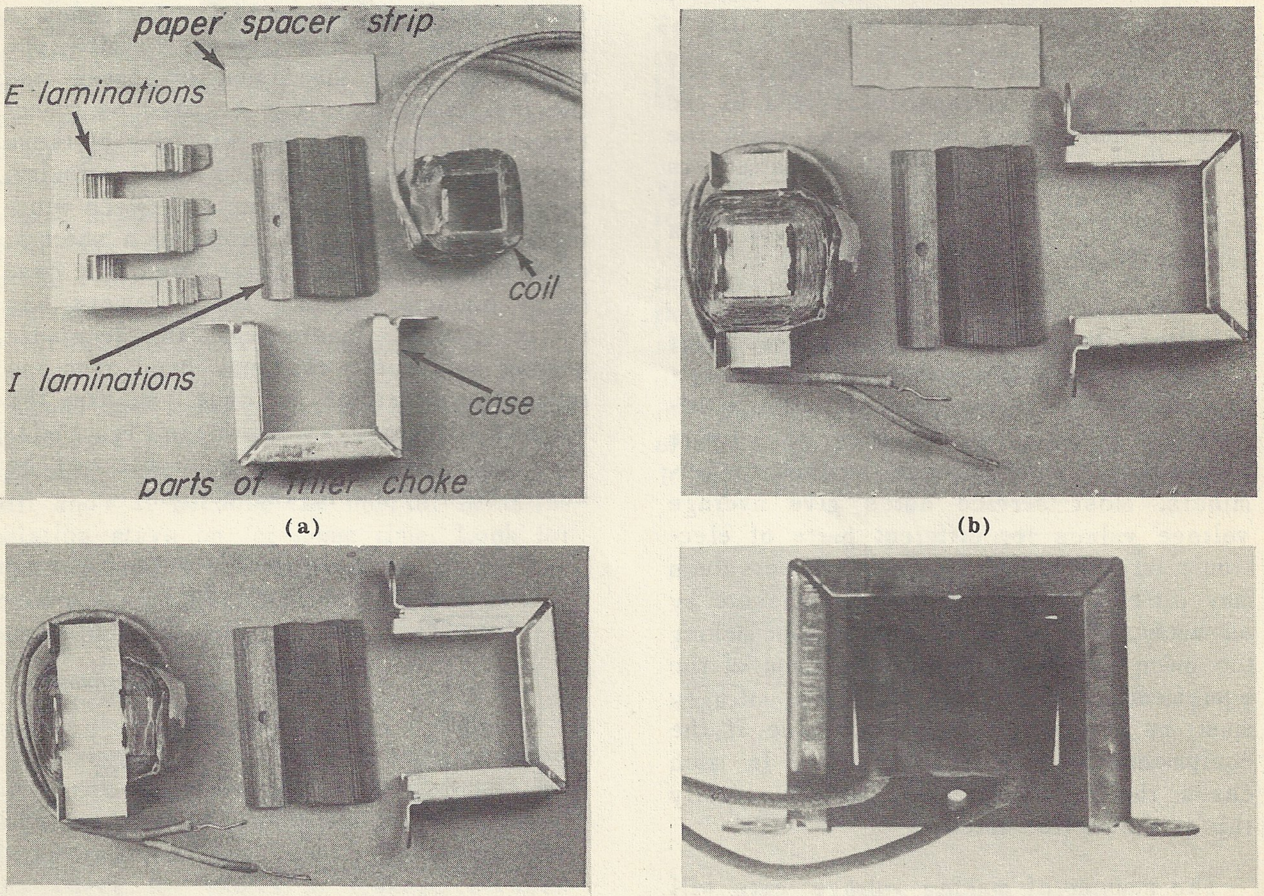
TABLE A



14-5. LOW-FREQUENCY INDUCTORS

Low-frequency inductors are usually wound upon cores of magnetic material of high permeability. The cores are usually laminated to reduce eddy-current losses, as explained in previous lessons. Typical inductors of this type are power transformers, filter chokes, audio-output transformers, and audio-interstage transformers. We will discuss the testing of each one of these types separately in the sections that follow. We will start with the filter choke, which has only one winding, and, therefore, just two leads, and then go on to the testing of inductors with more windings and many more leads.

Filter Chokes. Filter chokes are used in power-supply circuits that produce direct current for the operation of the receiver from the alternating-current supply. The purpose of the filter choke is to help remove the variations or ripples in the direct current so that a smooth unvarying direct current is obtained. You will learn more about this when you study filters in a later Theory Lesson.



(a) (b) (c) (d)

Fig. 14-12

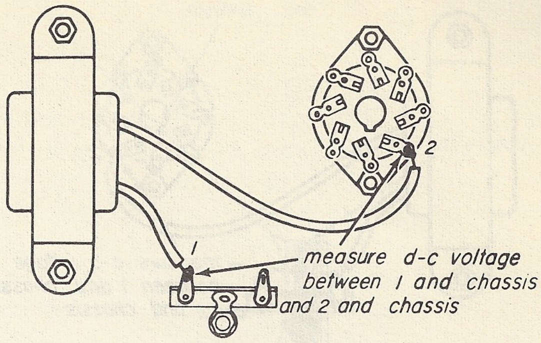
The construction of a typical filter choke used in broadcast receivers is shown in Fig. 14-12. The d-c resistance of such chokes varies from about 100 ohms to 500 ohms. Although the inductance of such chokes ordinarily is not measured for servicing purposes, it is useful to remember that the inductance of filter chokes varies from about 5 henries to 10 henries.

The filter choke has only one winding and two leads. The two leads are the two ends of the winding. Color-coding is not used on the leads of such filter chokes. If the leads are colored, the colors have no significance, except to determine the *start* (point at which the winding is begun) and *finish* (point at which the winding ends) leads.

Filter chokes may become defective in a number of ways: They may become open; they may become partially or entirely shorted; or they may become shorted to the case. Sometimes loose laminations may cause a hum or buzz to come from the filter choke. This buzz does not come through the loudspeaker and can be heard with the volume control set at minimum. If the laminations cannot be tightened by tightening the bolts holding the core together, and the buzz can be heard when the chassis is in the cabinet, the choke should be replaced.

Open Filter Chokes. The effect of an open filter choke is to cause the receiver or other electronic device in which it is used to stop operating because the open circuit stops the operating voltage from reaching the various sections of the receiver. An open circuit in the filter choke may be due to burnt-out wires caused by excess current through the winding or to broken connections at the leads.

The filter choke may be tested for an open circuit by the resistance test, in which case the receiver *must be turned off.* Since the resistance to be expected is about 500 ohms, the multmeter should be set on its R x 10 scale, and the leads from the meter should be placed across the terminals of the filter choke. If the ohmmeter indicates either infinity or a resistance much higher than the d-c resistance of the filter choke as given in the service data, the choke is open.



testing choke with voltmeter

Fig. 14-13

A filter choke may be tested for an open circuit using voltage measurements. This is done, of course, with the receiver on. To make the test, set your multimeter to its highest d-c voltage range. Connect the COMMON lead of the multimeter to the chassis. Connect the other lead of the multimeter first to one side of the filter choke and then the other as shown in Fig. 14-13. If you measure voltage on one side of the filter choke but zero voltage on the other, the filter choke is open; if the voltage on the other side is very low, the filter choke is not open, but there is probably a short in the receiver. *Turn the receiver off quickly to prevent possible further damage.*

Shorted Filter Chokes. If a filter choke becomes shorted, the smoothing action is lost and a loud hum appears in the output of the receiver. Shorted turns in the filter choke may be due to a breakdown of the insulation between layers of the winding caused by overheating or a high-voltage surge. The filter choke may be tested for shorted turns by the resistance test, in which case the receiver *must be turned off.* Measure the resistance of the filter choke as described previously, and compare it with the manufacturer's data. If the measured resistance differs by more than 20% and hum is present in the receiver, the filter choke should be suspected as a possible cause.

