SHOP WORK BENCH FOR RADIO AND TELEVISION REPAIRS

LESSON TV-1

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

YOU MUST KNOW BOTH RADIO AND TELEVISION

With this lesson you start a specialized study of Radio and Television repair methods. As you are probably well aware by now, television is nothing more than advance applications of well known radio and electronic principles. Thus, it is impossible for you to be a television expert without at the same time also being a radio expert.

The two fields are, therefore, intimately tied together and you will of necessity find yourself doing work in both radio and television—in fact, we accept the responsibility of preparing you to handle either type of work. You will, therefore, be capable of handling any type of electronic repair or installation job that is brought to you.

Because of this close interrelationship, we start you off in this special study first in basic components which are common to both radio and television. Then when you have a thorough mastery of the testing and replacement of defective parts and circuits you advanced into the more complex television work with the assurance of thorough preparation.

This lesson will give you many ideas about setting-up your own workbench—either in your own home or in your own private workshop. You will see that it includes facilities for handling all kinds of radio receivers and, of course, all of this basic material applies to television and FM receivers just as it does to the ordinary AM receiver.

So for the next few lessons in this series you will study the testing and replacement of basic component parts as well as the adjustment of tuned circuits. In studying this series of lessons, keep in mind that the information given applies to all types of receivers (including FM and television). Thus, when the word receiver is used, remember it is a broad term covering all of the well known receiver types in general use.

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This is a good example of a well lighted neatly arranged bench. A bank of overhead fluorescent lamps provide adequate light. The test instruments are both portable and fixed mounted. Power outlets are provided along the front edge of the bench. Note the cabinet racks to the right and shelves for spare parts. It is recommended that you study this layout and the others in this lesson because they show practical bench arrangements which you can probably put to good use. Courtesy of Sylvania.

Shop Work Bench for Radio and Television Repairs

Lesson TV-1

This lesson is the first in a special series relating to Radio and Television repair methods. It is designed to emphasize the practical side of repairing all kinds of radio and television equipment. While it is intended to specifically apply to radio and television receivers of all kinds, the information given need not be limited in its application to receivers and amplifiers alone. Most of the testing and repair information will apply equally as well to transmitters and to all other kinds or types of electrical equipment since all of this equipment operates on the same basic laws and makes use of the same basic materials. So as you make progress with this special set of lessons try to keep the fundamental purpose of this special course in mind.

This lesson has as its subject "Your Shop Work Bench." Limited information on this general subject is given in one of your Business Builders. This lesson, however, will go into detail and will describe a permanent set-up which you will eventually need in one form or another. In writing this lesson, we have to consider all of the possibilities but this does not necessarily mean that you have to include everything we mention. For instance, if you live in a large city, you need not be concerned with a 32 volt power supply at your work bench; and on the other hand, if you live in a town which is supplied entirely with 60 cycle AC current, you need not be concerned with a 110 volt DC line for your work bench. So you should use the ideas presented in this lesson only when they will meet your local conditions.

Also in studying this lesson, you may think of an improvement which will fit in better with your individual set-up. If so, don't hesitate to make improvements or changes. This lesson is merely a guide, and you should make every change or improvement which will contribute to your convenience and efficiency.

Your work bench is comparable to the manufacturer's tools, machinery, and other facilities. It is the vehicle by which you make your living. So it should be designed for convenience and high efficiency. Your work bench and its panel can be a highly complex electrical gadget—just as you care to make it. However, it ought not to be so complex that you or your hired help cannot make quick efficient use of it. So good practical judgment should be exercised in its design. This electrical system of your work bench can also be expensive and in laying out your system, total overall cost should be kept in mind. If a certain unit will increase your efficiency or make for convenience in getting out a job quick, then that unit will probably be well worth any reasonable amount you put into it.

The Electrical System of Your Work Bench

We shall describe an electrical system for a typical work bench. This will be done without regard to the physical size and form of the bench. It will then be up to you to fit these ideas to your particular bench with due consideration to any special conditions which may be present.

AUTOMOBILE RECEIVER POWER SOURCES: There are several methods employed at the work bench to operate automobile type receivers direct from the AC power line. These include the use of lamps in series with one side of the power line, direct operation from a battery charger, and operation from the so called "A" eliminators. While a type of operation is possible from all of these methods, they all provide high AC hum levels and none of these methods

This work bench layout belongs to a Sprayberry graduate. The picture was made before he graduated and before a main test panel was constructed. In this layout a flat top work bench is used with a shelf built at the rear for holding instruments in view while repair work is being done at the bench. Many radio repairmen start out in this way and over a period of months gradually build up their bench test panel as experience and time prove the need for certain items.

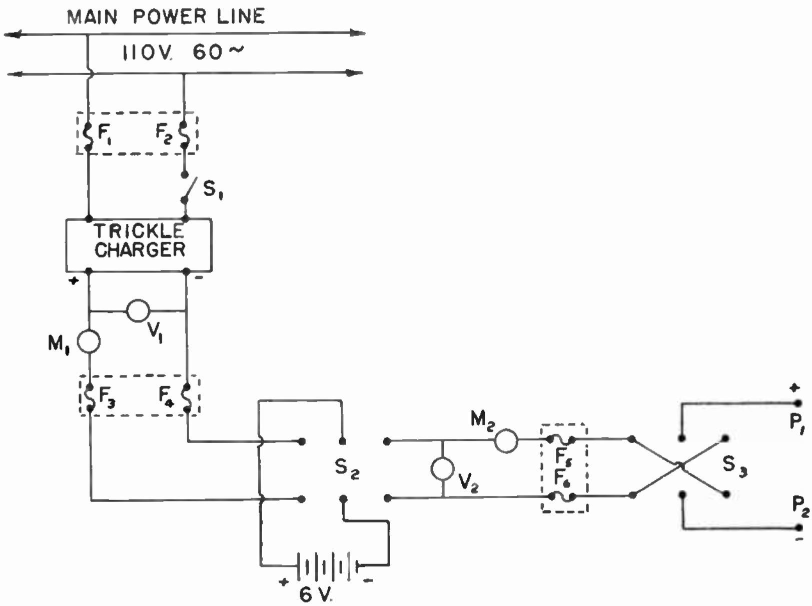


FIG. 1

simulate actual operating conditions. Thus, we don't recommend them. Besides the automobile type receiver, there are many farm type receivers which obtain all their operating power direct from a 6-8 volt storage battery wherein a vibrator is used as in an automobile receiver. Thus, for these two types of receivers, a good dependable source of power (6-8 volts) is required at the work bench. There is nothing better for this than a good high ampere-hour storage battery. By use of such a battery, actual operating conditions for the receiver under test can be duplicated. For this requirement, we recommend the circuit of Fig. 1. Its two main items are a trickle charger and a 6-8 volt storage battery. It is properly fused and metered with necessary polarity changing facilities. Note it is connected to two wires which should be a separate 110 volt line to your work bench—that is, a line to which there will be no connections of receivers under test nor should AC test equipment be connected to this line. Separate branch circuits should be used for these other things as will be explained later on.

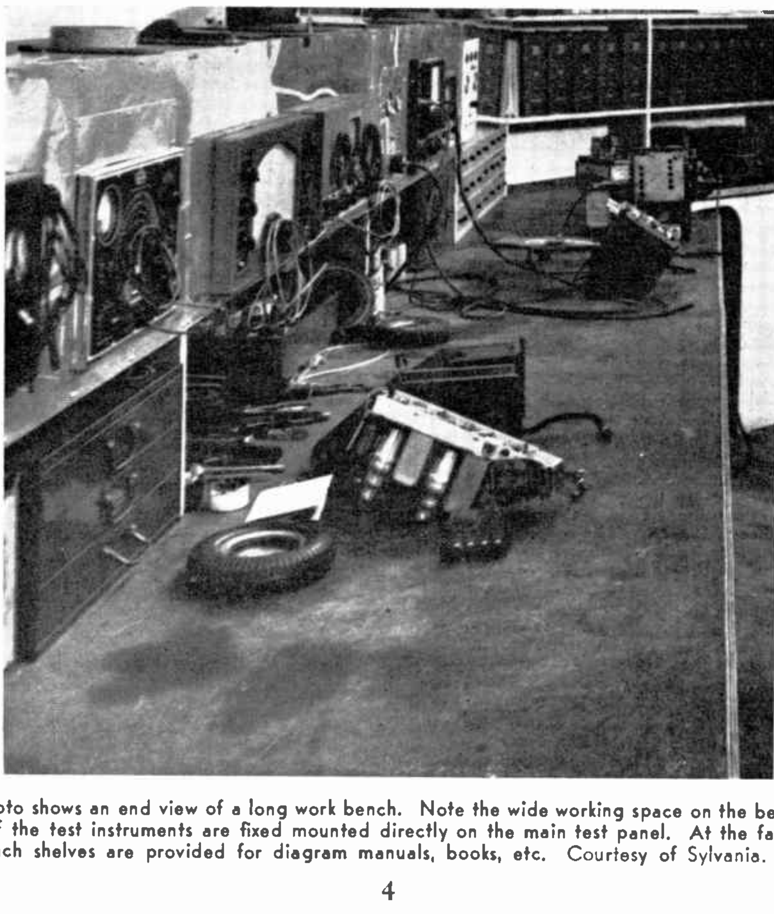
The two fuses F1 and F2 are standard screw type fuses (15-25 amperes). A metal box with hinged cover can be obtained from any electrical supply firm to hold these fuses. Such a box will contain the fuse holders and may also contain switch S1 or if you prefer switch S1 may be contained in a separate switch box with a red pilot light to indicate when the charger is turned on. The General Electric part number for this type of switch with pilot light is GX3A1 and the switch box cover number is GE2735. The entire assembly will fit in any standard metal switch or outlet box. The pilot light bulb number is S-6. Any G. E. supply house can supply these items as they are standard.

The capacity or output of the trickle charger will depend on how often you use the storage battery. For average use, the charger need not be rated in excess of .25 ampere. A copper-oxide type of charger is generally satisfactory; but if you require a charging rate in excess of 1 ampere, a tungar bulb type of charger might be more satisfactory.

At the output of the charger, Figure 1 meters V1 and M1 are shown. These are not essential but may be used if desired. Meter V1 could be on 0-10 magnetic vane type voltmeter and M1 may be the automobile type ammeter (range of about 0-30 or less). The virtue of these meters is that they indicate the charger output voltage and the rate at which the battery is being charged.

Fuses F3, F4, F5, and F6 in Fig. 1 may be standard automobile cartridge type fuses rated at about 5 to 10 amperes. Switch S2 is a double-pole, double-throw knife type switch. When it is turned to the left, the charger may charge the battery; and when it is turned to the right, the battery may supply power to the receiver under test on your work bench.

Meters V2 and M2 are very desirable. V2 indicates the storage battery voltage while M2 indicates the amount of current drawn by the auto receiver under test. These meters may be of the cheaper magnetic vane type if desired although there is no reason why V1, M1, V2 and M2 could not be



This photo shows an end view of a long work bench. Note the wide working space on the bench top. Most of the test instruments are fixed mounted directly on the main test panel. At the far end of the bench shelves are provided for diagram manuals, books, etc. Courtesy of Sylvania.

This view shows a bench arranged for two workers. There are three sets of drawers below the level of the bench top—one at each end and one in the center. Note how neatly the test instruments are fixed mounted on the main panel. Two men on a panel such as this can turn out a large volume of work in a day. In the foreground is a counter on which merchandise can be placed and it serves as well to keep the public away from the work bench. Courtesy of Sylvania.

moving coil type meters. Many old obsolete testers contain meters which may be adapted for the functions of meters V1, M1, V2 and M2. If such meters are available to you, you can very probably adapt them for your need by using suitable multiplier resistors. Use a series resistor for a voltmeter and a shunt resistor for an ammeter or milliammeter.

Switch S3 in Fig. 1 is very convenient for it will enable you to reverse the polarity of your storage battery quickly. Some auto receivers may have the positive grounded and others will have the negative grounded. The connection of the vibrator usually determines which polarity is grounded. You will receive more information on this subject in your lesson on automobile type receivers. Regardless of which polarity is grounded, switch S3 will correct the condition if it needs correcting. Like S2, it is a knife type double-pole, double-throw switch. As viewed in Fig. 1, the switch handle would normally be turned to the left which would make P1 positive and P2 negative. If a reversal of polarity should be needed, the handle of S3 would be turned to the right which would make P1 negative and P2 positive.

P1 and P2 may be small tip jacks into which connecting leads may be plugged or they may be binding posts, depending on your preference. Perhaps binding posts are best for the connections must carry considerable current (0-5 or more amperes). The connecting leads between P1 and P2 and the receiver under test must be tight at all times. Binding posts will carry more current than the average small tip jacks and as a rule a binding post keeps a firm contact all of the time. For these reasons binding posts are most often used where heavy currents are involved.

Next you will need to consider the actual layout of the parts which make up your auto power supply circuit. We suggest that you make use of a sectional panel on your work bench for this purpose. This panel may be made from any good insulating material such as hard rubber, bakelite, masonite, veneer wood panel, etc. On this panel should be mounted all fuses, meters, switches, and the two connectors P1 and P2. The trickle charger and storage battery should be mounted underneath your work bench with connecting leads running up to the panel location. Since the entire circuit must carry heavy values of current, the use of heavy solid wire is suggested—No. 14 or larger. No exact panel size and layout will be given because of variation in individual requirements. One good plan to follow is to first obtain all of the parts you will require for the construction of the panel. Next layout these parts on a flat surface such as your work bench top. This will give you a good idea of the amount of space they will occupy. Move the parts about on the flat surface until you get them in the positions most convenient and pleasing to you. When you have made your final decisions on the mounting positions of the parts, make a rough drawing of them. Then layout these mounting positions on the panel you have chosen. Get the position of each part exactly indicated on your panel before boring holes, making cut outs, etc. By being careful and sure in this way, you are not likely to ruin your panel. By following the foregoing general information, you should be able to layout and mount your auto power supply test panel without trouble.

The AC Power Supply Circuit

For best results, two different AC power lines are required for the work bench. One should be a voltage regulated line and the second should be a preliminary line used when first applying power to a receiver in doubtful condition. First the regulated line will be described. One of the most useful and important accessories for your work bench is a regulator for line voltage. With this, you are assured of a constant line voltage for your test instruments and for the receivers on which you may be working. This is particularly important in localities where the line voltage varies over wide values. Figure 2 shows a very satisfactory circuit for this purpose.

In the main, it consists of a special

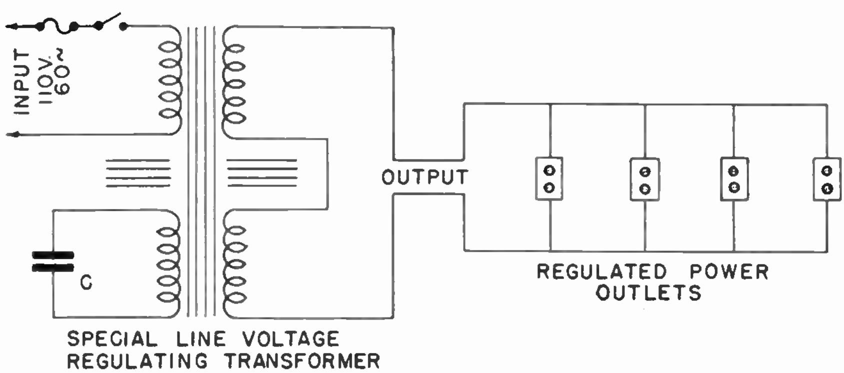


FIG. 2

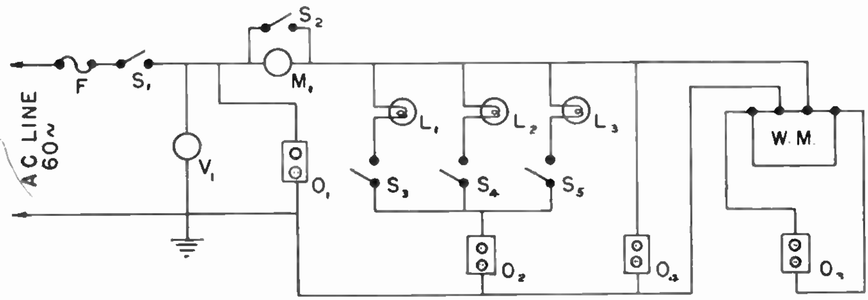


FIG. 3

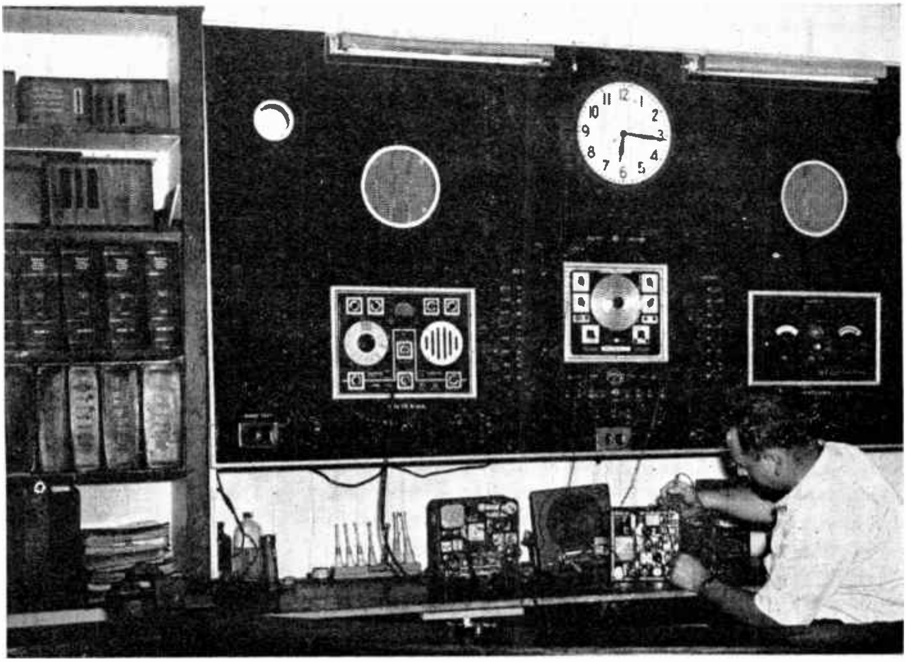
regulator transformer (such as those made by Solar and Raytheon) which keeps the output voltage constant in value regardless of the load (within the transformer rating). These transformers are available in several sizes—depending on the load requirements. For the average work bench, a regulator transformer rated at 200 watts will be entirely satisfactory because only one radio receiver is likely to be connected to the line at a time and most receivers on which you will be working will be rated at less than 100 watts. This will permit the operation of the receiver under repair as well as the usual AC operated test equipment such as the signal generator, tube tester, multimeter, etc. Where the line voltage does not vary over wide limits in a 24 hour period, the regulator transformer is not essential but may be used especially for test equipment which depends on a constant line voltage value for accuracy of calibration. A power supply line of this type may be used *after the defects in a given receiver have been found* and corrected. The receiver is then connected to this regulated line and all necessary tuning adjustments made. Your final operational check should also be made from this regulated power line before delivering the receiver to your customer.

The second and most frequently used power line should be arranged somewhat as in Fig. 3. This may be called your *work horse* power line for it is the one which will be subjected to the heavy loads and the one which will be used more often.

Switch S1 of Fig. 3 is the main power switch which controls the entire line. It may make use of a pilot light arrangement as previously mentioned for the automobile power line circuit. Meter V1 may be either a magnetic vane or moving coil type of meter as extreme accuracy is not required. It is an AC voltmeter and its purpose is to measure the line voltage. Its range should be 0-150 volts.

Meter M1 is an AC ammeter of 0-10 or 0-15 ampere range. A toggle switch S2 is connected across it so that the meter may be shorted out of the circuit should a heavy overload occur or should it be desired to switch it out of the circuit for some other reason. This meter may be used to indicate the exact current drawn by an amplifier or receiver under repair. Such information can be very useful as you will learn later on.

The outlet 0_1 should be used for a soldering iron or for a bench fan. Note current drawn from it will not be indicated by Meter M1. This outlet should be of the duplex type mounted in a standard metal box. A good position for it is on the front



This layout shows an example of one main panel with cutouts provided for the units mounted on it. Note the symmetry of the panel—how one side of it balances the other. By giving careful attention to detail this layout proves symmetry of a test panel can be obtained as well as practibility. A book shelf to the left permits diagram manuals to be within easy reach of the work bench. Courtesy of Sylvania.

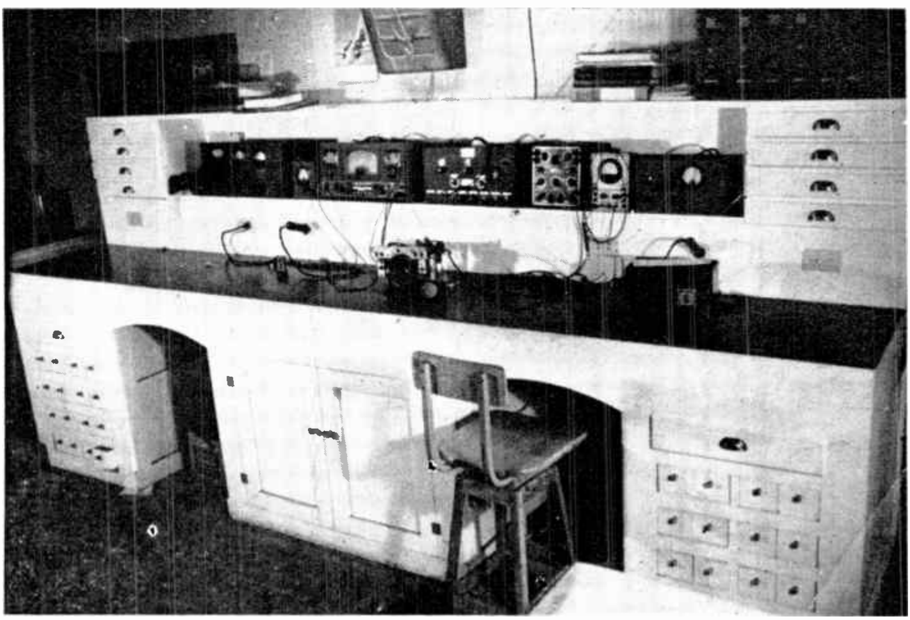
edge of your work bench. If another soldering iron outlet is wanted at some other location on your work bench, it may be connected in parallel to 0_1.

The next device in the circuit of Fig. 3 is a lamp controlled circuit which acts not only as a protective device (for a receiver or amplifier with a full short) but also has many other uses as will be described. In this circuit L1, L2, and L3 are 20, 50 and 100 watt lamps respectively. Switches S3, S4, and S5 control the lamps and these may be small toggle panel type switches or they may be the usual single pole type switches mounted in metal outlet boxes—the kind usually used to turn room lights on and off. The outlet box 0_2 is in series with these lamps and thus a receiver plugged into 0_2 cannot draw any more current than the lamps will permit to pass. For instance with S2 turned to the on position, only 20 watts of energy can be drawn from the line. Assuming a line voltage of 115 volts, the current is thus limited to 20/115 or .173 ampere. Likewise the 50 watt lamp will limit the current to .434 ampere. With S3 and S4 both turned to the on position, the current that may pass cannot exceed .607 ampere; and with S3, S4, and S5 on, the current will be limited to 1.575 amperes and the total power that may be dissipated will be 170 watts. Another combination of the lamps with S3 and S5 on gives 120 watts and with S4 and S5 on the power cannot exceed 150 watts. All of these various lamp power combinations are very important as you will learn from a study of Lesson 1R-1. These lamps are used for the same purpose as explained for Lesson 1R-1. They are a protective device and enable you to control the current to any receiver or amplifier under test. Each receiver or amplifier coming to your work bench should first be connected to outlet 0_2 until all major repairs have been made, then you can utilize the power circuit of Fig. 2 to finish the job. Switches S3, S4, and S5 should, of course, be utilized to select the proper lamp rating as explained in Lesson 1R-1.

These lamps and their switches should be mounted on a shelf on the main panel of your work bench, at a point where you can watch the intensity of their glow. They may set out in the open or you may have a panel to cover them with holes opposite each lamp which will permit you to see whether they are lighting or not. Reference to mounting and the location of the lamps on your main panel will be discussed further on in this lesson.

Referring to Fig. 3 again *if desired*, a wattmeter may be mounted on your main panel with an outlet in series with it. Outlet 0_3 is used for this purpose and WM indicates the wattmeter. This may be rated at from 0-150 to 0-300 watts. A small panel type wattmeter is available from most of the meter companies—write to them if you are interested in such a meter for your work bench.

This wattmeter is used as follows. On the name plate of most receivers the power consumption in watts is given. This may be used as a reference. Plug the receiver into outlet



This view shows another two man bench layout. Note all of the instruments are portable which permits moving them to any position on the bench where they may be needed. The top of the panel is wider and lower than usual permitting it to be used as a book shelf. Note the use of drawers above the work bench top and also those below it. Drawer space always comes in handy and every work bench design should allow for it. Courtesy of Sylvania.

0_3 and after the receiver warms to operating temperature, check its power consumption as read on the wattmeter. If it shows a power reading in excess of the rated power, you will know there is a heavy overload in the receiver. It will probably be in the form of a defective power transformer, rectifier tube, filter condenser, etc. Thus, you have an immediate clue as to the defect and will know what type of defect to check for. Most small receivers will be rated at from 50 to 100 watts. Other larger receivers and amplifiers will be rated up to 300 watts. When a receiver is operating normally it will draw normal power from the line, which in itself is a check on the condition of the receiver. Conversely, if the wattmeter shows very much below normal power consumption, it indicates there is an open in a vital part of the circuit. So again the wattmeter is useful in indicating what is wrong. If its readings are interpreted correctly, the wattmeter can be very useful at the work bench and can be a great time saver. In like manner, the lamps L1, L2, and L3 of Fig. 3 can serve as a substitute for the wattmeter if the brilliance of the lamps is interpreted properly and if the right watt size of lamp is used. Read and study lesson 1R-1 in careful detail for exact information on how to use lamps in general testing. They can be most useful if you employ them right and interpret the effects correctly.

The remaining outlet 0_4 in Fig. 3 is not a special power outlet and may be located at the opposite end of your work bench in relation to outlet 0_1. It may be used for a soldering iron, fan, or any other electrical device which requires no special attention.

The power wiring for your work bench will be permanent, so you ought to use good materials for it. The wires used should be No. 14 or larger and should be enclosed in BX cable or standard electrical conduit. Standard metal boxes should be used for all switches and power outlets. Fuses should also be enclosed in metal boxes for full safety and protection. All connections should be well soldered and taped or otherwise insulated if exposed in any way.

Other Types of Power Supplies

In many sections more than one type of power supply is in common use. Whether or not you provide for this at your work bench will depend on how much of this type of work you are required to do. For instance you may find it necessary or desirable to have DC available at your work bench—either 32 or 110 volts. This may be provided in the form of a small motor generator or rotary converter. These units can be secured to operate direct from the available power line. If you have an AC line, this device will provide DC; and if you have a DC line, it will provide AC at its output at whatever frequency is needed.

In the same way, if you live in or operate from a 60 cycle district and must do work on 25 or 40 cycles, rotary converters can be employed for the frequency conversion. The reverse is also possible by using a rotary

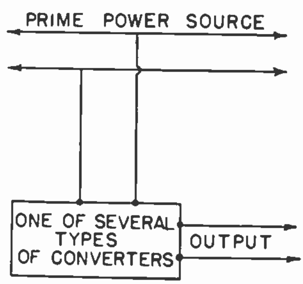


FIG. 4

This photo shows a triangular shaped work bench layout. The main panel is composed of sections which is one good way to arrange it. The various test instruments are fixed mounted to the sectional panels. The small tools are mounted underneath the sectional panels by use of a leather strap. This shop evidently follows the slogan "a place for everything and everything in its place." Courtesy of Sylvania.

converter to convert a 25 or 40 cycle line to 60 cycles.

If you live in a farm or rural district where there are no power lines, inverters may be used to operate from storage batteries. These give 110 volts 60 cycles, AC and are available in several power sizes. So regardless of local conditions, devices are available to meet your power requirements. In general no matter what the power conversion problem, it will electrically take the form shown in Fig. 4. The output of the power converting device may be wired to bench circuits similar to Figs. 2 and 3, depending upon requirements. If you do find it necessary to use one of these power converting devices, be sure and get one which has a power rating large enough to handle your expected requirements.

Speaker Substitute for the Work Bench Panel

There are two very good reasons why a substitute speaker is desirable for the work bench. First is the fact that many receivers will be brought into the shop without the speaker; and second if a speaker substitute circuit is already arranged on your work bench, you can quickly substitute for the speaker of the receiver under test. Such a test is often desirable when checking for hum generating conditions, for noise, distortion, etc. For such a system to be truly universal and to fit all possible conditions, it will need to have variable characteristics. Figure 5 shows a suitable circuit. It consists of a heavy duty universal output transformer, a 5 to 8 inch PM speaker, and a tapped iron core choke—the choke being made special for work bench use by several transformer manufacturers. The entire arrangement may constitute a sectional panel on the main or large panel of your work bench.

Transformer T1 in Fig. 5 may be any good heavy duty universal output transformer. Your radio parts jobber can help you make the proper selection if you are not familiar with this item. The primary of this transformer should be center tapped for push-pull tubes. The secondary should have several taps but they need not have the exact values shown in Fig. 5. At least four taps should be provided on the secondary and as many as six or eight may be used if desired. The transformer shown in Fig. 5 has five taps of 4, 6, 8, 10, and 16 ohms. Note these values refer to AC impedance values in ohms and do not refer to DC resistance values.

The transformer should be mounted in back of your speaker sectional panel. Wire leads from the transformer terminals are then soldered to tip jacks mounted on the panel—tests leads are to be connected to these tip jacks from the front side of the panel as will be explained later.

The speaker may be any good PM type speaker with a five to eight inch cone—the smaller the cone the better, for you will probably need to conserve space. This speaker should be bought without output transformer because T1 in Fig. 5 will act as the output transformer for it. The speaker should also be mounted on your sectional panel near the other parts. A hole should be cut in the panel slightly smaller than the circumference of the speaker cone. This will expose the paper cone of the speaker towards the front. To protect this cone, a large mesh wire screen should be mounted over the opening in the panel. This will permit normal function of the speaker, yet it will be protected from objects which might hit or tear the paper cone. Note terminal 4 of the secondary of the output transformer is permanently wired to one side of the voice coil of the PM speaker.

The iron core tapped choke should also be mounted behind your sectional speaker panel. Wire leads from it are to be wired to tip jacks as explained for the secondary of the output transformer. This choke is rated for a maximum steady load of 40 milliamperes and a maximum intermittent load of 55 milliamperes. The taps are at 500, 1500, 2000, 2250, 2500 and 3000 ohms. Note this refers to DC ohm values only and does not refer to AC impedance values as in the case of the transformer.

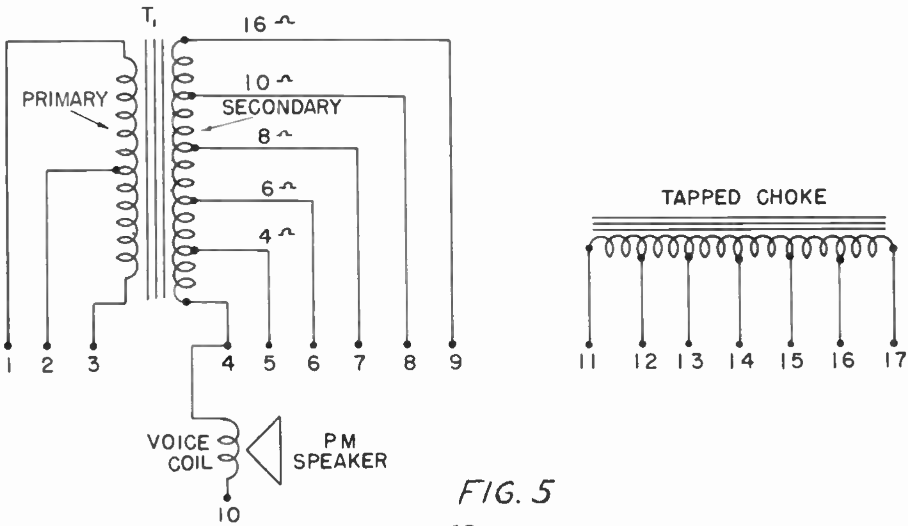


FIG. 5

Here is a nice layout for the combination store-shop arrangement. There are two shop work benches one to the right along the wall with a convenient overhead fluorescent light. The other bench is along the rear wall and is used principally for heavy work, thus jars and shocks will not disturb the electrical instruments mounted on the panel. Note the use of shelves along the rear wall for spare parts and tubes. Courtesy of Sylvania.

The purpose of this iron core tapped choke is to substitute for the field winding of any dynamic speaker. It may also act as a substitute for an iron core choke in a receiver under repair.

There are various circuit conditions which this arrangement will have to meet. For the primary side of the transformer, note it will meet conditions for either a single output tube or for two push pull tubes. To meet this flexibility, three test leads should be provided for tip jacks 1, 2, and 3. One end of these should be fitted with tips which may be plugged into the tip jacks. The other ends of the test leads should be fitted with alligator clips so that quick connections can be made to the receiver.

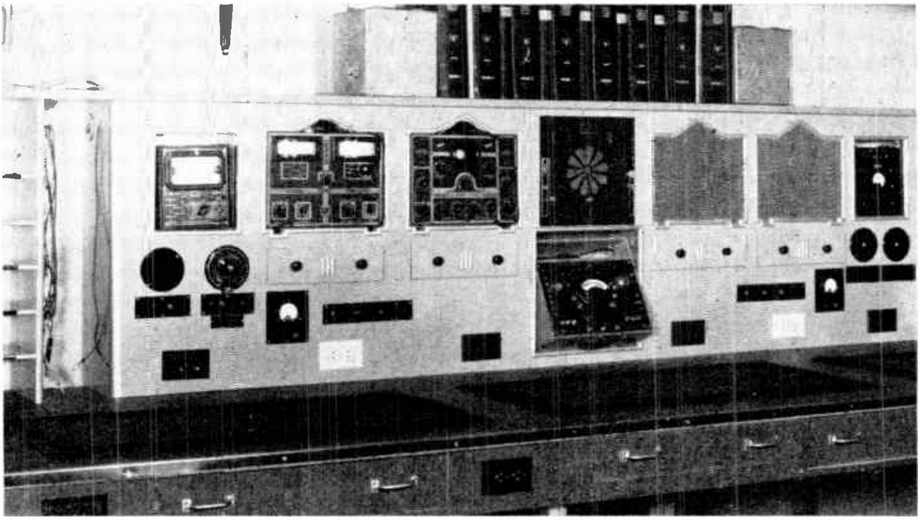
To illustrate how the system is used, suppose a receiver is brought to the shop without its dynamic speaker (which will probably mean the output transformer and field winding will also be missing). To correct for this condition plug the aforementioned test leads into tip jacks 1 and

2 for a single output tube and add the third one to tip jack 3 for push pull tubes. For a single tube connect the lead of 1 to the plate terminal of the output tube and connect the lead of 2 to the B+ for the same tube. If push pull tubes are used, connect the leads of 1 and 3 to the plate terminals of the two tubes and connect the lead of 2 to the B+ for the same tubes. On the secondary side of the transformer, 4 will be connected to one side of the PM voice coil. With a jumper test lead, connect it between 10 (which is permanently wired to the other side of the voice coil) and 5, 6, 7, 8, or 9. Depending on the AC impedance of the PM voice coil, 10 will normally remain connected to one of the secondary taps which most nearly matches its impedance. For instance if the PM voice coil impedance is 8 ohms, 10 will normally connect to 7. For most conditions, 10 will remain connected to 7 for this impedance value. The only thing which might change this is single or push-pull tube conditions for the primary. Also there may be times when you wish to match the output transformer to another speaker rather than the one on your work bench. When this is desired, at least two of the impedance taps on the secondary will usually give a satisfactory match. To make sure you have the best impedance match (in case of doubt) 10 may be tried connected to 5, 6, 7, 8, and 9, letting it remain connected to the tap which gives the most volume with the least distortion.