The filter choke can be tested for shorted turns by using voltage measurements. Since the purpose of the choke is to reduce the amount of a-c voltage present, the test is

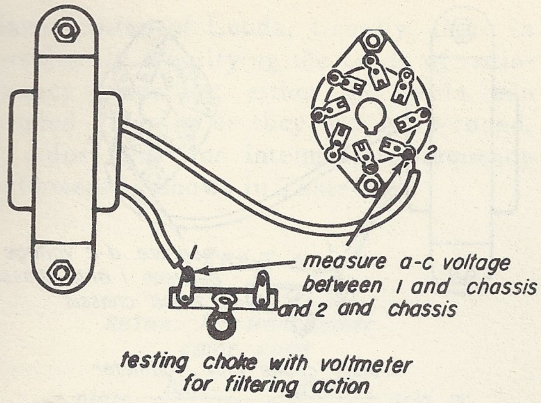


Fig. 14-14

made using the multimeter as an a-c meter, as shown in Fig. 14-14. Also, to keep out the d-c voltage for this measurement one test lead is placed in the yellow OUTPUT JACK instead of the red jack (a 0.1-mf 600-volt capacitor is used in series with the a-c voltmeter leads). The multimeter is set on its highest voltage range. Connect the common lead of the multimeter to the chassis. Connect the other lead of the multimeter first to one side of the filter choke and then to the other. The a-c voltage should be much lower on the output side of the filter.

Shorts to the Case or Core. The effect of a short to the case or core in a filter choke is to short out the operating voltage of the receiver to ground. This may damage the rectifier tube, the power transformer, the filter choke, or all of these. It may also cause the fuse protecting the a-c outlet where the receiver is connected to blow.

Never replace a burnt-out rectifier tube without first determining the cause. Check to see whether there is any short in the receiver. If the receiver or any electronic device causes fuses to blow, locate the cause before connecting it to the a-c supply again. This will be discussed further later in this booklet.

Shorts to the core or case may be due to breakdown of the insulation caused by moisture, overheating, or a high-voltage surge. Shorts to the case may also be caused by improperly dressed exposed leads at terminals where the connections are made inside the case. Another cause may be a burr or sharp edge of the case cutting through the insulation of the lead wires at the point where they come out of the case.

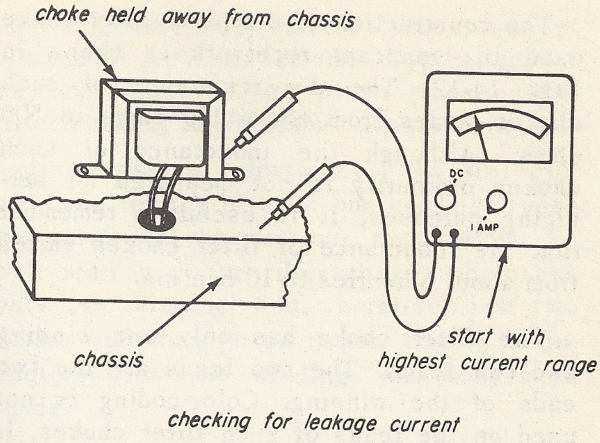
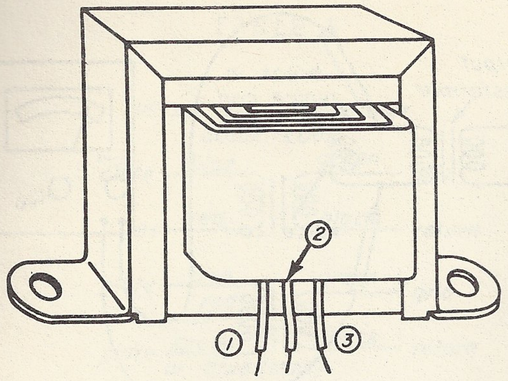


Fig. 14-15

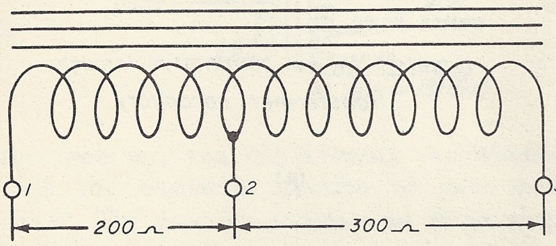
The best way to locate such shorts is through resistance checks. Set the multimeter on its highest resistance range and measure the resistance between each winding and the chassis. Any reading less than infinite indicates leakage between the winding and the case or core. Sometimes the leakage does not occur until voltage is applied. In this case, resistance measurements will not show that there is leakage.

Shorts of this type may be measured by the following technique: Disconnect the suspected choke (or other iron-core inductor) from the chassis and support it so that it is insulated from and clear of the chassis, as shown in Fig. 14-15. Connect one meter lead to the case of the inductor and the other lead to the chassis. Set the meter to its highest current range. Switch to lower ranges carefully until the lowest range is reached. If any current flows between the case of the inductor and the chassis, it indicates leakage from a winding to the case. In the absence of milliameter ranges on the multimeter, a neon lamp may be used whenever the d-c voltage in the circuit exceeds about 85 volts, which is the voltage needed to make the neon lamp light up, or fire. Connect the neon tester between the chassis and the case of the inductor. The neon lamp will light up if there is leakage between a winding and the case or core. To make sure that the neon lamp is not lighting up due to false capacity effects, reverse the a-c plug of the receiver. The neon lamp will light up on both positions of the a-c plug if leakage is actually present.

Tapped Filter Chokes. Sometimes you may come across a filter choke that is tapped, as



(a)



(b)

Fig. 14-16

shown in Fig. 14-16*a*. There are three leads coming out of the case. It is not difficult to find out which one is the tap. In fact, you have probably guessed the answer already. Set your multimeter to the R x 100 scale. Measure the resistance across any two leads. Let's say you take the two leads numbered 1 and 2, as shown in Fig. 14-16*a*. Suppose that the meter indicates 200 ohms. Next connect your meter test prods across leads 2 and 3 of the choke. Assume that the meter indicates 300 ohms. Now measure across leads 1 and 3. Assume that the meter indicates a resistance of 500 ohms. You have now identified the three leads. The two leads across which the highest resistance was measured are the two ends of the entire coil, and the third lead is the tap of the winding, as shown in Fig. 14-16*b*.

Speaker Fields. In some receivers, the field coil of the loudspeaker is also used as the filter choke, although this is not usually done in receivers being made at the present time. The tests and servicing procedures that have been already discussed in this booklet apply to this inductor.