If the foregoing described connections have been made, all that remains is a substitution for the speaker field winding. As with the transformer secondary, test leads may be used to connect the field winding to the receiver under repair. Let 11 represent one end of the field. Connect it to one side of the circuit to which the field normally connects. Then select a connection from 12 to 17 which most nearly matches the field winding of the receiver under test. Suppose the circuit calls for a 1200 ohm field winding. The tap nearest to this is 13 giving a value of 1500 ohms which is not off so much as to make a practical difference. With these connections made, you will have made a *bench* substitution for the receiver speaker and can proceed in a normal manner with your testing.

For the condition where the output transformer is mounted on the receiver chassis instead of the speaker, a different procedure is needed. In this case, you will have a low impedance winding which must be matched to a low impedance load on the secondary of your bench output transformer. To accomplish this with two test leads, connect the secondary of the output transformer on the receiver chassis to 8 and 9 on the secondary of your bench output transformer. This will cause magnetic lines of force to be set up in the entire secondary and you can proceed with your tests as usual.

If you have a receiver in which the iron core filter choke is defective, it may be removed or disconnected from the circuit and a section of your bench choke temporarily substituted for it. This is done by making use of test leads as previously explained. With the ends of the test leads which have alligator clips—clip the test leads to the circuit to which the leads from the choke normally connect. Then with the other ends of the test leads which have plug tips, connect one lead to 11 in Fig. 5 and try the other lead in 12, 13, 14, 15, 16, and 17. One of these connections will approximate the con-



This is an example of a versatile test panel and work bench. Everything is neatly mounted and the whole layout is in symmetrical balance. Power outlets are provided along the front edge of the bench as well as on the main panel itself. Above the test panel is plenty of room for diagram manuals and books. Along the front edge of the work bench note the use of drawers for tools, etc. Courtesy of Radio News.

dition of the original choke. Thus, you may go ahead and repair and adjust the rest of the circuit. You can tell which tap of the choke in Fig. 5 most nearly represents the characteristics of the original choke by the fact that DC voltage throughout the receiver will be about normal and hum will be reduced to a minimum. For the average receiver a 15 henry choke is required. Thus after you prove that a given choke is at fault, you would probably be safe in ordering a 15 henry replacement choke. On the other hand, if exact manufacturers specifications are at hand, they should be followed.

The previously described circuits represent installations for the average work bench. Many servicemen will get along with less than what has been described and others will employ many more substitute items on their bench panel. These will include such items as a power transformer, condenser bank, resistor bank, AF transformers, etc. The individual serviceman will have to decide for himself how many of these extra units he wants or needs.

If a bench power transformer is wanted, it can be arranged similar to Fig. 6 on its own sectional panel. The primary should be permanently wired to the power line as shown. The

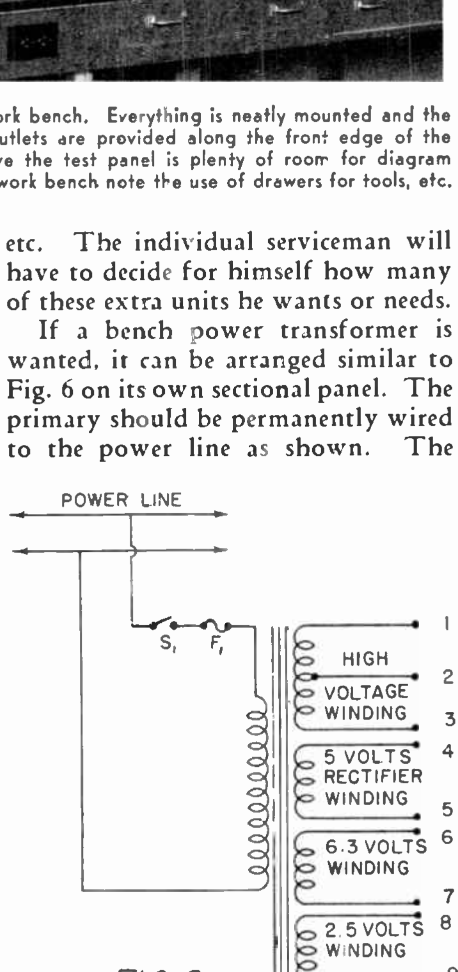


FIG. 6

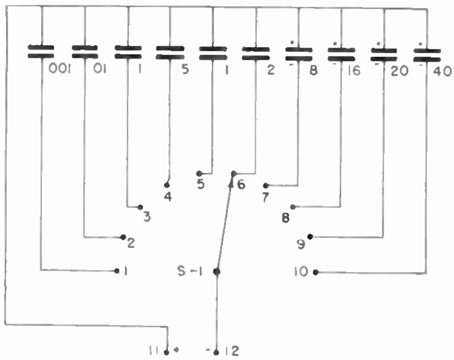


FIG. 7

switch S1 should be mounted in a metal box along with a pilot light to indicate when power is applied to the transformer. The fuse may be rated at about 2 to 5 amperes. The secondary terminals should be wired to well insulated tip jacks for high voltage is applied to tip jacks 1, 2, and 3. The rectifier filament winding should be rated at 2 amperes and 5 volts for most rectifier tubes operate on this value of filament voltage. The other two filament windings should be rated at 2.5 and 6.3 volts respectively. The current rating for these two windings should be as high as you can get them to take care of varying load conditions.

By means of a set-up of this kind, you can substitute for an entire power transformer if you wish to do so. Connections between the transformer secondary terminals and the receiver can be made by means of properly fitted test leads as explained for the other test circuits.

It may not be necessary for you to substitute for an entire transformer. A substitution can be made for one or more windings by making proper connections to the transformer secondaries. Also it may be necessary to observe proper connections at the receiver under test. Certain ground connections may be called for and it is essential to fully disconnect the original winding for which you are substituting. Beyond these elementary precautions, no special instructions are needed for this transformer substitute circuit.

A condenser substitute bank is very handy at the work bench and one should be included eventually even if you don't plan to install one immediately. A good circuit to use is shown in Fig. 7. Switch S-1 is a 10 terminal rotary single deck selector switch. This permits the use of 10 substitute condensers varying in capacity from .001 to 40 mfd. The .001 may be a mica type condenser. The .01, .1, .5, 1 and 2 mfd. units may be of the paper type rated at 400 to 600 volts DC. The 8, 16, 20 and 40 mfd. units should be of the dry electrolytic type. The 8 and 16 mfd. units should be rated from 400 to 600 volts and the 20 and 40 mfd. units may be rated at from 150 to 300 volts.

To use the circuit, insert test leads into the two tip jacks (11 and 12) and turn switch S1 to the desired position. If you are substituting for a condenser whose value is not included in Fig. 7, choose the value most nearly to the rated value. Always, when substituting for a given condenser, disconnect it from its circuit if you are checking for a short or an intermittent condition. If you are

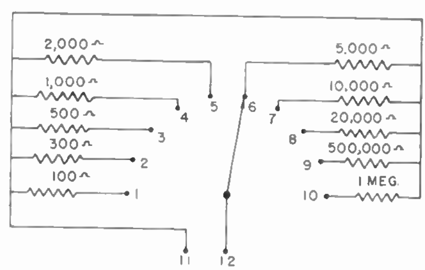


FIG. 8

This is a good example of making maximum use of small space. A layout like this must be used where space is at a premium. Most of the test instruments are within easy reach of the repairman at almost any position along the work bench. Spare tubes and parts are placed on shelves at the right of the work bench and diagram manual space is provided in enclosed shelves above the test instruments. Courtesy of Radio News.

checking for an open condition, it does no harm to leave the suspected condenser in the circuit while you put another one across it. If under this condition you get normal reception, it indicates the condenser in the circuit needs replacing. Remember, however, this holds true for an open condenser and does not apply to one which is shorted. There are many more condenser testing principles and applications which will be treated in a separate lesson devoted to this subject. Referring to Fig. 7 again, the electrolytic condensers will eventually dry out and will need replacing in time. The mica and paper type condensers will last almost indefinitely if they are not overloaded.

Figure 8 shows a very satisfactory resistor substitute circuit. It uses a ten terminal single deck rotary selector switch. Two tip jacks are used into which test leads are inserted. Thus any resistor in the group may be selected by proper use of Switch S1. Like the other substitute circuits already mentioned, this one may employ its own sectional panel on your main test panel. The resistors should have adequate power rating according to their expected use. The 1 megohm, 500,000, 20,000, and 10,000 ohm units should be rated at, at least, 1 watt and up to 3 watts may be used. The 5,000, 1000, 500, 300 and 100 ohm units should be rated at 5 watts. The use of the resistor substitute circuit is very simple. Test leads are first inserted in tip jacks 11 and 12. The other ends of these test leads should have alligator clips attached. They are then clipped to the two sections of a circuit to which a resistor normally connects. If the resistor you are substituting for is suspected of being open or *burned out*, the test leads may be clipped directly across the suspected resistor. Proper selection of the resistor value is next made by switch S1. The receiver should then be turned on. If this results in normal operation or the restoration of voltage where it did not exist before, it proves the suspected resistor is open. In other cases where you already know a given resistor is open, the circuit of Fig. 8 may be used to quickly restore normal conditions without having to wait and do a soldering job. Thus, you can go on with other tests such as checking for a shorted condenser which may have caused the resistor to open in the first place. In this way, you can do all soldering

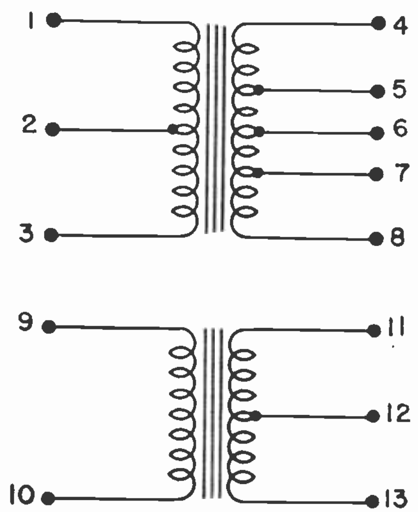


FIG. 9

operations at one time when you are ready to make permanent replacements. Another use for Fig. 8 is where you are required to replace a given resistor and don't know the exact value to use. This circuit will permit you to switch several values into use and from receiver operation you can usually make a satisfactory approximation of the correct value. This circuit does not of course provide all possible values which may be needed but with the available values you can at least restore operation long enough to get a check or to approximate the value of a given resistor. The resistor values in Fig. 8 are flexible and you may use any combination of values which fits your particular work.

If you want an AF transformer substitute circuit, the one shown in Fig. 9 will be satisfactory. The upper symbol is a universal output transformer similar to the one described for the speaker substitute circuit. However, the one shown in Fig. 9 should have a high impedance tap at 4—500 ohms or higher. This will permit coupling to a high impedance load such as a magnetic speaker. The other taps of 5, 6, and 7 should be of low impedance—from 4 to 16 ohms. Tap 8 is assumed to be the common terminal in reference to taps 4, 5, 6, and 7. For the primary side of this transformer use 1, 2 and 3 for push pull and for a single tube use 1 and 2, 2 and 3 or 1 and 3 depending upon the plate load requirements of the tube to which the transformer will be connected.

The lower transformer in Fig. 9 is primarily to substitute for a push-pull input transformer. For the primary 9 and 10 are used while 11, 12 and 13 are used for the secondary. This transformer can also be used for

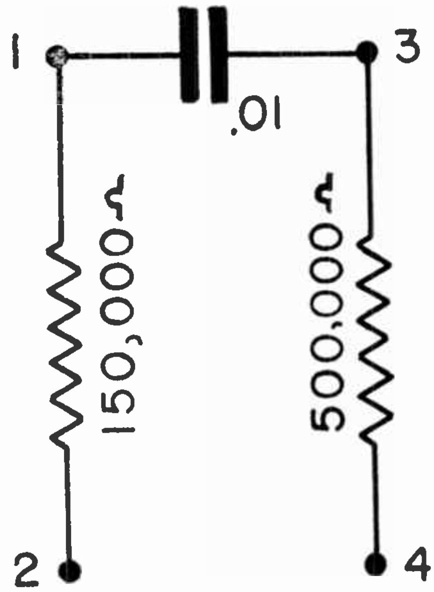


FIG. 10

a single tube on the secondary side by utilizing 11 and 12 or 12 and 13. The wire leads of the AF transformers should, of course, be wired to tip jacks and test leads used as explained for the other substitute circuits. Standard transformers as made by several companies may be used for Fig. 9.

There may be times when you will want to substitute for a resistance coupled stage. If you want a unit of this type, the circuit of Fig. 10 will work nicely. It consists of a 150,000 ohm resistor for the plate circuit, a .01 mfd. coupling condenser and a 500,000 ohm grid leak. Terminal 1 would normally connect to the plate of a tube, 3 to the grid of the following tube, 2 to B+ and 4 to ground or to the C bias connection for the stage in question. This coupling unit may be quickly substituted for another similar unit in a receiver under test. It is particularly useful where you suspect an AF resistance coupling unit as a noise source. Four leads would be needed and before using this unit the four connections of the coupling unit you are substituting for should be removed. The four test leads should then be clipped to the proper points in the receiver circuit. In this way you can substitute for the entire AF coupling medium between the plate of one tube and the grid of the following tube.

Other types of substitute circuits can be arranged for the work bench but those described in the foregoing are the most practical and most often used. As pointed out before in this lesson, the exact main panel arrangement should be left to the desires of the individual serviceman. The circuits and instructions included herewith are mainly guide posts and you should decide on what should be included on your main test panel based on your particular need and local conditions.

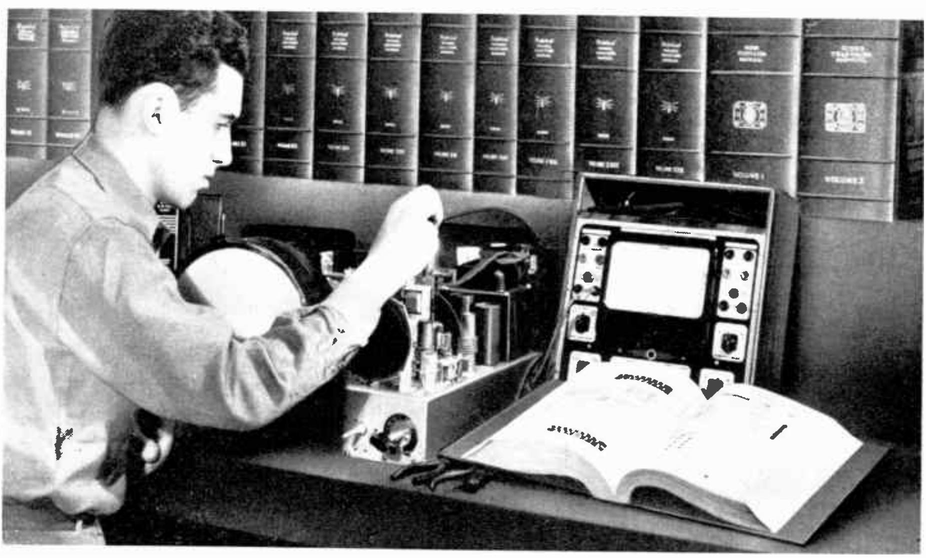
Lettering for Your Sectional Panels

Regardless of the way you arrange your main test panel its sectional panels should have legible lettering for the various controls. This is desirable both from the viewpoint of appearance and convenience. Also if you have hired help working in your shop it will be very necessary to have all controls lettered—it avoids mistakes and in general makes for better efficiency.

There are several ways to letter or label controls and you should select and use the system which is most easily available to you. The most economical method is by use of the typewriter. Type your lettering on stiff index card stock. This can be obtained from stationery stores and paper supply firms. A good weight to use is known as 110 pound stock. Keep the letters as close together as the typewriter will allow. Use abbreviations as much as possible for this will keep the lettering to a minimum space which you will find desirable where several controls are grouped together on a small sectional panel. If you are good at hand lettering or have a friend who can do this work, it will be better than the typewriter method. The letters can be made heavier and more legible and can be made in the form of circles and angles which is difficult to accomplish on the typewriter.

Once you have all of your lettering complete the next problem is to get this lettering mounted in the proper position. This can be accomplished in different ways. If your sectional panels are made from wood, small brass wood screws can be used to hold the paper or card stock in place. If your sectional panels are made from bakelite, metal, or other hard surface materials, machine screws can be used for mounting the control labels. Just drill proper size holes in the panel, insert the screws from the front and tighten on nuts on the rear side of the panel. Whatever your method of mounting the control labels, they should be protected by using a transparent covering. This may be celluloid or clear cellulose tape. This will keep all dirt and finger marks from soiling the paper or index stock on which the lettering is printed. If you use celluloid, it can be cut to the same size as the control labels and both celluloid and label mounted at the same time. Cellulose tape is transparent and may be stuck directly over the labels since one side of it has a form of cement coating.

All circular controls such as rotary selector switches should have a circular type of control label. This can be cut large enough to extend out away from the control knob. The lettering on the label should be exactly opposite each switch position.



Here is a simple work bench layout. Adequate space is allowed on a shelf above the working area for manuals, manufacturers literature, etc. Many Sprayberry students often start their own repair business with less space than is shown here—the important point is to have it organized properly.

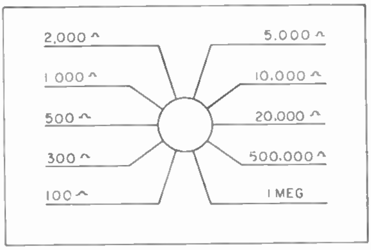


FIG. 11

If desired a center hole may be cut in the label which will fit over the shaft of the switch or other type control. The mounting nut for the control will then hold both control and label in place. It will be necessary to mount the label in the exact position so its lettering will coincide with the switch positions. Figure 11 shows how lettering or labels might be arranged for a resistor substitute circuit such as Fig. 8.

If you want a more elaborate and expensive lettering system for your sectional panels, commercial engraving may be employed. Most machine shops have an engraving machine which will do this type of work. It will engrave metal or the softer panel materials such as bakelite, hard rubber, etc. In employing this type of service, you must furnish the machinist with an exact drawing, showing positions of all lettering. The lettering may be done directly on your sectional panel or it can be done on metal or bakelite strips—the strips being mounted to your sectional panel. If you decide to use engraved lettering, try and be on hand while the lettering is done so you can show the machinist exactly what you want.

Main Panel for Work Bench

The main test panel for your work bench should be designed to fit the test equipment you have on hand or that which you expect to obtain in the future. Figure 12 shows a typical surface layout for the main panel of a radio repair or work bench. This panel should extend up vertically from the back of your bench—designed to fit against a wall. The bot-

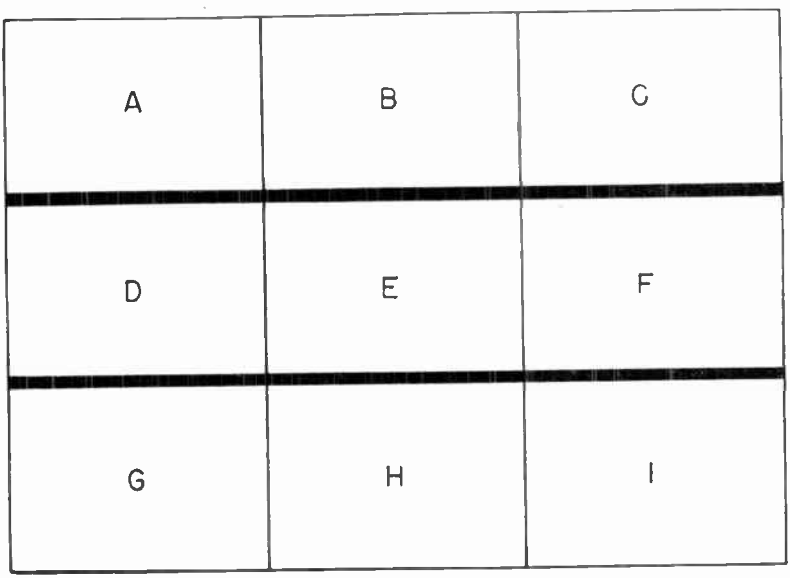


FIG. 12

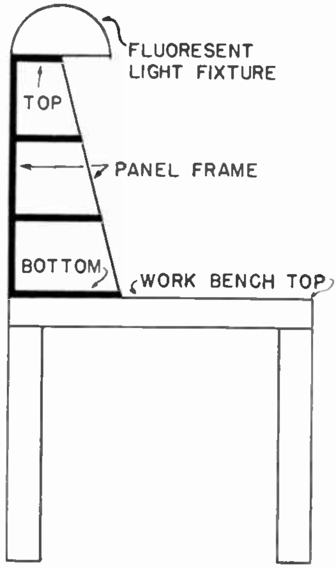
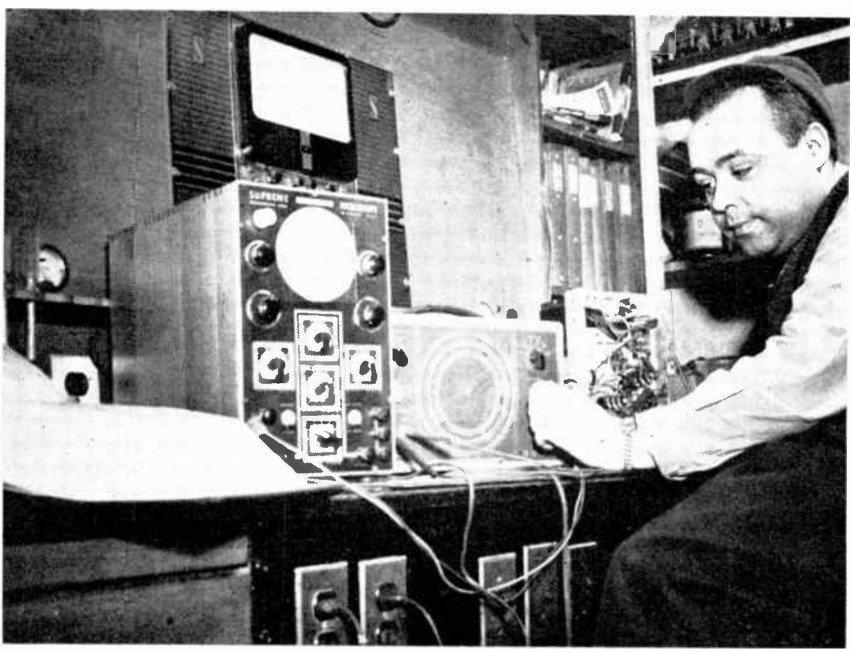


FIG. 13

tom frame for the panel should be wider than the top so as to give a sloping effect for the front of the panel. See Fig. 13 for an end view of this effect. A sloping panel makes an excellent appearance and glare from lights is reduced to a minimum.

To return to Fig. 12 again, the sections labeled A through I are the sectional panels or shelf sections for the main panel. The two heavy horizontal lines in Fig. 12 are shelves which are to be cut and fitted to the slope and angles of the panel frame work. Note these shelves must be square with the front of the panel. See Fig. 13 for an end view of the shelves. The frame for the main panel may be made from 2x2 lumber. If you are not accustomed to this type of work, enlist the services of a carpenter to help with the cutting and fitting of the frame.



This view shows a section of a work bench and test panel. Switches and power outlets are at the front edge of the bench and as explained in the lesson this is very convenient. Note the use of a large meter which permits easy reading at head and shoulder level. Courtesy of Radio News.

Here is a three man work bench with all test equipment portable so it can be moved about on the bench as needed. This is often desirable where several men must be working at once. In this case racks are often built along the back wall on which different pieces of test equipment may be conveniently placed. In this photo spare speakers are hung on nails above the workbench. Courtesy of Sylvania.

Note in Fig. 12 nine sections are shown. Remember, too, this is not a strict pattern for you to follow—you may use more or fewer sections, depending on your individual requirements. The three bottom sections labeled G, H, and I should not contain sectional panels but should be left open to accommodate your main test instruments such as signal generator (test oscillator), tube tester, multimeter or other type of meter tester. These instruments need to be portable for you may have to take them out on a job or you may find it necessary to move them to a more convenient spot on your work bench.

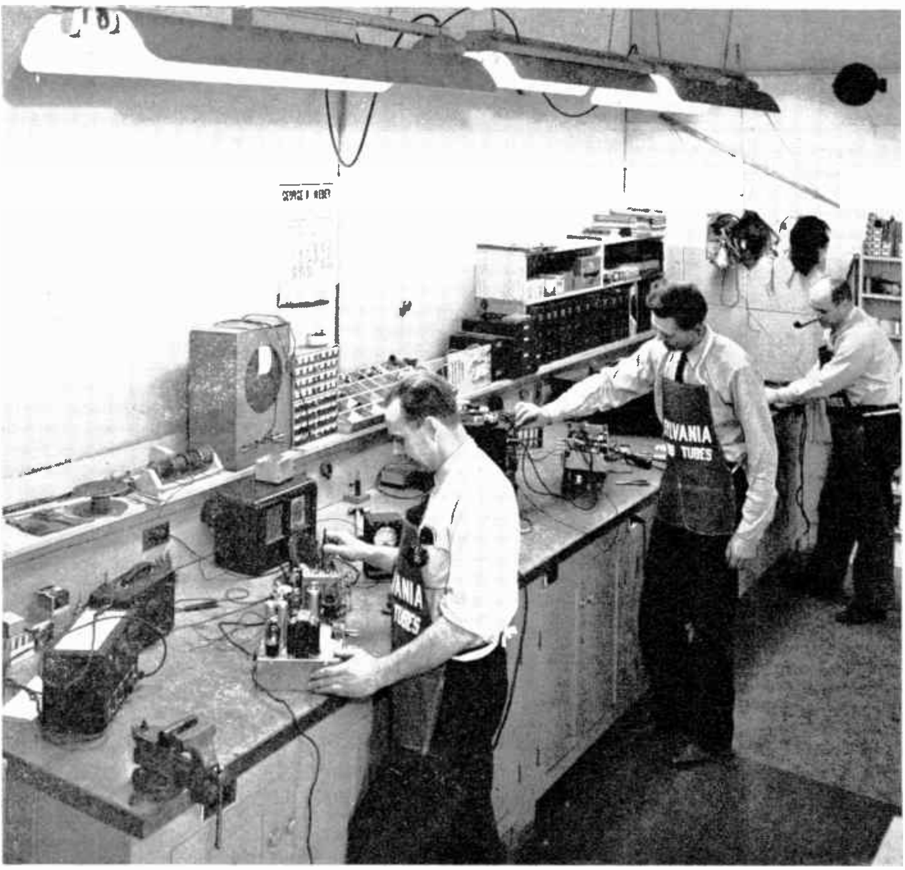
Sections D, E, and F may be sectional panels to accommodate substitute circuits such as those described for Figs. 1, 2, 3, 5, 6, 7, and 8. However, sections D, E, and F need not be used exclusively as sectional panels. For instance E might be an open book shelf. You will need a shelf of this type for diagram manuals, books, catalogs, and other literature. This shelf should be within handy reach from where you stand at the bench so position E would be a convenient spot for your book shelf.

Sectional Panels A, B, and C will be located at the top of your main panel so units not used very frequently should occupy these spaces. In this connection, the top row of panels should not be located so high that you have to crawl up on the work bench in order to get at the units located there. No sectional panel on your main panel should be so high that it cannot be reached with your hands. If for some reason you require a main panel so high that you cannot reach the top sections with your hands, then try and use the top section for storage or for something you do not need frequently.

It is not necessary to restrict one section of the panel to one test unit or substitute circuit. For instance, the circuits of Figs. 7 and 8 do not require much space and for this reason, both circuits might be mounted on one sectional panel. Also wide latitude may be allowed for the size of the sectional panels. They may be large or small depending on individual requirements. The various sections of the panel need not be the same size although the appearance of the complete panel may be more pleasing if the panel sizes are the same or at least symmetrical.

The Bench Top and Frame

The work bench frame should be made from good 2x4 lumber free from knots. This part of the com-



Above is shown another three man work bench. Note here no main test panel is used. A shelf at the rear of the work bench is used to hold test equipment, spare parts, manuals, books, etc. The lower part of the bench is entirely enclosed but note the bottom of the cabinets are above the floor thus allowing foot room. Courtesy of Sylvania.

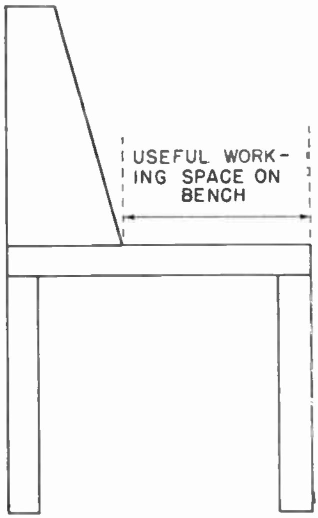


FIG. 14

plete bench may take several forms and its final arrangement is left to the individual who will use it. However, we will point out some general principles which it would be well to keep in mind. First consider the height of the bench top—this should be made to fit the individual, for it is very uncomfortable to work at a bench which is either too high or too low. The final height should be selected keeping in mind the height of the stool or chair to be used at the bench. What you want to avoid is a feeling of having to stoop or hump your shoulders to get at your work and at the same time you will want to avoid a height which will prevent you from bending naturally at the waist. The height of most work benches varies from 34 to 40 inches and no doubt somewhere between these figures there will be a measurement best suited to your individual requirements.

The width of the bench top should be decided on after careful consideration of all of the factors involved. The main panel at the top rear of the bench will probably take up from 8 to 12 inches and remember this will not represent useful working space. So you should figure that useful working space starts on the top of the bench where the main panel ends. See Fig. 14. Most radio men make the mistake of having the useful working space on the work bench too narrow. When this happens, you will be cramped for space—you want enough room on the bench to allow for the largest type of amplifier or receiver chassis. We recommend as useful working space on the top of the work bench from 20 to 30 inches, using the wider width if at all possible.

The length of your work bench

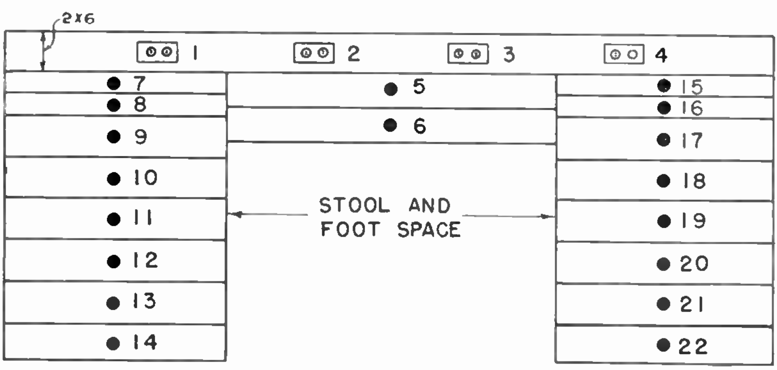


FIG. 15

frame will be determined somewhat by its location in the room in which it will be used and by the length required by the main test panel. The minimum length should be not less than six feet. You can make it as much longer as necessity dictates. In general it will be better to have the bench longer than needed rather than being too short. A good compromise would probably be somewhere between 6 and 10 feet in length.

The work bench top should be of a non-metallic smooth surface. It should be covered with plywood, masonite or linoleum. The edges of the work bench should be protected with some form of moulding made from metal, plastic or wood. Any good carpenter can advise you what to use and how to apply the moulding.

Figure 15 shows a layout for a typical work bench. This shows a front view of the bench. Such a layout need not include as many storage drawers as is indicated here. This is just merely one idea of a bench layout. Your own design should be worked out to fit your individual requirements.

The top section of lumber in Fig. 15 should be a 1x6 or a 2x6. On it will be located the power outlets and this piece of lumber should be wide enough to accommodate electrical metal outlet boxes without destroying the supporting strength of the lumber. These power outlets correspond to those shown in Figs. 2 and 3. It is better to have these power outlets (1, 2, 3, and 4) at the front of the work bench rather than at the rear

Here is shown a good example of the one man shop. Note a sloping main test panel is used and shelves to the right are used for spare parts and books. A large general purpose meter is mounted in the center of the main panel. This permits quick continuity testing as such a meter can be quickly read. Courtesy of Radio News.

In this shop layout the owner takes advantage of the counter to display merchandise for sale. In back of it is the shop work bench and test panel. Similar layouts like this are easily possible where the radioman wants to include both sales and service. Courtesy of Sylvania.

for then the connecting cords will not have to lay across the bench top and so get tangled with other things on the bench.

Sections 7 and 15 of Fig. 15 should be flat board pull outs similar to those provided for an office desk. Thus when you need a book or diagram manual for reference at the bench these pull outs are instantly available and can be pushed back into the bench when not in use.

Drawers 8 through 14 and 16 through 22 can be used for tools, spare parts, test leads, and other items needed at the bench. Drawers 5 and 6 located in the center are wide enough for your books in which to keep your records. These can also be used for writing stationery and other office supplies. The space below drawers 5 and 6 should be left open to allow room for your feet, chair or stool. If desired, the ends of the bench frame and also the back may be enclosed with plywood.

Laying Out Your Own Work Bench and Panel

As suggested on other pages of this lesson, we cannot give complete details on a specific design of a work bench and panel because of the many variations in individual requirements. If you have a permanent location, you can make your bench as large and as permanent as you like. However, if you expect to be moving about from time to time the bench should be as small and as portable as possible. It should be so constructed that it can be moved as a unit or it ought to be constructed in sections so it can be taken apart. For instance, the main panel ought to be detachable from the top of the bench. This will make two large units which can be handled by two men and can be hauled in the average truck.

If you have had no experience in carpenter work, it would be a good idea to seek the aid of a carpenter or cabinet maker. Get him to help you make out a list of materials. Make complete drawings of the entire set-up before you start—provide for all of the details in advance. If you will do this you will avoid costly mistakes such as cutting lumber to the wrong length, ordering wrong sizes, etc. With the general principles of this lesson kept in mind, using ideas obtained from photographs shown in this lesson and obtaining the advice of a competent cabinet maker or carpenter, you ought to be able to get just what you want at minimum expense.

Illumination for the Panel and Bench

One important thing you will want to give consideration is proper light for both your panel and bench. It is recommended that you use a fluorescent fixture at the top of your panel as shown in the end view in Fig. 13. You will need plenty of illumination and fluorescent lamps provide this most economically. One fixture for the main test panel will probably be enough. However, you will need one and possibly two more lamps directly over your bench, depending on its length. Other types of electric lamp fixtures may, of course, be used for both the panel and bench. However, most of these other types are less efficient than the fluorescent type and produce more glare.

Antenna and Ground Connections

You will need good antenna and ground connections at your work bench. Erect an antenna according to the directions given in your Business Builders. Insulate it well and keep it in first class condition for you will want the very best at your bench. The antenna lead-in may terminate at a binding post on one of your sectional panels. Many radio men connect the lead-in to a ¼ inch metal rod running horizontal to the main test panel. In this way an antenna connection is provided along the entire length of the bench. A test lead may then be clipped to the metal rod and thus an antenna connection is quickly provided. This metal rod should be mounted high up on the main test panel where it will not interfere with other functions at the bench. A metal rod may also be provided in a like manner for the bench ground connection. Separate this ground rod from 6 to 10 inches from the antenna rod. In connecting to ground, try and connect to a cold water pipe instead of pipes used for heating or one used for a hot water line.