14-6. VOICE COILS

The voice coil is the part of the loudspeaker to which the output current of the radio receiver is applied. The paper cone is

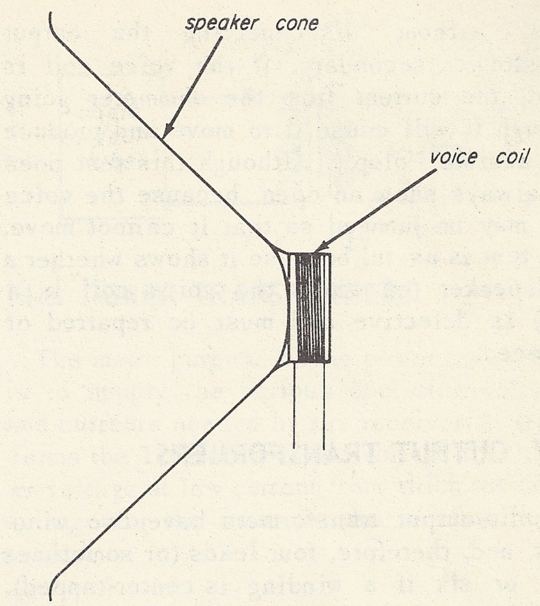


Fig. 14-17

attached to the voice coil, and the output current flowing through the voice coil causes the coil to vibrate, recreating the original sound. A typical voice coil is shown in Fig. 14-17. It consists of about 10 or 20 turns of fine wire wound around a paper or aluminum form. If an electrical defect occurs in a voice coil, the defect will be an open coil. The resistance of the voice coil is less than one ohm, and its continuity can be checked on the ohmmeter. But there is one complication. The voice coil is connected across the secondary of the output transformer. The resistance of the secondary of the output transformer is also less than one ohm. Therefore, if the voice coil is open, continuity will still be measured through the secondary winding, or vice versa as shown in Fig. 14-18*a*. Although the resistance of the combination is lower than the resistance in just one of them, the resistance in either case is so low that the average service-type ohmmeter will not be able to show the difference.

There are two quick ways in which the voice coil may be checked for continuity. A good test is to disconnect one lead of the secondary of the output transformer and measure the resistance of the voice coil, as shown in Fig. 14-18*b*. An open voice coil will give a reading of infinite on the ohmmeter.

Another test for continuity is to set the ohmmeter to its lowest resistance scale and touch the test prods of the meter to the terminals of the voice coil. This can be done without disconnecting the output transformer secondary. If the voice coil is good, the current from the ohmmeter going through it will cause it to move and produce and audible "plop". Although this test does not always show an open, because the voice coil may be jammed so that it cannot move, this test is useful because it shows whether a loudspeaker (of which the voice coil is a part) is defective and must be repaired or replaced.

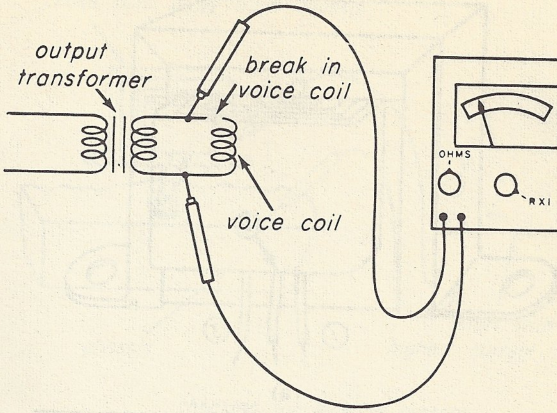
14-7. OUTPUT TRANSFORMERS

Audio-output transformers have two windings, and, therefore, four leads (or sometimes five or six if a winding is center-tapped). The purpose of such transformers is to transfer the signal from one stage to the next.

These transformers may have any of the defects described in the filter-choke section. In addition, because they have more than one winding, they may develop shorts between windings. Testing for shorts between windings has already been described. In this section, we will discuss the problem of identifying the leads from the various windings.

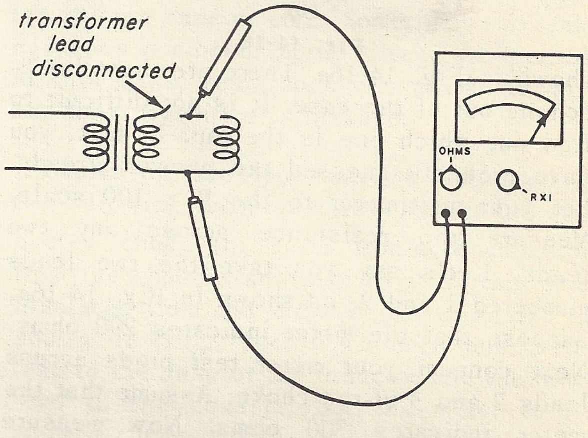
An output transformer has a high-impedance primary and a very-low-impedance secondary. The primary winding is connected to the audio-output tube in the receiver, and the secondary winding is connected to the voice coil of the loudspeaker, as shown in Fig. 14-19.

Usually the leads from transformers of this type are color-coded. The color code for transformers is given in Table B. If you have trouble telling the colors of the leads apart, try examining them in daylight. If the leads are color-coded, the identification is easy. Even if the leads are not color-coded, identification of the leads is not very hard. The audio-output transformers used in most broadcast receivers have secondary or voice-coil leads that are made of solid varnished wire; stranded cotton covered wire is used for the primary leads.



meter shows continuity through transformer secondary

(a)



meter now shows open in voice coil

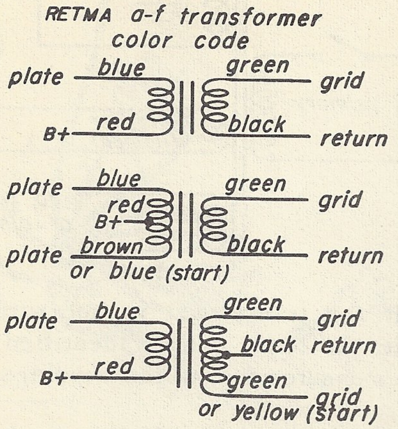
(b)

Fig. 14-18

However, suppose that the four leads coming out of the transformer are absolutely identical and that they have no color-coding whatsoever. All four leads then look exactly alike. You can still tell which winding is which quite easily. If the output transformer is correctly wired into place in a receiver, all you have to do is to look at the voice-coil terminals on the speaker; the leads connected across the voice coil are the secondary winding. The remaining leads are the primary leads.

Even if the transformer is not wired into

TABLE B



the receiver, you can identify the windings with the ohmmeter section of your multimeter. The process consists of three simple steps:

1. Pair off the leads. That is, find out which leads are the ends of the same winding. To do this, put your meter across any two of the leads. Note the reading. If you get a reading of infinite, these two leads are not a pair. If you get a reading showing continuity, then these two leads are a pair. Continue in this way until you have located two pairs of leads.

2. The higher resistance indicates the primary winding, and the lower resistance indicates the secondary winding. In broadcast receivers, the primary resistance of the output transformer will range from about 150 to 600 ohms. The secondary resistance will usually be less than an ohm, but it may run as high as four or five ohms. These are d-c resistances and not impedance values. The a-c impedance of these inductors is much higher.