If you use a cement floor or other type of floor which may conduct electricity, it is imperative that you put a rubber mat or other insulating type of mat in front of your work bench to stand on. At times, you will no doubt touch a *live wire* with your hands or with other parts of your body. If the floor you stand on is insulated, the electrical shock from contact with *live wires* will not be near so effective as it will while standing on an electrical conducting floor.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

Questions

No. 1 In what way are the substitute circuits on the main test panel connected to a receiver under test?

No. 2 What is the best power source to be used for automobile receiver testing?

No. 3 What three types of AC power should be available at your workbench?

No. 4 What types and ranges of meters are desirable for a workbench when testing automobile receivers?

No. 5 What protective devices should be included in workbench wiring?

No. 6 What are the three main purposes of a workbench wattmeter?

No. 7 Why is a series lamp bank used and what are its advantages?

No. 8 Under what conditions of testing will you find an adjustable condenser bank useful?

No. 9 What tests can be made with an adjustable resistance bank?

No. 10 When will you have need to use a substitute speaker arrangement?

METER MEASUREMENTS IN RADIO AND TELEVISION CIRCUITS

LESSON TV-2

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

LEARN TO KNOW YOUR BASIC CIRCUITS

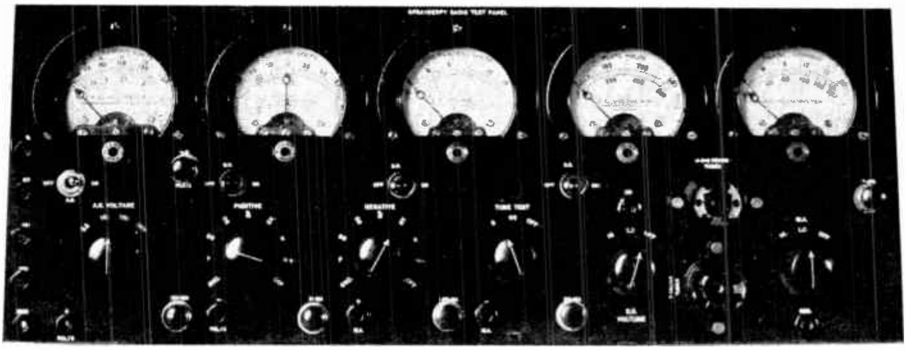
A radio or television repair problem can almost be reduced to the simple formula of a "game of checkers" if you know your basic circuits and how they react to different types of tests.

This lesson discusses these basic circuits for you in considerable detail, explains how to test them and tells how they should react for either normal or abnormal conditions. Thus, in every radio and television circuit there are tubes of various types involved. These all have in a varying degree (depending on tube type) filament, cathode, grid, screen grid, suppressor grid, plate and other tube element circuits. With these circuits will be associated condensers, resistors, inductances, switches, etc. Thus, for any type of receiver defect, the correction of it merely becomes a matter of seeing that a given part is in good condition and then going on with tests on other parts until the defect or defects are found. Then with replacements or adjustments made the receiver will act in a normal manner.

All of this applies with equal force to all receivers whether they be of the AM, FM or Television type. To find defects in these circuits, meters must be used. There are two general methods in wide use for testing these circuits. The older method known as analyzer testing is rapidly losing favor because of its limited applications — in fact this method is used very little in television testing. The second method of testing which this lesson describes is known as multimeter testing and is equally effective for AM, FM and television testing. In this latter method you actually connect the meter test leads to the circuit to be tested yourself whereas the analyzer connects the meters usually by multiple switching.

It will be well worth your time to study this entire lesson in detail for an understanding of the older analyzer method will help you apply the newer multimeter method better in all AM, FM and television testing.

K 15S2M



The above view shows an analyzer of special design. It employs five meters making it possible to obtain five simultaneous readings. This is only a panel view and the necessary plug, cable and adapters are not shown. This lesson explains how instruments of this kind are used in radio analysis work.

METER MEASUREMENTS IN RADIO AND TELEVISION CIRCUITS

Lesson TV-2

The history of diagnosing receiver defects is very interesting but will not be given here since it would require too much space. Many forms of electrical indicators have been used to indicate conditions in radio circuits. The most successful and widely used indicator has been the electrical meter because it may be made to read directly in terms of voltage, current, resistance, watts, etc. The basic meter method of measurement has taken two forms. The first and older form is known as the *analyzer* method. In this system the circuits of the receiver under test are extended (from the tube sockets) by means of a plug and cable arrangement to a measuring circuit known as an analyzer. Then by means of switches or jumper wires, meters are connected to the tube circuits which permits voltage and current measurements to be made. In this method resistance measurements (ohmmeter section of meter) are made by use of two test leads which may be connected to the ohmmeter circuit by means of tip jacks and switches.

The second and most widely used method makes use of a basic meter of the moving coil type. The meter is called a *multimeter* or *volt-ohm-milliammeter*. It is usually arranged to measure both DC and AC voltages in several ranges; DC current in several ranges; resistance in ohms in several ranges (which is a DC measurement) and in addition many of these meters are calibrated in mfd. for condenser measurements; in henries for inductance measurements and in decibels for gain or loss measurements. Some few such meters are also calibrated in AC current ranges and combination instruments are sometimes calibrated to test tubes in terms of *good* and *bad*. Regardless of the form of the measuring circuit and by whatever *trade name* it may be known, it will include tip jacks for test leads, a switching circuit and a basic moving coil meter fitted with a rectifier to permit AC measurements. Since this type of meter circuit is most often called a *multimeter*, we will refer to it as such and will henceforth call it a multimeter.

The analyzer method is convenient in that it permits measurements from the top side of the receiver chassis whereas the multimeter method in general requires that measurements be made from the underside of the chassis. With the growth in complexity of circuits and because the long cable leads of the analyzer introduce oscillation problems in tuned circuits, the analyzer method of receiver analysis has gradually given way to the multimeter method. However, both methods are acceptable, and because we want you to be able to handle either method with efficiency, both methods will be explained in this lesson.

In general either the analyzer or multimeter will localize the defect to a given stage in the receiver under test. It then becomes necessary to further trace the defect to a particular part by use of a continuity tester or ohmmeter as will be explained in a later lesson.

Analyzer Method of Receiver Analysis

Before you study this subject in detail you should have a clear idea of what constitutes a radio analyzer. Broadly speaking, it is a radio circuit test instrument which includes at least one electrical meter and sometimes more than one meter. If only one meter is employed, it is usually of the multimeter type. That is, current, resistance, and sometimes capacity, inductance, and decibel scales are provided. If only one meter is used a copper-oxide rectifier is usually included in order that AC voltage and current values may be measured. Other analyzers may include a separate AC meter. Thus there will be two meters. The DC meter in this case is usually calibrated for DC voltages and current. A multirange resistance scale is also usually provided for this meter. The second or AC meter is usually calibrated for AC voltage and current. In addition, this meter may also be calibrated for capacity, inductance and decibels.

At any rate, no matter how many meters are used, practically the same measurements may be made with all analyzers. The only advantage of a second or third meter is that two or more measurements may be made at the same time, and this is often desirable. Regardless of how many meters are used or what may be their arrangement—all of them basically connect to switches and circuits which terminate at a universal plug. This plug is fitted with pins exactly like those on a radio tube. Furthermore, by means of special *adapters* which fit onto the plug, it is possible to place the plug into any type of tube socket. If wires are connected to the pins on the plug, it follows that the tube circuits may be extended from the receiver to a convenient point away from the receiver where meters may be connected to the circuits which permits measurements to be made on each circuit.

A typical analyzer plug is shown in Fig. 1. This is known as the octal type—having 8 pins on its base. That is, it will fit into any octal type tube socket. In order that the plug may fit into any tube socket, adapters like those shown in Fig. 2 are employed. The top of each of these adapters have 8 tube pin holes in them exactly like those you will find in an octal tube socket. Fig. 3 shows an

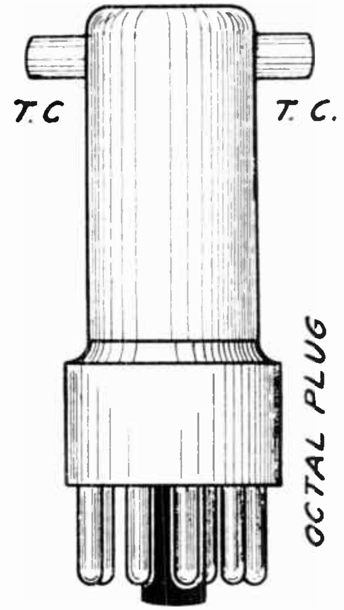


FIG. 1

end view of the top of the adapter.

Each of these adapters are fitted with a spring catch and when the adapter is fitted on to the octal plug it will be *mechanically fastened* to the plug and its metal terminals. Thus, when an adapter is fitted on to the plug and both of them are inserted in a tube socket, the adapter will not be left in the socket when the plug is removed because of the action of the spring catch. While the top of each adapter is exactly alike, you will note that the bottoms are all different—that is, each of them have a different number of pins on their bases. Figure 2A shows an adapter for tubes which have 4 pins on their bases. Figure 2B shows one for 5 pin tubes. Figure 2C shows the 6 pin type and Fig. 2D shows the 7 pin type. There are two sizes of the 7 pin tubes in general use. Therefore, to have a complete set of adapters, both sizes of the 7 pin type are required. Figure 2E shows an adapter for the lock in type tube socket. The lock in type tube has 8 pins with a center guide which locks into place when the tube is inserted into its socket. The pins of these lock in type tubes are very small and thus care must be exercised when inserting or removing this adapter from the socket. As the guide pin is locked into place when the tube or adapter is inserted, a slight side pressure must be used in removing them. Figure 2F shows an adapter for the small miniature type tube. There is no guide pin used with the small miniature type tubes and the pins are very small. Unless you are careful when inserting this type adapter or tube, the pins may be damaged. Manufacturers of analyzers usually furnish a complete set of adapters with their instruments. However, these adapters may also be purchased separately.

To get a clear understanding of the function of an analyzer, you must first be thoroughly familiar with tube sockets in general use. The seven types in general use at present are shown in Figs. 4 and 5, together with their official pin numbers—standard numbers adopted by the Radio Manufacturers Association—abbreviated RMA.

The only difference between Figs. 4 and 5 is that the sockets are *reversed*. When using an analyzer, you will be concerned in most cases, with the number of the pin holes when looking down upon them—their top side—this view is shown in Fig. 5. When you are examining and testing circuits on the underside of the chassis, you will be concerned with the bottom view of the socket pin holes—this view being shown in Fig. 4.

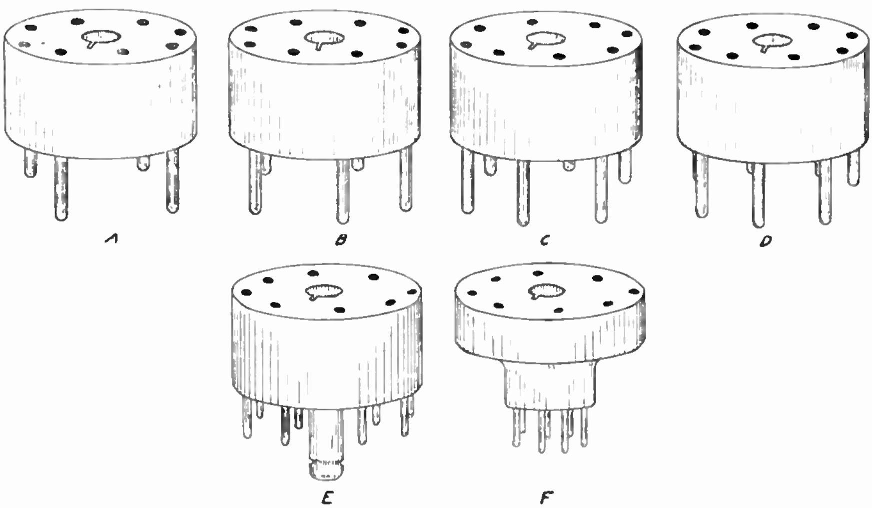
From this you can see that it is very necessary for you to be thoroughly familiar with the tube sockets—both bottom and top views—particularly with reference to the numbers of the pin holes. Many tube manuals and manufacturers service manuals list the official RMA numbers and unless you know just what is meant, you may lose much valuable time and become confused while tracing circuits. (See your ND tube lessons for information on tube pin numbers).

Many tubes employ a connection on top of the tube. This top cap is not connected to any pin on the tube socket. It, nevertheless, is an important circuit and will require just as much attention as any of the circuits connected to the tube socket. It, therefore, may be considered a special circuit and a connection is provided for it in the analyzer. The official RMA designation for this connection is TC—meaning top cap or top connection.

From an analysis of Figs. 4 and 5, you will note that since the numbers refer to the pin holes into which the pins of the tubes will fit, these same numbers also refer to the actual pins on the tubes. Thus, Fig. 4 shows the bottom view RMA numbers for both tubes and sockets. Referring particularly to tubes, the numbers of Fig. 4 apply when you are looking down on the ends of the tube pins.

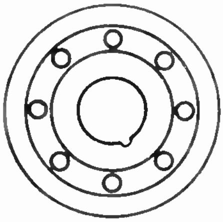
The basic circuit of an analyzer is a plug (with adapters) which will fit any tube socket, a cable with several wire leads which are soldered to the pins on the plug and an arrangement of tube sockets which will accommodate any type of tube in general use. The *elements* of a circuit of this type are shown in Fig. 6.

This is a simple parallel circuit. Note that each wire lead (enclosed in a cable) from the plug connects to the same numbered terminal on each socket. Thus all number 1 terminals are connected together. The same holds true for all terminals marked 2, 3, 4, 5, 6, 7, and 8. The TC circuit is separate. Its length from the analyzer panel is enough to permit placing it on top of any tube which may be placed in any of the tube sockets.



OCTAL PLUG ADAPTERS

FIG. 2



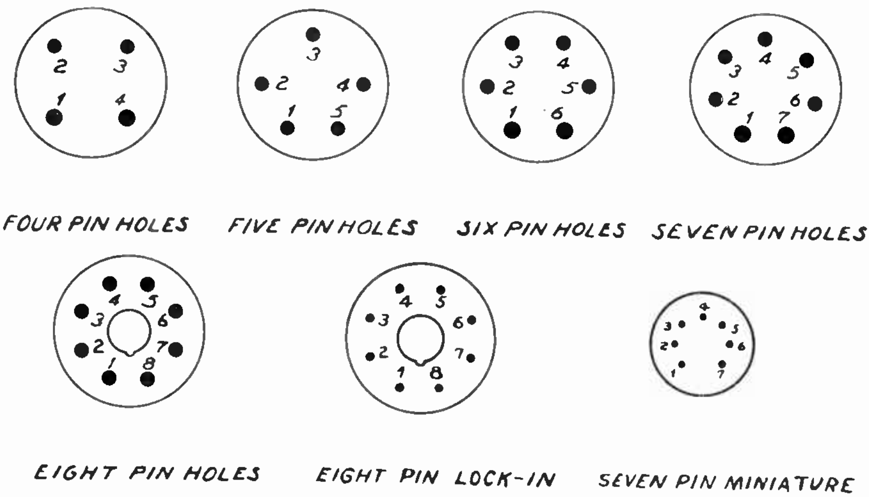
END VIEW OF OCTAL PLUG ADAPTER

FIG. 3

There are two sizes of TC connectors in general use. Sometimes the TC connection on an analyzer is a double unit (to fit either size of TC) and in other cases, the smaller size TC unit is in the form of an adapter which fits inside the larger size. Both systems permit the proper connection of both sizes of TC. The plug may be made in similar style. However, later types have both sizes of TC mounted at the top of the plug handle as shown in Figs. 1 and 6.

From a study of Fig. 6, you can see that this basic test circuit permits the circuits of any tube to be extended away from the receiver cabinet. The usual practice is to employ a wire cable from two to three feet long. This permits placing the analyzer box or cabinet on top of the receiver cabinet or on the floor while measurements are made.

The circuit of Fig 6, of course, makes no provision for measurements. *It is simply the basic extending circuit.* Figure 7 shows one type of a very simple analyzer circuit. The socket in the lower right-hand corner fits a special plug attached to the analyzer end of the cable. The five tube sockets are arranged as explained for Fig. 6. At the left end, tip jacks are provided. These are marked J1 to J8. These pin jacks are of the double contact type—that is, each one is so arranged as to permit the *series* connection of a milliammeter in each circuit. Thus when the test lead (special type with two wires) from the milliammeter is inserted into the hole of any one jack, *the circuit is automatically*



BOTTOM VIEW OF SOCKETS

FIG. 4

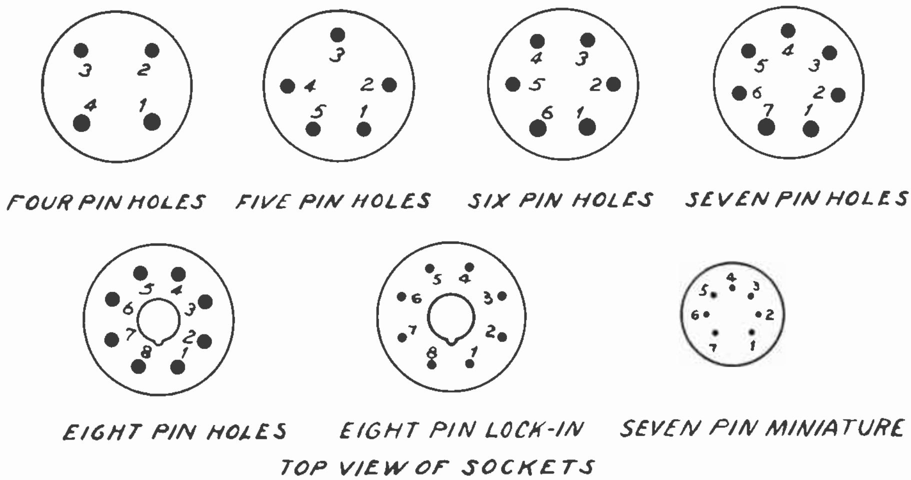


FIG. 5

opened and the meter is in series with the circuit. By connecting another type of test lead to the jacks, voltage measurements may be made.

When using a circuit of the type shown in Fig. 7, you shift the multimeter leads around by hand—that is, by inserting the leads in different tip jacks. This is sometimes a slow method but it has its advantages. In the true analyzer, the various shifting of the multimeter leads is accomplished by means of switches. Thus all measurements may be quickly made since the turn of a switch quickly connects the meter the way you want it connected. This type of circuit is shown in Fig. 8.

While at first glance this may seem to be a complicated circuit—it is not. It is a simple parallel circuit—that is, all numbers on the switches and tube sockets are connected in parallel.

The meter for this circuit is not shown simply because it is not an essential part of the analyzer switching circuit. Any multimeter circuit such as the one shown in Fig. 9 may be connected to terminals A and B of Fig. 8 to serve as the indicating instrument. The meter may be of low, medium or high sensitivity. Also, it may be incorporated as an integral part of the analyzer or it may be a separate external unit with provisions for connecting to a circuit similar to A and B of Fig. 8.

The chief difference between Figs. 7 and 8 is that in Fig. 8 three switches have been added. These make it possible to measure both current and voltage in any circuit of the analyzer. Switches S1 and S2 *are separate and independently operated.* They are of the single deck type having 10 fixed terminals and one rotating member. Such switches as these are known as the rotary type. By turning the movable member it will in turn make electrical contact to each of the fixed terminals. Since the multimeter leads are connected to the two movable members of both switches it follows that the voltmeter leads may be connected between any two circuits by setting the switches as desired. In this way the voltmeter is not limited in its application. Since the voltmeter leads are free to be connected to any tube circuit this system is often

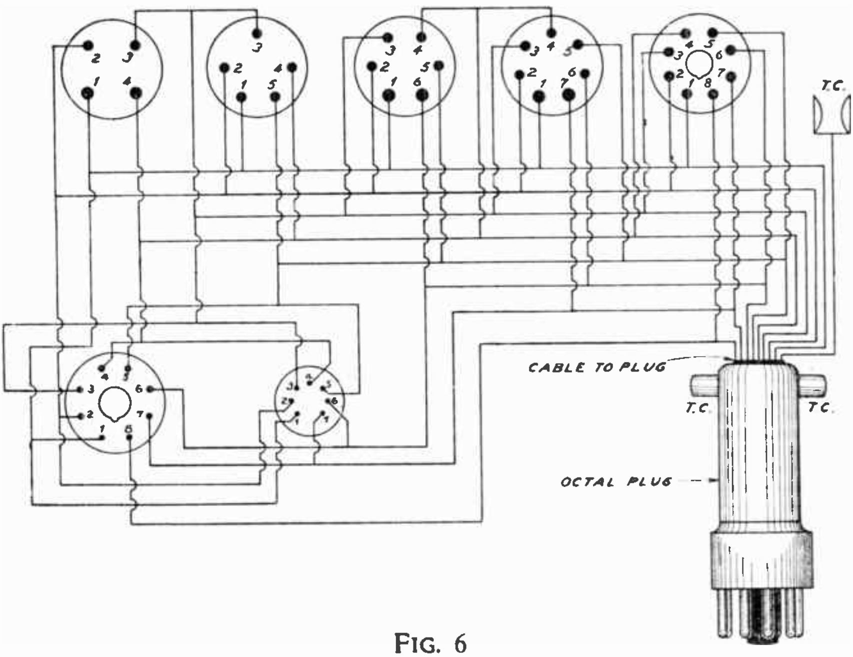


FIG. 6

called the *free reference method of connecting the meter leads.*

Thus, if you wanted to connect the voltmeter between circuits 3 and 8 (a plate voltage measurement for a 6L6 tube), switch S1 (positive meter lead) would be set to 3 and switch S2 (negative meter lead) would be set to 8. Other voltage measurements would be made in a like manner using standard RMA tube pin numbers as a reference.

In the commercial analyzer all identifying numbers and letters are engraved on the analyzer panel near the switch control knobs. Some of the commercial analyzers also provide many auxiliary measurements and may even be combined with other test units such as a tube tester or signal generator. In all cases the manufacturer's instructions should be followed.

This section of this lesson is not intended to show you how to operate all analyzers, since this is adequately covered in the manufacturer's instructions. Between the section of S3 in Fig. 8, the small circuit breakers are used to open the leads between the two sections and insert a milliammeter in the circuit.

Fundamental Analyzer Principles

Before going further, get the two following fundamental principles firmly fixed in your mind. Always remember: (1) *An analyzer connects a voltmeter across positive and negative polarities in a circuit to measure voltage.* (2) *An analyzer connects a milliammeter in series with a circuit to measure current.*

There will be more about current measurement later. To return to voltage measurements and positive and negative polarities—when a certain circuit element is referred to as positive or negative, reference is not always made to the source of power. A consideration of Fig. 10 will make this clear. A and B in this figure represent the source of power. A is positive—B is negative. Now consider from A to E with respect to B; any point between A and E is positive with respect to B. Now remember this: with respect to C, *D is negative.* At the same time D is positive with respect to E. From this it can be seen that polarity is relative and that one point may be both *negative and positive* with respect to *two different points.* This is a fundamental principle, be sure to remember it.

The point where current enters a resistance or a circuit is negative. If, then, the point where current enters a circuit is negative, the point where current leaves a circuit *must be positive.* Circuit is used in a general sense here to denote a resistance, coil or other conductor.

Another very important point to remember is that an analyzer has certain limitations as to the connection of its meters. The switches allow only certain fixed connections. (This refers to making a measurement with the plug in the tube socket. It is, of course, always possible to use the external leads of the analyzer voltmeter to measure across any two points). Usually the switching system is so arranged that the voltmeter negative terminal is connected to some one point, and all voltage measurements *are made with reference to this one point.* (Another limitation of the analyzer).

In older analyzers this reference point is usually the cathode in tubes having a cathode and to the filament in other tubes. This limits the use of the analyzer, and is a real handicap where tubes were manufactured which have their cathode connection to some pin other than the usual cathode pin. The analyzer, of course, connects the meters to the same pin regardless of the type of tube being tested (unless a free reference switching system is employed). If tube manufacturers make a tube with a cathode terminal where the grid is usually employed, *the older type of analyzer will not make proper measurements on this new tube.* In this case, where reference is made to the negative meter terminal being connected to either the cathode or filament, the circuit elements referred to are *those circuits*

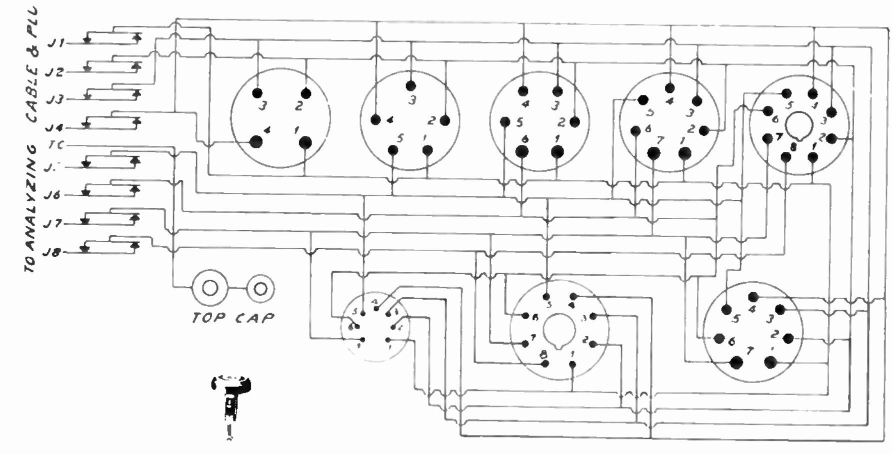


FIG. 7

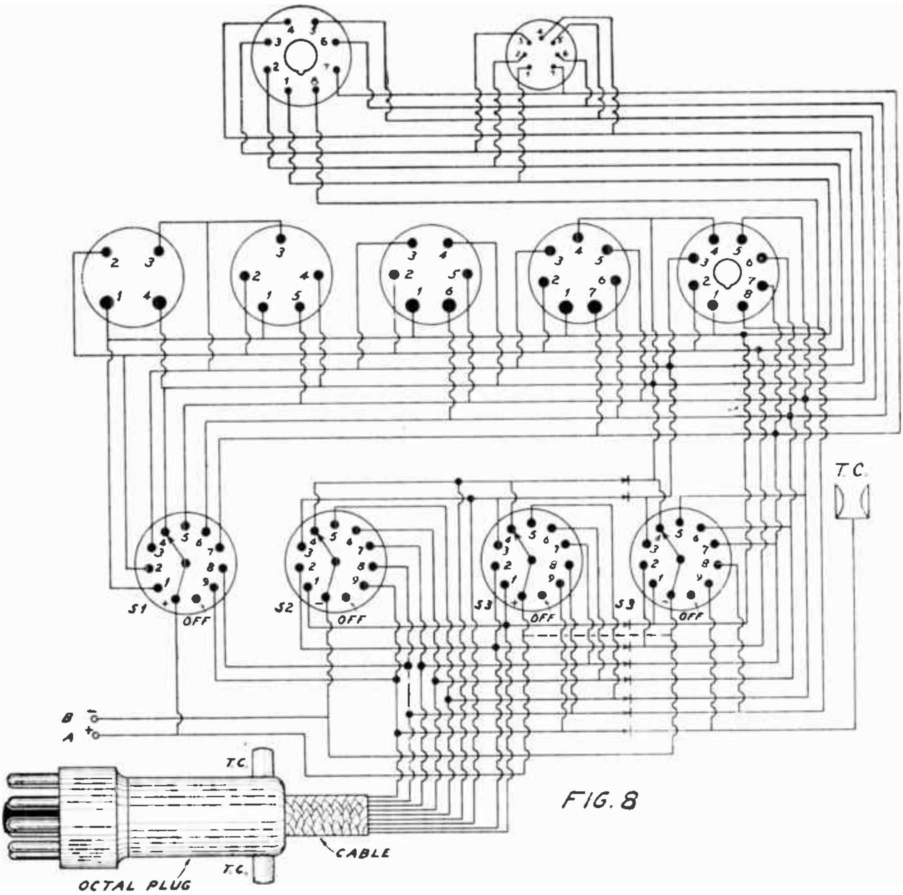


FIG. 8

usually employed for these elements.

The later type analyzers use a *free reference system.* That is, the negative of the voltmeter can be connected to any tube socket terminal and also to ground. This works particularly well with the octal base tubes, since pin No. 1 is usually a ground connection and all voltage measurements can be made using this point as a reference.

Now consider Fig. 11. Suppose you have made a plate voltage measurement on tube A, and you find it to be 180 volts. Suppose too, you make the same measurement on tube B. Ordinarily you would expect the voltage for this tube to be about the same as that of tube A, since the voltage for both tubes is applied from the same common positive circuit. If ground or the chassis is used as the common reference point, you will not obtain the same plate voltage reading for both tubes. If the separate cathodes are used as the reference points, you will still *not* get the *same reading* for both tubes. Notice the connections of these two cathodes. The cathode of tube A connects to ground (through bias resistor R1) while that of tube B connects to the voltage divider at a point which is positive with respect to the cathode connection of the other tube. Therefore, tube B will have less plate volt-

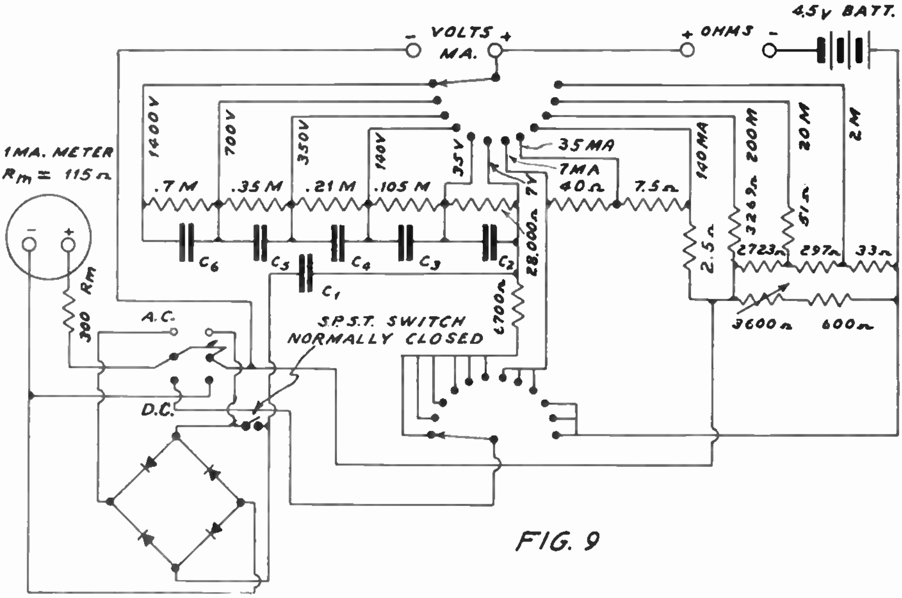


FIG. 9

age than tube A. Thus the point being used as the reference in any receiver must be taken into consideration.

This is easy to see when you study Fig. 11. However, in a complete complicated radio circuit, it might not be so apparent. You must always have it clearly in mind where the negative of the voltmeter is connected so that you will know between which two points you are measuring voltage.

Some of the older analyzers have a switch to change the negative terminal of the voltmeter from cathode to filament. In others, the change is automatic. In later analyzers, the lead from the negative terminal of the voltmeter is usually definitely made the reference point. It is arranged to connect to any of the analyzer circuits just as for switch S2 in Fig. 8. Next

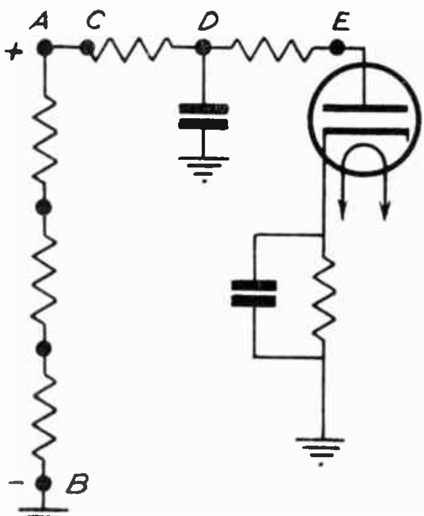


FIG. 10

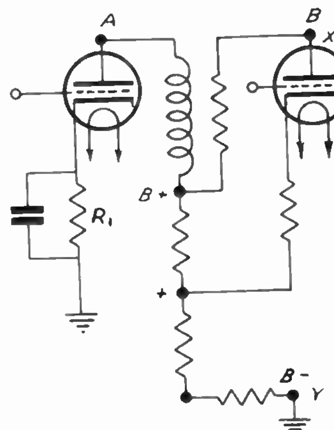


FIG. 11

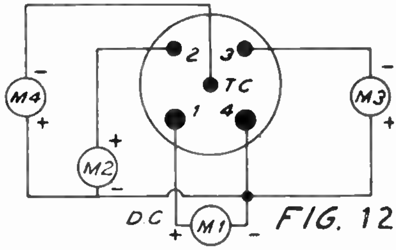


FIG. 12

consider the connection of the positive side of the voltmeter.

In general it has several variable or possible connections. It may be connected to the plate, screen grid, control grid, suppressor grid, filament or any other element of a tube circuit.

To be quick in your analysis of receiver defects, you must learn to get a mental picture of the connections of the analyzer voltmeter regardless of the measurement you are making. For instance, if you are measuring screen grid voltage on a 6K7 tube, you should immediately visualize the voltmeter as being connected between the screen grid and cathode or ground—even though you connect to pin numbers rather than to certain tube elements. When you are able to do this, you will also visualize the screen grid as positive and the cathode as negative. You should know that a voltage probably exists between these two points, and that you should be able to *measure it with a voltmeter.*

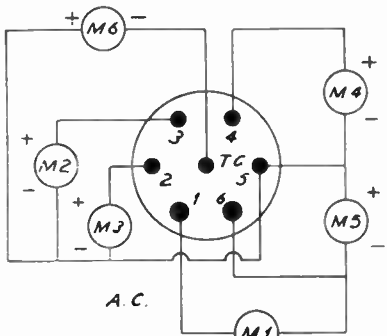


FIG. 14

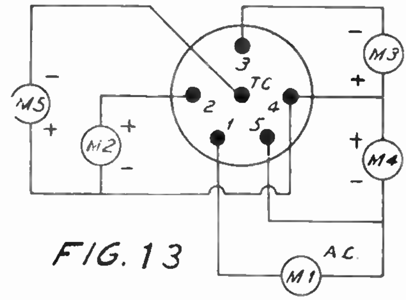


FIG. 13

In analyzers using the cathode as the common reference point, it will sometimes be necessary to connect the positive side of the voltmeter to the cathode. In this case, some method of reversing the polarity of the meter must be used. This is often accomplished by a reversing switch, although some of the earlier analyzers automatically reverse leads when testing control grid circuits of certain tubes.