3. If the primary of the transformer is center-tapped, as in push-pull amplifier circuits, the transformer will have five leads coming out of the case. The procedure for identifying the leads is the same. In this case, three leads will show continuity through the same winding. The way to find which lead is the center tap and which leads are the ends of the winding has already been described in connection with tapped field

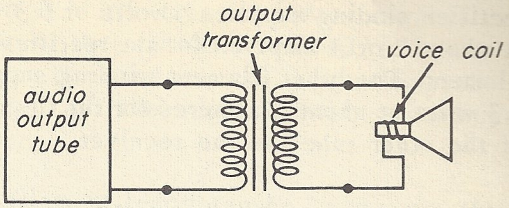


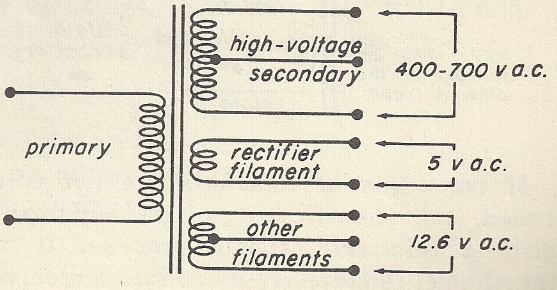
Fig. 14-19

14-8. POWER TRANSFORMERS

The major purpose of the power transformer is to supply the various operating voltages and currents needed by the receiver. It transforms the 110-volt a-c line voltage to a higher voltage at low current from which the plate voltage for the tubes in the receiver is obtained.

Power transformers may develop all of the defects that have already been described in connection with other iron-core inductors. The testing of power transformers is a little more difficult, however, because of the greater number of windings and the way the power transformer is tied in with the rest of the set. Let's discuss how to identify the windings of the power transformer and then consider the testing of the transformer. Because the power transformer is an expensive component, and because it is more apt to be damaged, the testing of the power transformer must be done very carefully.

As you have learned in previous lessons, the power transformer consists of a primary winding, to which the a-c line voltage is applied, and various secondary windings, as shown in Fig. 14-20. The high-voltage secondary winding is usually center-tapped and used to supply a high voltage necessary for the receiver's operation. The filament

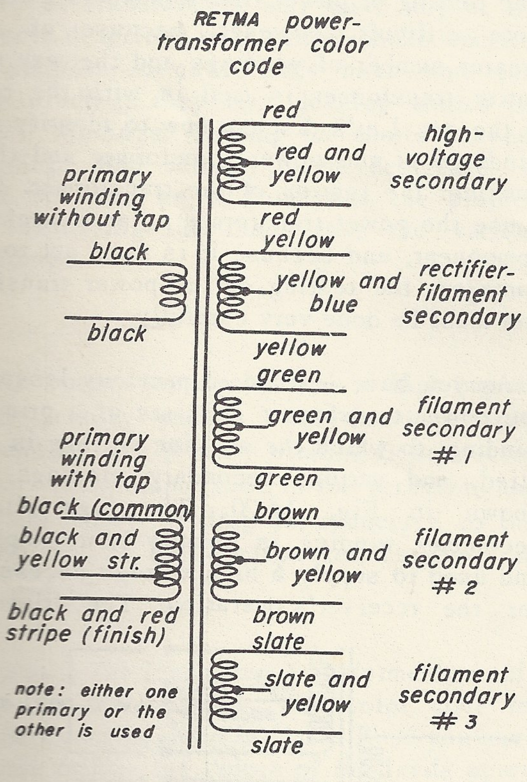


a typical power transformer

rectifier winding supplies 5 volts or 6.3 volts at about 2 or 3 amperes for the rectifier-tube filament. The other filament winding supplies 6.3 volts at about 2 amperes for the filaments of the other tubes in the receiver.

Identification of Windings. Connections to transformers may be made by means of leads which come out of the transformer, or by means of terminals on the transformer case. In order to test such a transformer or wire it into a circuit, you must know which leads or terminal lugs connect to the various windings. In modern equipment, transformer leads are color-coded, and terminal lugs are numbered and identified on the transformer case. If they are color-coded or numbered, the identification is easy. The standard color code is below in Table C.

TABLE C



If the leads or terminals are not color-coded, the identification of the windings is still a relatively simple process. If the transformer is correctly wired into a receiver, the various leads can be identified by circuit tracing; each of the windings is connected to a definite part of the circuit. The process will be explained later in this booklet. If the transformer is not wired into a circuit, the leads can be identified by resistance measurements of the windings.

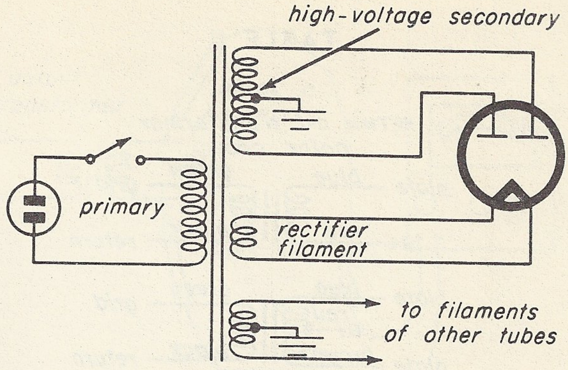


Fig. 14-21

The method of identifying the leads of a transformer that is wired into a receiver depends upon the following practices, which are illustrated in Fig. 14-21.

1. The primary of the power transformer is always connected to the a-c line through the on-off switch.

2. The high-voltage secondary winding is always connected to the two plates of the rectifier tube.

3. The center-tap of the high-voltage secondary is always connected to the chassis or to a common *bus*, or B- line.

4. The rectifier-filament windings are always connected to the filaments of tubes.

Examine the wiring diagram shown in Fig. 14-22. The transformer leads are numbered in the drawing from 1 to 9, but let us say that they are all the same color and we have to identify them. To locate the primary winding, start at the a-c plug and trace the line cord all the way into the receiver. One side of the line cord will go directly to one side of the primary winding, and the other side of the line cord will go through the on-off switch to the other side of the primary. If you start with the side of the line cord marked *A*, you will find that it goes to lead 1 of the transformer. If you follow the other side of the line cord, marked *B*, you will find that it goes to the line switch and from the line switch to terminal 2 of the transformer. Therefore, leads 1 and 2 are the primary winding of the transformer.

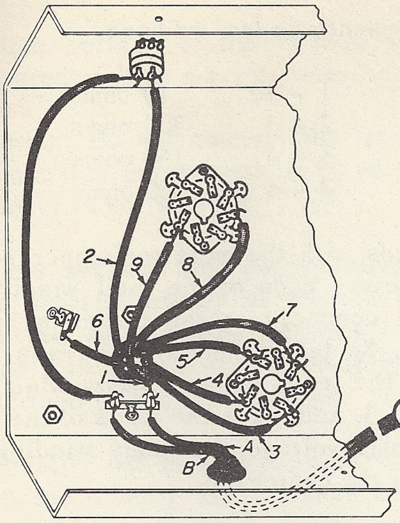


Fig. 14-22

Most of the remaining leads of the transformer are connected to the tube sockets. To trace the windings further, we must find out which is the rectifier tube and which terminals on the rectifier-tube socket are the plate terminals and the filament terminals. The rectifier tube socket is the socket to which most of the transformer leads are connected. The plate terminals are found by looking up that tube in a tube manual. For instance, a typical rectifier tube used in broadcast receivers is the 5Y3GT. If you look up this tube in the tube manual, you will find (Fig. 14-23) that the plate terminals are pins 4 and 6 and the filament terminals are pins 2 and 8. To find the high-voltage secondary, trace from pins 4 and 6 back into the transformer. You will find that pin 4 is connected to lead 4 of the transformer, and pin 6 of the tube socket is connect to lead 5 of the transformer. Lead 6 is connected to the chassis, and is, therefore, the center-tap of the high voltage secondary winding.