If the ground is used as the common reference point for the voltmeter it is seldom necessary to reverse the leads, since it is usually the most negative point in the circuit although this is not always true. Such a case will be found in measuring the grid bias of the power tube. In the design of the receiver circuit this voltage is usually obtained by placing a resistor between B negative and ground. This makes ground positive with respect to B negative. In any case, polarity must

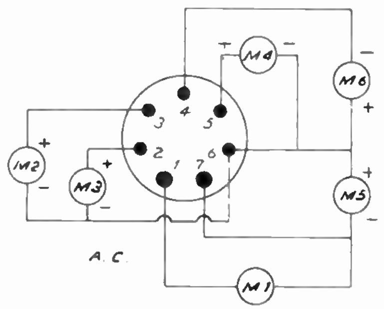


FIG. 15

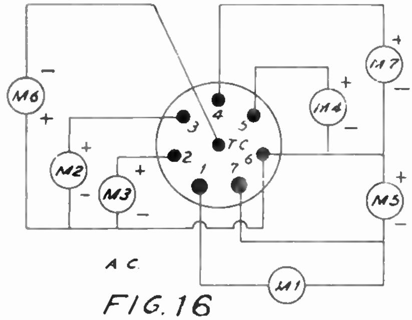


FIG. 16

always be observed when making a voltage measurement.

Thus you must have a clear mental picture of the two points between which you are measuring voltage and be sure that the voltmeter leads do not need reversing. If the leads are not reversed, the meter will try to read backward or off scale. This may damage the meter, or it may not be noticed and give you the impression that there is no voltage between the two points under test.

When the cathode or filament is used as the common reference point, the analyzer voltmeter will be connected by its switches as shown from Figs. 12 to 17. These figures show bottom views of 4, 5, 6, 7, and 8 pin tube sockets. Figure 12 shows the analyzer voltmeter connection for a 4 pin socket with polarity of the analyzer voltmeter properly indicated. M1 in Fig. 12 measures DC filament voltage. Although separate meters are shown for these circuits, in reality only one meter is used in the average analyzer. The analyzer switches connect a single DC voltmeter from *one* point to another in the circuit under test.

Note when a negative voltage measurement must be made the polarity of the meter is reversed with respect to the cathode or filament. For instance, for a plate voltage measurement the positive of the meter connects to the plate and the negative to the cathode. In a negative or control grid voltage measurement, the positive of the meter must connect to the cathode and the negative of the meter must connect to the control grid.

The socket of Fig. 16 is for all small base 7 prong tubes, such as the 6A7. Since such tubes as this have a TC connection on top of the tube, and since tubes that fit the type of socket shown in Fig. 15 do not have a TC connection, Fig. 16 will have one more circuit than 15, even though both sockets have the same number of terminals.

Not all of the octal base tubes have 8 pins although any of them will fit in the 8 hole socket. Figure 17 is for the 6K7 and other tubes, which have pin 6 vacant. However, the same principle will apply to all octal base tubes and they are not unlike other types of tubes.

Some of the older analyzers do not have facilities for making measurements on all the circuits, but a free point tester will make measurements on any receiving circuit. This type of analyzer is recommended. To make measurements on all circuits, your analyzer should have a 9 wire cable with an octal plug.

Since most present day repairing is done on AC receivers assume meter

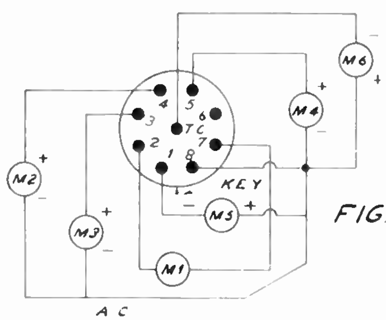


FIG. 17

M1 of Figs. 13 to 17 to be an AC meter. All other measurements for these figures are considered to be DC. In Fig. 13, meter M2 for most tubes is connected for a plate voltage measurement: M3—negative grid voltage or positive screen grid voltage depending on polarity; M4—cathode voltage (that which exists between cathode and filament) and M5—negative control grid voltage. In Figs. 14 to 17, meter M3 for most tubes for plate voltage: M4—Figs. 14 to 17 is connected for a suppressor grid voltage for most tubes: M5—Figs. 14 to 17 is connected for cathode voltage: M6—Figs. 14, 16, and 17 is connected for control grid voltage: M2—Figs. 14 to 17 is connected for screen grid voltage: M7—Fig. 16 is connected for voltage which is applied to pin No. 4.

Please understand that in modern circuits of various types, the tube elements may be connected in various ways—*a positive connection in one type of receiver may be a negative connection in another type of receiver.* In view of this, the meter connections shown in Figs. 12 to 17 might not always hold true. However, these figures do show how the analyzer normally connects the meter or meters for various measurements.

If the ground is used as the common reference point, the meter will be connected in much the same way as Figs. 12 to 17, except that the negative connections *will be to ground instead of to the cathode.* The connection of the meter to the filaments will, of course, be the same. That is, from one heater pin to the other heater pin.

It is suggested if you use an analyzer that you study Figs. 12 to 17 until you have memorized them. Then make it a practice to visualize

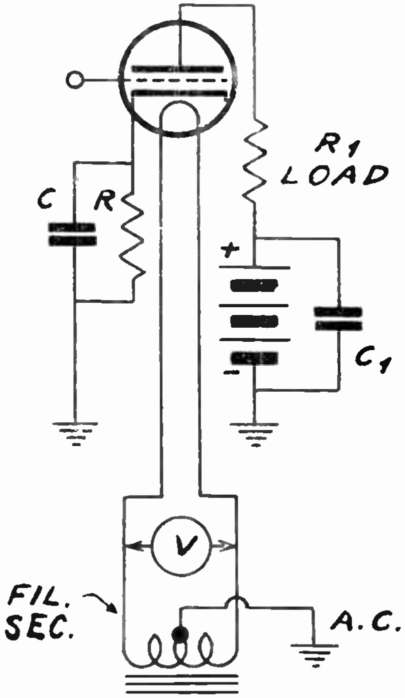


FIG. 18

the meter as it is actually connected to the circuit. This is to be done every time you use the analyzer. If you will do this, you will find your work becoming easier, and you will soon learn to name almost the exact cause of the trouble without taking the chassis from its cabinet.

Now that you understand the fundamental DC voltmeter connections as the analyzer makes them, you are ready to study the actual use of the analyzer. What follows is intended to help you interpret the analyzer readings in terms of normal or abnormal receiver operation.

Interpreting Analyzer Measurements

Note in Figs. 18 to 23, resistors are used to represent the load on the

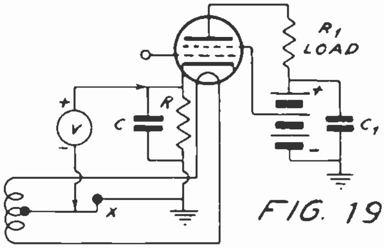


FIG. 19

plate and grid circuits. *Actually these may be coils, transformers, chokes, or any other form of impedance.* In any case, the same principles apply. The battery in these figures represents the high voltage DC power supply, while the plate by-pass condenser may represent either the filter condenser system in the power unit or one or more of the regular plate circuit by-pass condensers.

Filament Voltage

Consider Fig. 18. This represents the AC voltmeter (V) filament connection as the analyzer would make it for any type of receiver. You will be interested in what *might cause high, low or no voltage* to be indicated on the AC meter. If the meter shows no voltage, you can be almost positive the filament circuit is open. A *continuity check* (ohmmeter with test leads) will enable you to prove or disprove the diagnosis. (A later lesson will take up continuity testing). It is assumed, of course, that AC voltage is applied to the primary of the power transformer. The pilot light or the lighted tube filaments should tell if this is true. If the voltage is low, any part of the filament circuit may be shorted or grounded, or the line voltage may be low.

If the filament voltage is high, the secondary winding of the power transformer may be shorted to another secondary or to the primary, or the line voltage may be high. Make a continuity test with your ohmmeter for shorts and grounds. Use the high range of your AC voltmeter to check the line voltage. Keep in mind, however, that the primary circuit may be partially shorted or grounded, which might also cause high or low secondary voltage.

Cathode Voltage

Now consider Fig. 19. In this circuit, the analyzer meter connections are arranged for the measurement of the cathode-to-filament voltage. Again, what conditions could exist to cause *low, high* or *no* voltage? Consider low voltage first. Since the cathode voltage in this case depends on the plate current of the tube (by virtue of the voltage drop across R) a low voltage will mean low plate current. This, in turn, may be caused by decreased emission, low plate or screen grid voltage, or the rectifier tube may not be supplying sufficient voltage for the entire receiver. An indication of no voltage between cathode and filament will be obtained on the meter if condenser C in Fig. 19 is shorted, since R then will also be shorted. High cathode voltage is usually caused by an open bias resistor. Since the meter will then be taking the place of the bias resistor, and since it will likely have a higher resistance, the voltage drop across it will be greater. This will show up especially if the negative of the voltmeter is connected directly to ground. No cathode voltage will indicate one or more of the following: No plate voltage, open plate circuit, or condenser C or C1 in Fig. 19 shorted.

Control Grid Voltage

In the years gone by most tubes employed one grid only. Nearly all of the present day tubes have more than one grid. In nearly all cases,

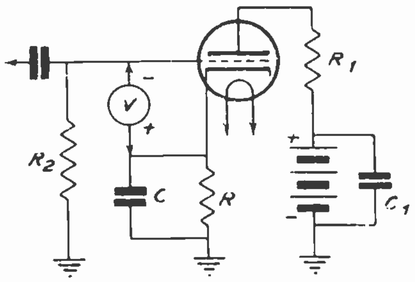


FIG. 20

one of these grids has a negative voltage applied to it. This grid, then, is the *control grid* because it controls the action of the tube. Therefore, when reference is made to the control grid, no one type of tube is referred to but rather all types, *since all amplifying tubes employ a control grid.*

Now consider Fig. 20. This shows the analyzer voltmeter connections for a control grid measurement. The tube may be any common type. In any case, the same principles apply. Analyzing this circuit, you will find that many conditions could exist to cause *high, low or no voltage.* R2 in this circuit might easily be a 500,000 ohm grid leak in a resistance coupled stage. Should this be true, would the voltmeter indicate correct voltage? *It would not.* If R2 were a *low resistance coil*, then correct voltage would be indicated. However, since, it is a high resistance, *the needle of the voltmeter will only move slightly.* If you will examine Fig. 21, the reason for this will be readily apparent. This figure gives a better electrical picture of the actual condition of a circuit arranged like the one of Fig. 20. You will now see that R2 of Fig. 20 is nothing more than a high resistance in series with the voltmeter. Now what happens when a high resistance is connected in series with a voltmeter? You will remember from one of your earlier lessons that its range is merely extended.

If the tube in Fig. 20 is a 6C5 you would not expect the grid voltage to be more than 8 to 10 volts. Therefore, in measuring it you would use the 15 volt range of your voltmeter. This would make the meter resistance equal to 15,000 ohms, if the meter were of the 1000 ohm per volt type. But note R2 is also in series with the meter, as shown in Fig. 21. This makes 515,000 ohms in series with the meter. *Thus you have automatically changed the range of the voltmeter from 15 volts to 515 volts,* (1000 ohms per volt). This same condition holds true if the measurement is made in a plate circuit, employing resistance coupling. The high resistance is still in series with the meter.

Now what happens when you try to measure a low voltage with a high range meter? If you have ever tried this, you know that the meter needle just barely moves. Thus you can get no more idea of the actual value of the voltage in the circuit than before you made the measurement. Consequently, you can see even though you make this measurement, it does not mean anything. Yet, under normal conditions, the true and correct voltage is

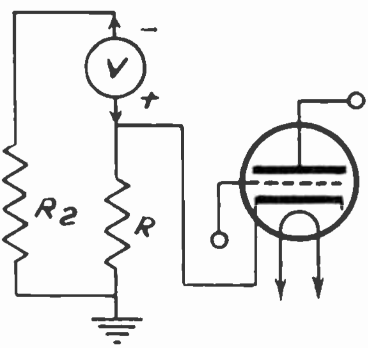
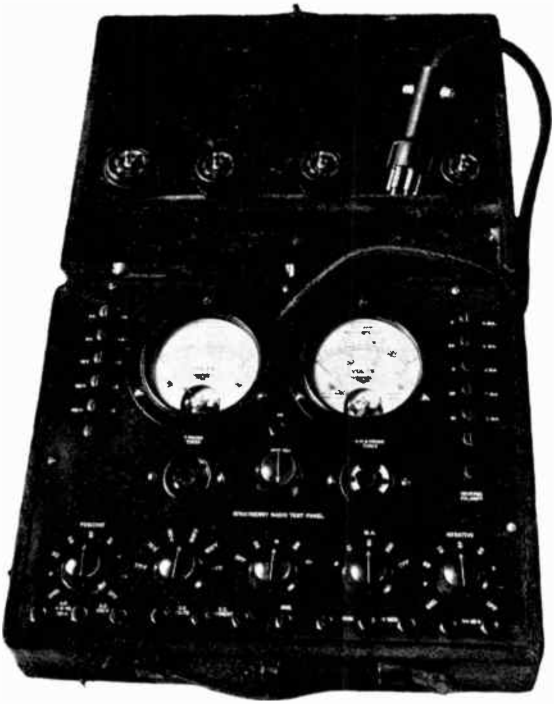


FIG. 21



This is another view of an analyzer. This one employs two meters. It is a revised version of the Jewell 408 and 409 models. Plans for the construction of such models as this are no longer available. Each serviceman will need to work out his own design if he plans to use such a unit.

actually applied to the control grid. This could be proven by shorting R2 and making the measurement, or you can use the external leads of the voltmeter and measure the cathode voltage across R in Fig. 20 or 21 which is the same as measuring the control grid voltage. This limitation may be overcome by using a meter with a higher internal resistance or by using a vacuum tube voltmeter as will be explained in a later lesson.

It is quite possible that C of Fig. 20 may be shorted. This, of course, would result in no control grid voltage. However, with an analyzer you can prove whether or not C is shorted. Simply switch your milliammeter in the circuit to measure the plate current. If current is high (above normal) you can be sure C is shorted. This is true because R will also be shorted which means the tube will not have a negative voltage.

If R of Fig. 20 happens to be open and a control grid measurement is made, the meter will show a very high value. The reason for this is that *the voltmeter is taking the place of the regular bias resistor.* The moment the meter is connected across the circuit, the cathode circuit is completed, and a small current flows through the tube (limited by the resistance of the meter). This same current in turn, also flows through the meter, and since it is a high resistance, a large voltage drop occurs across it. Therefore, you will get a very puzzling condition of high control grid voltage. The problem becomes more puzzling when a plate current measurement is made, for the meter will show no current. Whenever you have a condition of *high grid voltage* and *no plate current,* then you may be positive the bias resistor is open.

Another common condition—the plate current is high and the control grid voltage is positive instead of negative. Where this condition is met, always check the coupling medium ahead of the control grid circuit in question. The chances are this coupling device is leaking current, causing a positive voltage from the preceding plate circuit to be applied to the following control grid circuit. Consideration of Fig. 22 will make this clearer. Suppose C is leaking a DC current. If the voltage drop across C is greater in value than the negative

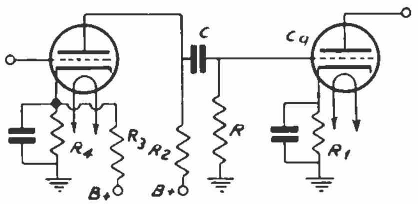


FIG. 22

voltage applied to Cg, the Cg will become positive. The plate current of the tube becomes high and R1 may burn out. R may also burn out under this condition. Current leaking through C must start at ground, and its only path is through R. This resistance (R) as a rule is not made to carry DC current. Therefore, it begins to heat and soon burns out. This opens the control grid circuit, resulting in a blocked tube—a condition where little if any plate current flows. Thus, you readily see that if C leaks in Fig. 22 or in a similar circuit it may cause both R and R1 to become open. Remember that the current leak is not necessarily through a condenser. This condition could occur in any stage employing any type of coupling.

Such circuits as Fig. 22 present another common problem with reference to R3 and R4. There is always a current flow through R3 as long as the cathode circuit to ground is complete. Thus, not only the plate current of the tube, but also the bleeder current through R3 serves to produce a voltage drop across R4. Should R3 become open, grid voltage will be low and plate current will be about normal. Thus there is the condition of low control grid voltage—yet the entire plate circuit is complete. The remedy, of course, would be to replace R3.

There is another condition to consider in this or a similar circuit. The tube may be so weak that it will not draw current or the plate circuit may be open, yet voltage can be measured across R4. The reason for this is that there is a bleeder current through R3, and, therefore, causes R4 to produce a voltage drop which results in a negative voltage being applied to the grid of the tube regardless of whether or not plate current flows.

When ground is used as the common reference point, the measurement of Cg voltage cannot be made in the usual way. The reason is that the Cg is nearly always at ground potential, and is negative with respect to the cathode because the cathode is positive with respect to ground. Although there may be a resistor between the Cg of the tube and the ground, there will be no voltage drop across it, because normally there is no grid current flowing. Thus the grid will be at ground potential. In other words, the voltmeter must be connected between control grid and cathode to measure a control grid voltage.

Plate Voltage and Plate Current

Figure 23 shows how a typical analyzer connects the meters for plate voltage and plate current. The same

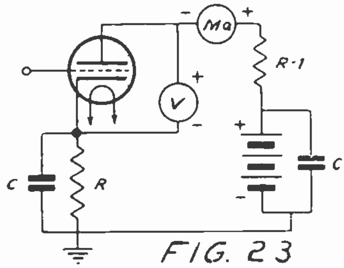


FIG. 23

meter may be used for both measurements with switches changing its connections. It is always a good plan to use the highest range of the milliammeter first. This gives protection to the meter should a short or other condition exist that would cause a high current. You can always use lower ranges once you know the current is normal.

It is a good plan to take a final reading of plate or screen grid current on the meter range that provides the greatest needle swing. For instance, if the current value is about 20 milliamperes, and there is a current range of 25, then use the 25 milliampere range. This makes reading of the meter much easier and more accurate.