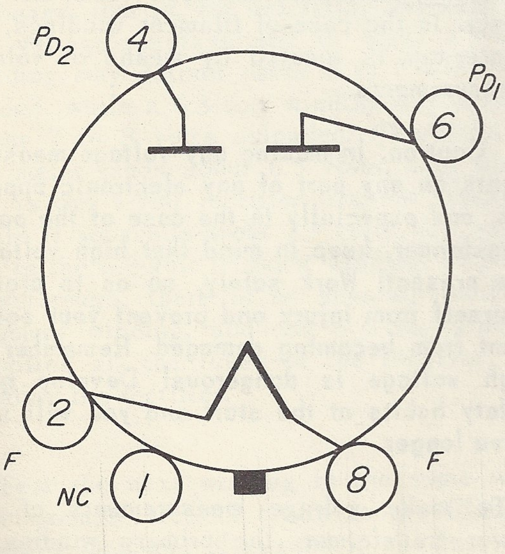


Fig. 14-23

The filament leads can be located in the same way. Tracing back from pins 2 and 8 of the tube socket, you will see that they connect to leads 3 and 7 of the transformer. These are the rectifier filament leads. The remaining two leads, 8 and 9, are the leads of the other filament winding. Thus, we have completely identified the leads of the transformer by circuit tracing.

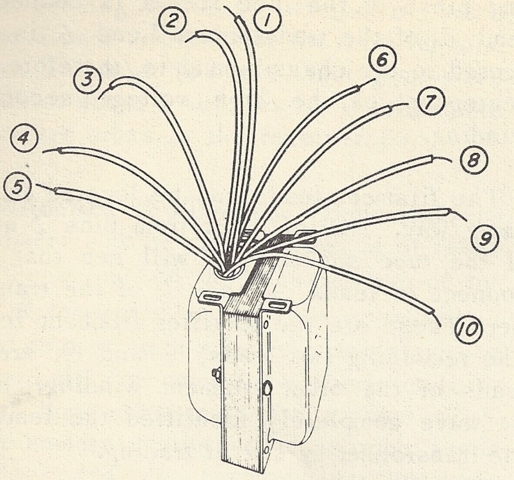
Now let us imagine that we have a transformer that is neither wired into the circuit nor color-coded. The windings of this transformer can be identified by a few simple resistance and voltage measurements. Although such an unmarked and uncoded transformer is rarely found nowadays, learning how to identify the windings through resistance and voltage measurements will be a good review of your knowledge of transformer principles. The process of identification consists of three simple steps:

1. Pair off the windings by continuity measurements.

2. Note the resistance of each winding. The winding with the highest resistance — about 200 to 400 ohms — is the secondary high-voltage winding. The winding with the next lowest resistance — about 5 to 15 ohms — is the primary winding. The windings with the lowest resistance — about one ohm or less — are the secondary filament windings. You can tell the various secondaries apart by voltage measurements.

3. Take voltage measurements of the various secondary windings to identify the filament windings.

The process of pairing off the leads has already been described in the section on the audio-output transformer. Exactly the same method is used here, except that there are more leads to work with. The transformer



power transformer with plain leads

Fig. 14-24

appears as shown in Fig. 14-24. Let's put some numbers on the various leads so that we can talk about them. Connect one test prod from your ohmmeter to any lead, say 1. Then touch the other test prod to each of the other leads in turn and look at your meter to see if it indicates continuity. Let us say that continuity is shown by the ohmmeter when the other test lead is connected to lead 10 of the transformer. This tells you that leads 1 and 10 are a pair; that is, they are the ends of the same winding. At the same time that you are seeing if the meter shows continuity, note the resistance of that winding. Suppose that the resistance of the winding between leads 1 and 10 is 10 ohms. Make a note of this, in this way:

1 – 10	10 ohms

Now continue to pair off the remaining leads. Suppose that we connect one test prod of our meter to lead 2 and touch the other test prod of the meter to all the other leads while observing the meter for a continuity indication. Let us say that the meter now shows continuity to more than one lead; that is, to leads 3 and 4. This tells us that the winding is center-tapped. Which lead is the center-tap? That should be easy to discover by this time. Let's say that the resistance between 2 and 3 is 300 ohms, the resistance between 3 and 4 is 150 ohms, and the resistance between 2 and 4 is 150 ohms. Making a note of all our measurements so far, we have

1 – 10	10 ohms
2 – 3	300 ohms
3 – 4	150 ohms
2 – 4	150 ohms

The leads with the most resistance between them are the ends of the total winding, and lead 4 connects to the center-tap of this winding. So far, we know that leads 1 and 10 are the leads of the primary winding and leads 2, 3, and 4 are the leads of the center-tapped high-voltage secondary winding, with 4 being the center-tap.

By continuing the pairing off process, let us say that we find 5 and 6 to be a pair, and that the resistance between them is less than one ohm. This tells us that we have found a filament winding. We will find out just which filament winding it is when we measure its output voltage.

Check the remaining leads. Let's say that you find continuity between leads 7, 8, and 9. This shows a center-tapped winding. The resistance is less than an ohm, so you know that it is a filament winding. But if you try to identify the center-tap by resistance measurements, you will find that you cannot measure any difference in resistance between the various leads. That is, the resistance between 7 and 8, 8 and 9, and 7 and 9 is much less than one ohm, and you cannot see any difference between them on your meter. In the case of filament windings, the center-tap is located by means of voltage measurements.

Caution: In making any voltage measurements on any part of any electronic apparatus, and especially in the case of the power transformer, keep in mind that high voltages are present! Work safely, so as to protect yourself from injury and prevent your equipment from becoming damaged. Remember — high voltage is dangerous! Develop good safety habits at the start and you will stay alive longer.

To make voltage measurements of the power transformer, the primary winding is connected to the 100-volt a-c supply, and the output voltage of the various windings is measured with an a-c voltmeter.

Caution: Do not connect the transformer to the a-c line unless you are sure that the transformer is not shorted.

If you suspect that the transformer may have a shorted primary or shorted turns in any of the secondaries, connect it to the a-c supply in series with a protective lamp, as described in the next section.

To identify the various filament windings, connect the primary winding (and be sure it *is* the primary winding) to the a-c line. Make sure that none of the leads are shorting to each other. Set up your multimeter to read a-c volts and set it to the highest a-c voltage scale. This is just in case you have made an error and the winding that you think is the filament winding turns out to be the high-voltage winding. Touch one of the test prods of the meter firmly on one of the leads of the winding and hold it in place. Take the other test prod of the meter and lightly brush the other lead of the winding while watching the meter. If this is the filament winding, the meter will just barely move on the highest scale. Turn the range switch to the next lower a-c volt position and brush the lead of the winding again. Repeat this operation until you have determined the proper scale on which to take your reading. Read the voltage indicated by the meter. Since the windings are completely *unloaded*, that is, not delivering any current, the voltage readings will be high. A 5-volt winding may deliver about 6 or 7 volts unloaded, while a 6.3-volt winding may deliver about 7 to 8 volts unloaded. Therefore, if the meter reads about 6.5 volts, this winding is the 5-volt rectifier filament winding, while if its reads about 7.5 volts, this winding is the 6.3-volt filament winding. In some transformers, there is no separate rectifier filament winding, and one 6.3-volt winding supplies all the tubes of the receiver, including the rectifier.

Test the next winding in the same way. For example, let us return to the filament winding that was discussed in the last section. The leads of this filament winding were 7, 8, and 9. To find the center-tap, measure the voltage between each pair of leads. Let us say that you measure 12.6 volts between 7 and 8, 6.3 volts between 7 and 9, and between 8 and 9 you measure 6.3 volts. The leads between which the highest voltage is measured are the ends of the winding, and the remaining leads is the center-tap.

Testing the Power Transformer. You have studied the kind of defects that a power transformer may have, how to identify its windings, and how to test the power transformer for some of these defects with resistance measurements. However, some defects cannot be detected in this way. For instance, shorted turns usually cannot be detected by resistance measurements. The normal resistance of a secondary winding is less than one ohm, and, if a short occurs, the difference in resistance cannot be measured on the average service-type ohmmeter. If the normal resistance of the primary of a transformer is 15 ohms, a partial short may reduce the resistance of the primary winding to 12 ohms or 10 ohms. This is entirely within the normal range of primary resistance. However, even a few shorted turns are more serious than the slight change in resistance indicates. Just a few shorted turns in the primary or any secondary winding will cause the transformer to draw a considerable current overload which will quickly damage the insulation or even burn out a winding. If a power transformer with shorted windings is connected to the a-c line, the fuse may blow in time to prevent damage to the transformer; but this does not happen often, as the line fuse is usually rated at 15 amperes or more.

Short Tester. A short tester is a simple protective and testing device that will prevent the line fuse from blowing, protect the transformer, and, at the same time, indicate the presence of shorted windings. The wiring diagram of the short indicator is shown in Fig. 14-25. A 40- or 50-watt incandescent lamp is placed in series with the primary of the transformer. Current drawn by the receiver, which is plugged into the socket, must flow through the lamp. The principle of this tester is that if the transformer is not shorted, and the receiver is drawing the normal amount of current, the

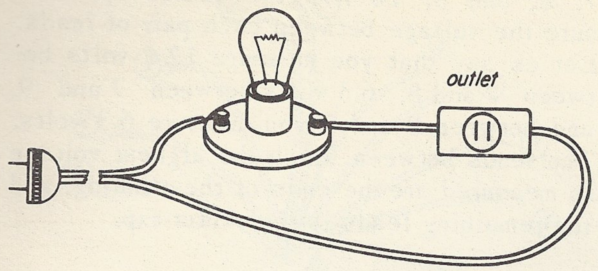


Fig. 14-25

current flowing through the lamp will not light it to anywhere near its normal brillance. However, if the transformer has any shorted windings, or if there is a short in the receiver, the lamp will light up to almost its full brilliance, depending upon how much of a short there is. Since the lamp limits the current, no damage can occur to the receiver and the line fuse will not blow.

To use the tester, plug the receiver into the a-c test socket. By throwing the switch so as to short out the a-c test socket, the full line voltage is applied to the lamp, and you can see how bright the lamp is at full voltage. When the switch is thrown back, the current is reduced because the lamp and the receiver are in series, and you can note the difference in brilliance. If you construct such a tester, use it first on a number of operating receivers so that you get a mental picture of how bright the lamp should be. The lamp will be brighter if more tubes are in the receiver. The average five-or six tube receiver should make a 50-watt lamp just glow red. For use in testing a television receiver, or any other appliance drawing more than about 200 watts, a 100-watt lamp should be used in the tester.

The brightness of the test lamp gives a rough indication of the amount of current flowing through the appliance. However, this is not the normal current that flows into the appliance during operation because the series lamp is reducing the voltage applied to the receiver to a point below normal. For this reason, the receiver may not operate when it is in series with the test lamp.

It is possible to make a more elaborate tester to measure the amount of power in watts being consumed by the device. The measured wattage can be compared with the value given in the manufacturer's data. If the discrepancy is much more than 20%, the receiver should be checked for a possible short. This simple wattmeter is made by adding two resistors, another a-c receptacle, and a switch, as shown in Fig. 14-26. To use this tester, the appliance is plugged into the receptacle marked watts, the meter is set to read a-c volts, and the meter leads are inserted into the pin jacks to read the voltage across one of the resistors. The resistor values have been calculated so that if the line voltage is 115 volts, the wattage on the HI scale can be found by multiplying the meter reading by 100. On the LO scale, the wattage is obtained by multiplying the meter reading by 10.

If the line voltage is very different, or if other resistors are used, the wattage can be obtained from this simple formula; the results are approximate:

$$P = \frac{e\,E}{r}$$

where: P = the power consumed in watts

e = the voltage across the resistor, in volts

E = the line voltage in volts

r = the value of the resistor in ohms.

The LO switch setting should not be used unless the voltage obtained on the HI setting is too low to be read on the a-c meter.

Caution: In using this tester, test the receiver for shorts in the shorts-test socket first. Do not plug the receiver in the watts socket if the test lamp shows a short.

The maximum range of this simple wattmeter is about 200 watts; therefore, it will handle most TV sets. Its accuracy is about ±10%. If you do not have manufacturers data, use Table *D* as a rough guide to wattage consumption of typical receivers.

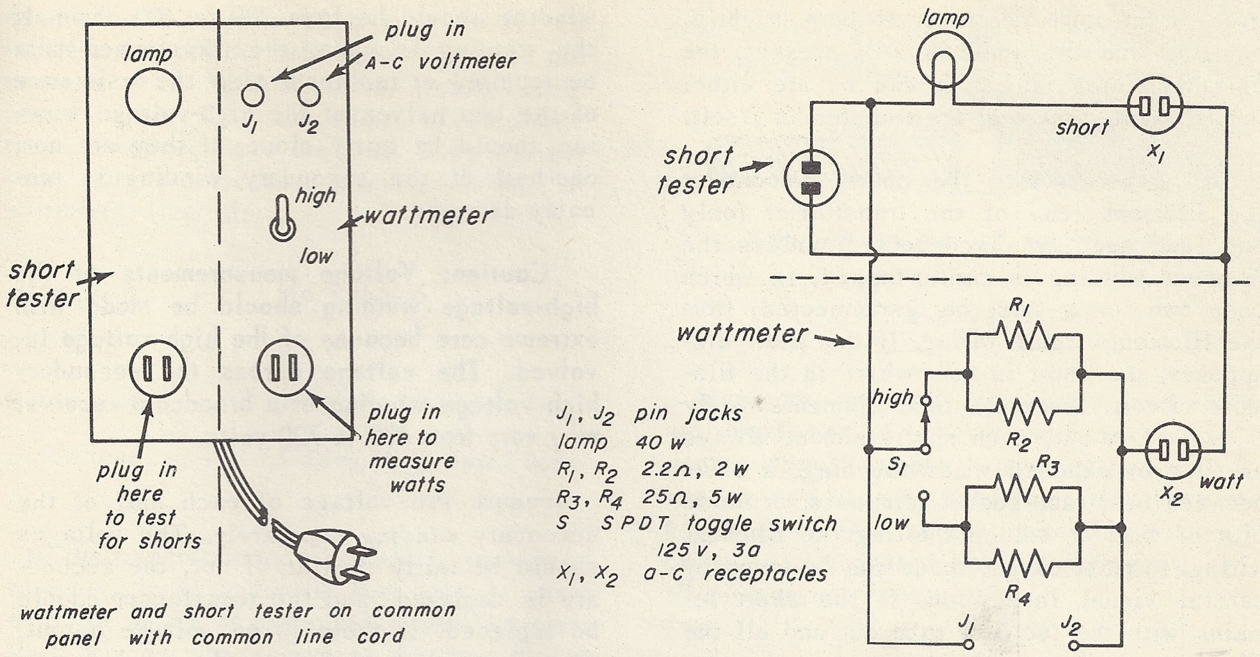


Fig. 14-26

TABLE D – WATTAGE CONSUMPTION

Set or Accessory	Watts Consumed
AC-DC battery portables	10 to 20
Average 5-or 6-tube receiver	30 to 40
Receiver with push-pull audio amplifier	50 to 100
AM-FM receiver (8 tubes)	70 to 80
High-fidelity receivers	70 to 150
Phonograph-turntable attachment	add 15
Clock (in clock radios)	add 2

The wattage measured may disagree with the manufacturer's data by as much as 20%. If the difference is greater than this, the receiver should be examined further.

Shorts in the Receiver. If a receiver is plugged into the short tester and the test lamp burns at full brilliance, showing that there is a short, the location of the short must be found. The short may be:

1. In the transformer
2. In the rectifier tube
3. In some other part of the receiver
4. In the filament circuit of the receiver

The relationship between the power transformer and the rest of the receiver is shown in block-diagram form in Fig. 14-27. If there is a short in the rectifier tube, this short will cause the primary of the power transformer to draw excess current and show a short on the test lamp. If there is a short in some other part of the receiver, that short will cause an increase in load on the primary of the power transformer. Thus, the first step in locating the location of the short is to remove the rectifier tube from its socket while keeping the receiver plugged into the short tester. This separates the rest of the receiver from the power transformer, except for the filament circuit. If the test lamp now burns at a low brilliance, showing that the short is no longer present, the short is either in the rectifier tube or the rest of the receiver. Further troubleshooting of the short is covered in later parts of the course. How-

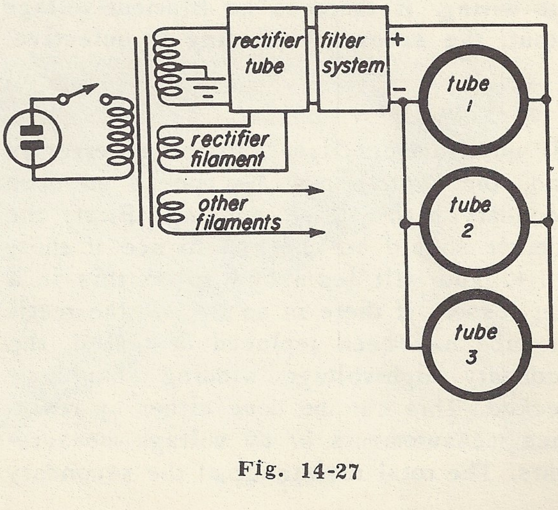


Fig. 14-27

ever, if the lamp continues to burn brightly, showing that the short is still present, the only remaining places it can be are either the filament circuit or the transformer itself.

To further isolate the short, disconnect the filament lead of the transformer (only one lead need be disconnected, unless the filament winding is center-tapped, in which case two leads must be disconnected) from the filament-circuit wiring. If the short disappears, the short is somewhere in the filament circuit. Since the tube filaments rarely if ever *short* out, such shorts almost always are due to exposed wires touching, a short between bent tube-socket terminals, or loose bits of wire or solder shorting the filament wiring. In most cases, these can be found by careful visual inspection. If the short remains with the rectifier tube out and all the filament windings disconnected, only one possible place for the location of the short remains – the transformer itself. In most cases, the transformer cannot be economically repaired and should be replaced.

Open Windings in the Transformer. If the receiver is connected to the a-c supply and the tubes do not light, the trouble may be in the transformer. However, the line cord, the a-c switch, and the wiring to the transformer should be checked first. If a resistance check of the primary shows that it is not open, the voltage output of the filament windings should be checked. To do this, set your meter to read a-c volts and set the line switch to a 15-volt or higher range. If the winding delivers the proper voltage output, there is an open circuit in the filament-circuit wiring. If there is no filament-voltage output, the secondary winding is defective.

If no filaments light and the receiver is dead, the trouble may be due to an open secondary high-voltage winding. First, the receiver should be checked to see if there is B+. You will learn how to do this in a later lesson. If there is no B+ and the rectifier tube has been replaced or tested, the secondary high-voltage winding should be checked. This can be done either by resistance measurements or by voltage measurements. The total resistance of the secondary winding should be from 200 to 400 ohms. If the winding is open, the transformer must be repaired or replaced. Also, the resistance of the two halves of the high-voltage winding should be fairly close. If they are not, one-half of the secondary winding is probably damaged.

Caution: Voltage measurements of the high-voltage winding should be made with extreme care because of the high-voltage involved. The voltage across the secondary high-voltage winding of a broadcast receiver may vary from 400 to 700 volts.

Measure the voltage of each half of the secondary *winding separately.* The voltages should be fairly similar; if not, the secondary is damaged, and the transformer should be replaced. If there is no voltage output, there is an open winding. If the break cannot be repaired, the transformer must be replaced.

14-9. REPLACEMENT OF INDUCTORS

The correct inductor for replacement purposes usually can be found by referring to the manufacturer's service data for the receiver. If you do not have this data, your parts-supply house may be able to look up the correct replacement for you. If you cannot locate such data, you can still figure out a suitable replacement by taking into account what the inductor must do, the current it must carry, the required voltage output, the frequency at which the inductor operates, and the necessary d-c resistance and a-c impedance. Also, the replacement inductor should fit in the available space and in the same mounting holes, if possible. Choosing a replacement inductor to fit these requirements will be discussed later in this course, when the various sections of the receiver are studied in detail. In most cases, however, you will be able to look up the correct replacement, which may be either an inductor made by the same manufacturer or an equivalent made by a replacement-parts manufacturer.

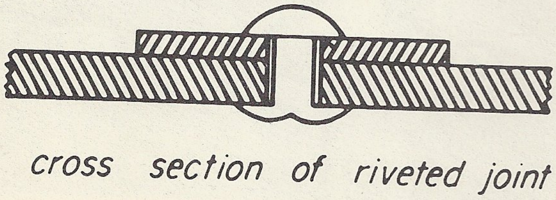
Don't rely on your memory to connect the new inductor back into the circuit correctly. That is a dangerous practice. Before removing the inductor, make a sketch showing the connections. Identify each tube socket by labelling it with the tube number and the pin numbers of the tube socket or terminal strip that is used. Show the colors of the leads that are connected to the pins. When you become more experienced, a few notes may be sufficient, like this:

Blue lead	–	pin 5, 6AU6
Red lead	–	pin 6
Green lead	–	pin 6, 6AT6
Black lead	–	3rd lug on terminal strip

If the transformer or other leads are twisted together, it is important that this be done with the leads of the replacement inductor. Mark this on your sketch so that you do not forget. Also, run the leads in about the same way on the chassis as the leads of the old inductor. If the old transformer is not color-coded, identify each of the leads, as previously explained, before disconnecting them. Then mark your sketch in accordance with the standard color-code for the inductor you are replacing. Then you will be able to install the new transformer quickly and correctly.

After you have made a sketch that contains the information necessary to help you reconnect the replacement inductor correctly, you can unsolder all the leads of the old transformer. After unsoldering all the connections, you are ready to unfasten the inductor.

Removing Inductors. Large inductors, such as power transformers, are usually held in place with bolts and nuts. Smaller inductors may be held in place with bolts and nuts, rivets, or special spring-clip fastening arrangements.



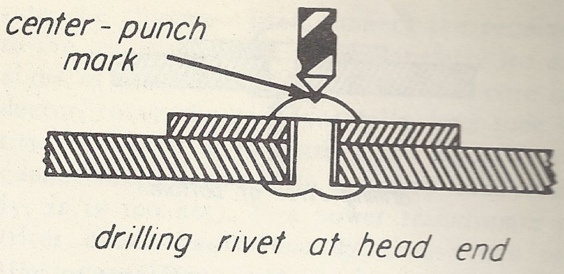
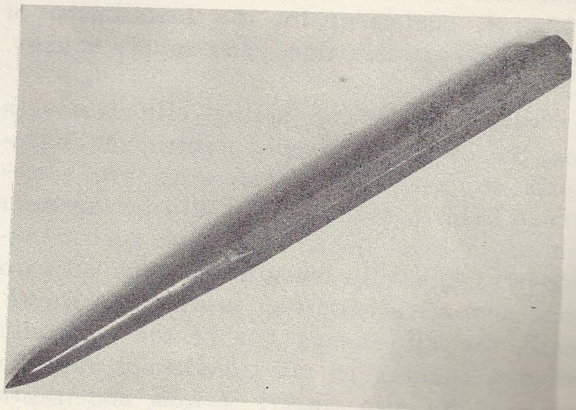


Fig. 14-29

Inductors mounted with bolts and nuts are most easily removed with the correct socket wrench, although an open end or box wrench may also be used. You may have to keep the bolt from turning by holding a screwdriver in the slotted head of the screw until the nuts are loosened.

A cross section of a typical riveted joint is shown in Fig. 14-28. Rivets may be either drilled out or sheared off with a cold chisel. If the rivet must be drilled out from the smooth side, as shown in Fig. 14-29, a center-punch mark must first be made in the center of the rivet head; otherwise the drill will wander all over the chassis. A typical center punch is shown in Fig. 14-30. To center-punch the rivet, place the point of the center punch in the center of the rivet, holding it straight up. Tap the head of the center punch lightly with a small hammer. Check to see that the small punch mark is in the center of the of the rivet head. If not, try again. If it is centered, replace the point of the punch in the punch mark and strike the center punch



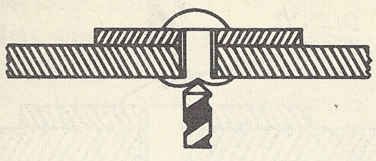


Fig. 14-31

again until an indentation sufficient to hold the point of the drill is made. Using Fig. 14-28 as a guide, estimate the size of drill that will just cut away the metal of the rivet next to the hole in the chassis and drill into the rivet. Usually a drill with a diameter of one-half the rivet head is the proper drill to use. An electric drill or a hand drill may be used. It is not necessary to drill clear through the rivet. If sufficient metal is removed from the head of the rivet, it will fall off or be weakened so that it can be easily removed.

Caution: If drilling from the top of the chassis, examine the wiring and parts underneath the chassis near the rivet. Temporarily move out of the way any part that may be damaged if the drill goes through the chassis. If possible, control the drill so that it does not go all the way through down into the chassis wiring.

If the drilling can be done from the side of the rivet that has the depression in it, as shown in Fig. 14-31, center-punching is not necessary; the depression in the rivet will hold the drill in place until the hole is started.

The replacement inductor is most easily installed with machine screws and nuts. although equipment for the installation of rivets is available from parts-supply houses.

Various types of spring clip fasteners may be employed to hold lightweight inductors. Miniature i-f transformers are sometimes held in place by the clip arrangement shown in Fig. 14-32. To remove such transformers, the clip should be bent outward with a small screwdriver inserted as shown until the clip snaps out of the specially shaped opening in the transformer can. To replace the clip, insert it from underneath the chassis through the slots and press it

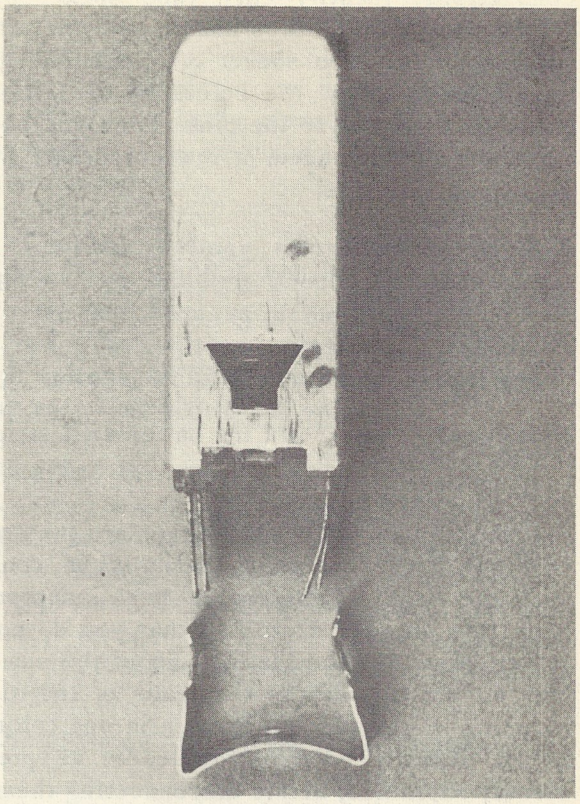


Fig. 14-32

into place into the holes in the transformer can.

The spring-clip fasteners shown in Fig. 14-33 are found on many loopsticks, oscillator and antenna coils, and many types of coils used in television receivers. To re-

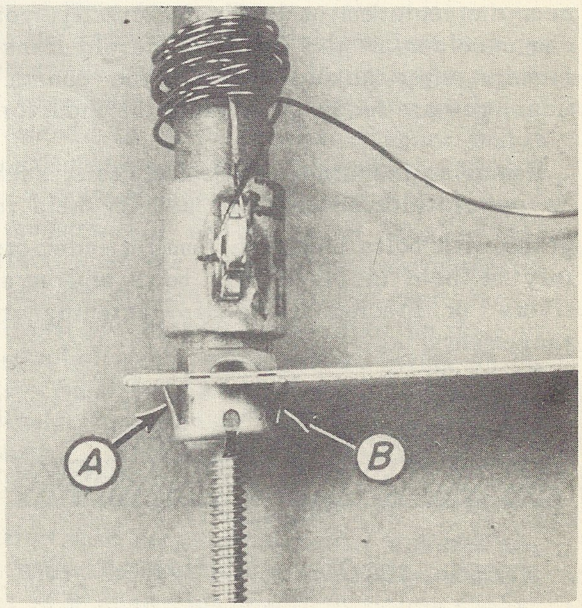


Fig. 14-33