The cause for low plate voltage may be difficult to find. The reason for this is that any short in the entire receiving circuit will cause a low plate voltage measurement. For instance, R1 or C1 of Fig. 23 may be only slightly grounded or shorted—yet it will be enough to cause low voltage and may cause you to go over the entire circuit before you find the defect.

There are usually one or more bypass condensers associated with the plate circuit, either in the receiver proper or across the voltage divider in the power unit, and as these often puncture or break down, the result will be a reduction in the value of the applied voltage because it short circuits the power supply.

Then again, a resistor is usually used to reduce the plate voltage to the correct value, and if this becomes grounded or the condenser across it becomes shorted, the voltage will be lowered or there will be no plate voltage at all.

You will not always find the trouble in the stage under test. In most receivers, several tube circuits are *common* with respect to their connection to the source of voltage. Consequently, a ground or short in another stage common to the one under test may be causing the trouble.

High Plate Voltage

High plate voltage may be caused by one or more weak tubes (due to the fact that they don't draw current, and as a consequence, the plate voltage rises due to the regulation factor of the power unit) or an open in the plate circuit proper, or an open in the cathode circuit. If, in Fig. 23, resistor R becomes open, a plate voltage will not be measured by connecting the analyzer voltmeter from plate to cathode. However, plate voltage will be indicated if the analyzer meter is connected from plate to ground.

If the plate circuit is open, no plate current will be indicated on the milliammeter. The open may be in the cathode resistor or its circuit. A continuity test will show whether it is between the source of power and the tube socket. If the cathode and plate circuits are complete from the tube socket to the source of power, then the defect must be in the power unit itself.

If DC voltage cannot be measured on any of the tubes, examine the center tap to the high voltage winding and the B+ lead to the rectifier filament circuit. Either one of these connections may be poorly made or the circuit may be entirely open.

Other Grid Voltage Measurements

Figure 24 shows the analyzer connections for a tube employing one or more extra grids to which a positive voltage is applied. R is a voltage reducing resistance connected from the power unit to the screen grid circuit. If C shorts, excessive current is forced to flow through R. Under such conditions, R usually burns out. Thus it may be necessary to replace both R and C to get normal operation again. R2 in Fig. 24 is a resistance often used in such circuits to provide bleeder current for R3 and R4. This, in turn, causes a large voltage drop across R3 and R4 which is applied to the Cg of the tube. If C3 shorts, excessive current flows through R2 and may burn it out. C4 is not likely to short because low voltage is applied to it, but if it does short, there will be no Cg voltage. If your meter shows no screen grid voltage, R is open or condensers C or C1 is shorted, provided voltage is available at the power unit voltage divider.

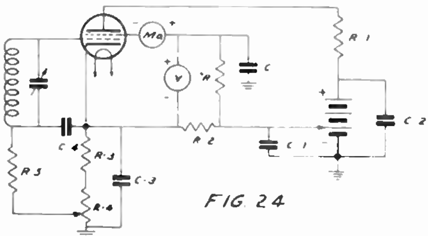


FIG 24

R5 and C4 in Fig. 24 comprise a filter circuit. If R5 becomes shorted, it may not affect receiver operation. However, if it becomes open, there will be no Cg voltage. Bear in mind that R2, C3, R3, R4, R5, and C4 *may be common to several* other cathode circuits, and, therefore, the defect may be in one of these circuits even though it shows up in the circuit you are working with.

This brings up the point of considering the effects of an abnormal condition in one circuit showing up in another circuit. For instance, there may be the condition of low screen grid voltage. This affects both plate current and Cg voltage. Again there is the condition of high plate voltage which will cause high plate current and high Cg voltage. Thus, it is easily seen that you should not be too hasty in the final diagnosis of the trouble. After all, the analyzer does not always indicate the exact defect. Your experience and the analyzer readings may indicate strongly a certain defect—yet you can never be sure until you have made careful continuity tests on the parts suspected of being defective.

Current Measurements

The ideal analyzer should be capable of measuring the current in any tube circuit. Nearly all analyzers are so equipped although many of the older models could measure current in only one or two circuits. Much dependence can be placed on the current measurements—for they nearly always give a true indication of the actual conditions in a circuit.

Fig. 25 represents a power tube in a transformer coupled stage. A milliammeter is placed in all circuits except the filament. (An AC ammeter would also be desirable in this fila-

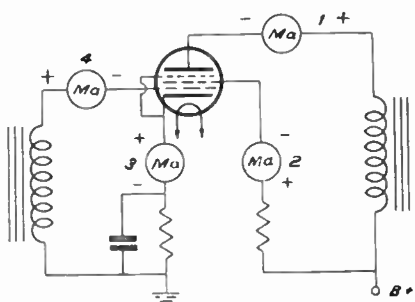


FIG. 25

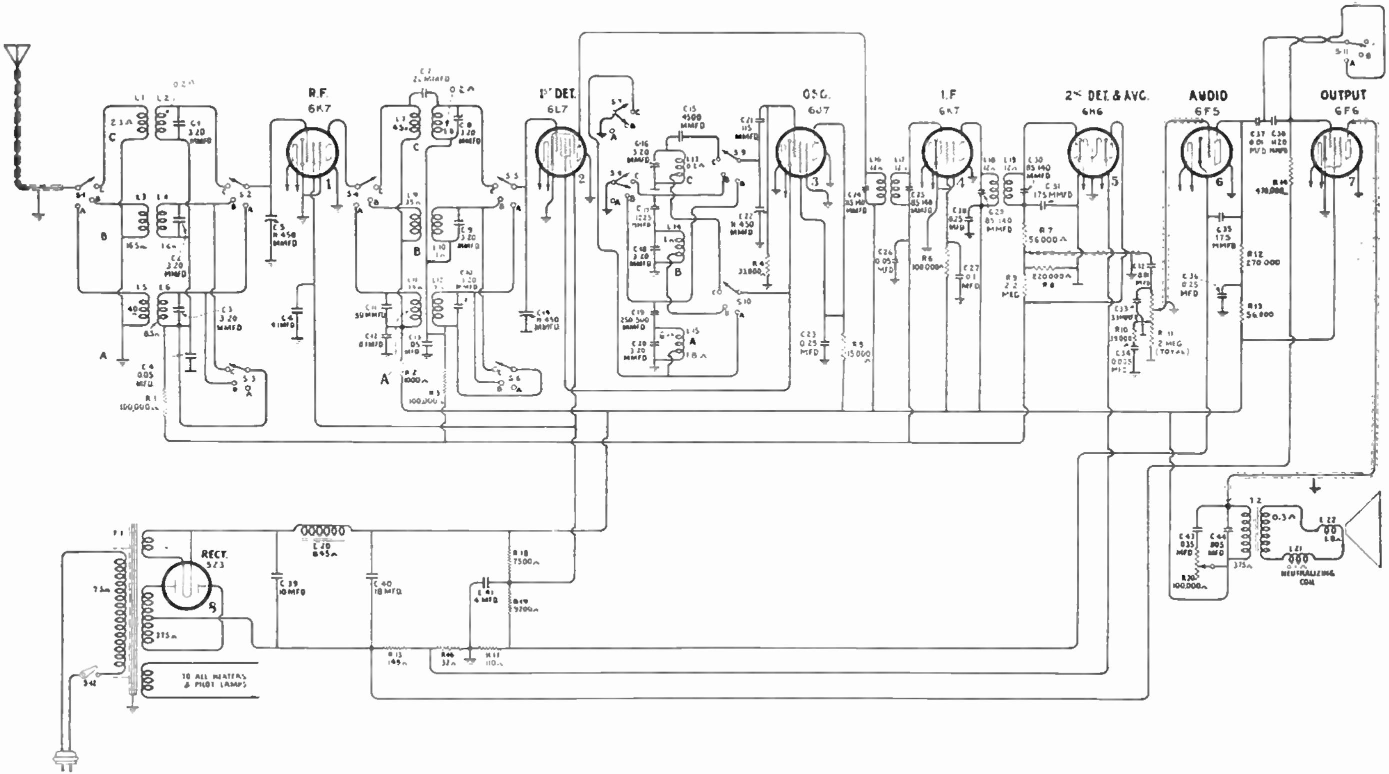


FIG. 26

NOTE: CAPACITOR C-33 IS CONNECTED TO TAP ON VOLUME CONTROL AND NOT TO GROUND AS INDICATED.

ment circuit to indicate any fluctuation of current in this circuit.) Since a current meter must always be in series with a circuit, you will immediately know whether the circuit is complete from the negative of the power unit to the positive of the power unit—no current registration on the meter means the circuit is open. You will also know that the circuit is not grounded or shorted if normal current flows. If it were grounded, the meter circuit would be shorted—consequently, there would be no current in the tube element circuit under test.

Meter 1 in Fig. 25, measures the plate current and indicates if the entire plate circuit is complete. Meter 2 measures screen current, and indicates if this circuit is complete. Meter 3 measures the combined plate and screen currents (cathode current), indicating if these two circuits are complete. Meter 4 is not always necessary—yet it is desirable, especially if the grid is drawing current. At least if the grid does draw current, you will know that this circuit is complete. Most analyzers provide current measurements for the plate and screen circuits. If your analyzer does not provide for all current measurements, and you are interested in measurements for meters 3 and 4, you can always connect the external leads of your milliammeter in series with these circuits to get the current values.

Rectifier Circuit Tests

Rectifier tests will tell much about the conditions in a receiver if the readings are interpreted properly. The usual test with the rectifier tube in the analyzer socket includes AC plate voltage and DC plate current measurements. The AC voltage test indicates if correct AC plate voltage is applied, if the same value is applied to both plates, and whether or not the high voltage secondary is grounded, shorted, or open. If there is a ground or short circuit, voltage will be abnormal. If there is a ground, short, or open, it is usually necessary to replace the power transformer (but make a continuity test of its windings to be sure about the condition of the transformer).

The DC plate current measurement of a rectifier is the most important because the rectifier plate current has a direct relation to all other DC measurements in the entire receiver. If your voltage measurements on the other tubes show a low value and the rectifier plate current is low, the chances are the rectifier tube is weak and needs replacing. On the other hand, if plate voltage on the other tubes in the receiver is low and the rectifier plate current high, you may be sure that a ground or a short circuited positive circuit exists in the receiver at some point.

MULTIMETER TESTS

In the multimeter method of testing, the same fundamental measurements are made as in the analyzer method. However, the accomplishment of the actual measurement by this method is much different than when employing the analyzer. When using the multimeter, you make the actual meter connections yourself by hand. By the other method, meter connections are made by the analyzer switches. The meter connections of the analyzer may be limited in their application, whereas in the multimeter method there is *no limit* to the connections you may make. This is the method employed by radio men in laboratories and in research departments of receiver manufacturers. Since this method is employed by those who make the most exacting tests, perhaps you, too, can use the multimeter method of analysis to advantage.

The primary purpose behind any method of receiver analysis is to *locate defects quickly* and accurately. The exact method employed is not so important as the actual location of the defect, and the quick repair of it.

In the preceding discussion, you studied about the analyzer method. In this part of the lesson you are going a step farther and study about measurements on actual parts of the receiver circuits, or more particularly about measurements to be made at the *work bench*.

To be able to employ the test method to be described, the serviceman will require an AC voltmeter that will measure all values of transformer voltages, either high rectifier plate voltages, or filament voltages in common use, a multiple scale DC milliammeter and a multiple scale DC voltmeter. These may be separate meters or they may be contained in one unit such as a multimeter.

Voltage Analysis

In Fig. 26 is shown the diagram of an RCA receiver model T8-14 and C8-15. This is an 8 tube superheterodyne, using metal tubes and has three frequency bands. This circuit will be used as an example of a typical receiver. The discussion of testing by voltage analysis will refer to this receiver. The same method can be applied to any receiver, whether superheterodyne, TRF, battery operated, DC operated or AC operated.

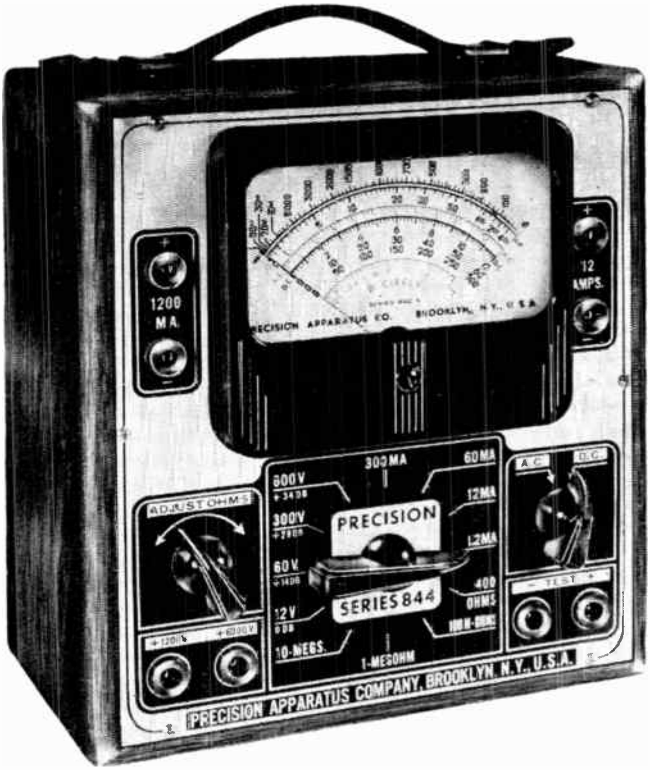
You should have meters with the previously mentioned ranges, and of good quality. The DC voltmeter should have a sensitivity of 1000 ohms or more per volt. You will also want test leads and a soldering iron, since you may want to make and break several connections.

The test instructions which are to follow are best suited to the shop or test bench. However, the same principles are also applicable and may be practiced in the home of the receiver owner. In this case, however, it becomes necessary to make a work shop of the owner's home, which to say the least, is to be avoided whenever possible.

Assume the chassis is turned upside down before you ready for testing. Since there are so many things that could be causing trouble, assume that the entire receiver is dead and that any part may be at fault.

First measure the AC line voltage. Turn on the power and place the AC voltmeter test leads across the primary terminals of the power transformer. If you measure voltage of correct value, you may assume that voltage is applied to the primary. This, of course, does not indicate if the primary is open. However, if the tubes and the pilot light are lighted, you will know without testing the primary that it is not open. There is a possibility that the primary may be grounded or shorted, but other DC measurements that will be described will indicate if this is true. If you find everything else in the receiver to be in good order, yet abnormal voltage is measured, you will know that the trouble is in the primary circuit, and a detailed continuity test will indicate exactly where the defect is located.

After making voltage measurements on the power transformer primary, consider the secondary voltage measurements. Using an appropriate voltage range of the AC voltmeter, measure the rectifier filament voltage



The above photo shows a modern multimeter employing several scales. The selector switch in the center permits the selection of the different ranges. Note the use of four pairs of jacks for different measurement functions. Test leads are inserted into these jacks and they in turn are connected to the circuit under test by hand. Courtesy of Precision Apparatus Co.

by placing the test leads across this circuit—Fig. 26. If you find low, high, or no voltage, give the complete circuit a detailed continuity test for ground, shorts, and opens. Do the same thing for the 6.3 volt or other filament circuits. It is not often that you will have trouble with the filament circuits unless there is a burned out winding on the transformer. In this case, replace the entire power transformer.

Next consider the high voltage AC circuit. Using the high range of the AC voltmeter, connect your test leads across the two plates of the rectifier tube socket. Suppose you find the voltage to be 670 volts. Next measure the AC voltage between the center tap of the high voltage winding and each plate of the rectifier. There should be approximately 335 volts across each circuit. Note that this is one-half the total AC voltage applied to the rectifier plates. See Fig. 27. By making this last measurement, you check both halves of the high voltage winding for opens, shorts, and grounds, all in one operation. If there is anything wrong with either circuit between the center tap and the plate terminals on the tube socket, the voltage for the two circuits will be unequal. If you find it to be unequal, check the circuit for continuity between the transformer terminals and that part of the circuit to which these terminals connect.

If your tests prove the defect is in the high voltage winding, replace the entire transformer. Remember that this test and other similar tests de-

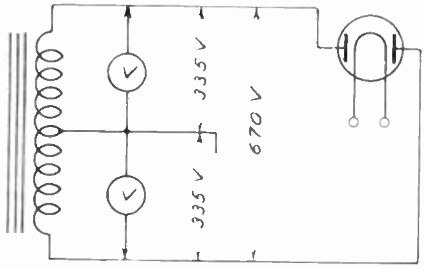


FIG. 27

scribed in this lesson apply to all receivers, and are fundamental tests that you will often be required to make.

Direct current voltage measurements are next in order. The greatest DC voltage value in a receiver is that which exists between the rectifier filament circuit (or cathode) and the center tap of the high voltage winding. Always remember that all other DC voltage values in the receiver should be less than that across the output of the rectifier.

Fig. 28 shows the power unit circuit of Fig. 26. Suppose the 10 mfd. condenser across the output of the rectifier was shorted or was excessively leaking current. In this case, voltage throughout the receiver would be low. A quick way to check this condenser for shorts or excessive DC leakage is as follows: First connect your DC voltmeter between the rectifier filament circuit and the center tap of the high voltage winding as shown by meter VI in Fig. 28. Note the value of the voltage. Then unsolder one of the 10 mfd. condenser leads. If the filter condenser is shorted or excessively leaking current, the voltage across the output of the rectifier will now be considerably higher, and the hum level may increase.

Some rectifier circuits employ three or four filter condensers. Any of these may become shorted or they may have excessive leakage current. In any case, this voltage method of measurement will enable you to determine if any of the filter condensers are at fault.

Now, if one of these condensers should be open, it will not affect the DC voltage to a large extent. It is true that if the input filter condenser becomes open, you will have, in effect, a choke input filter system. This type of filter gives a lower output voltage than the condenser input type. Therefore, if you know from previous experience what the output filter voltage should be, then you have a clue that one or more filter condensers may be open. There is another important angle to consider in this connection.

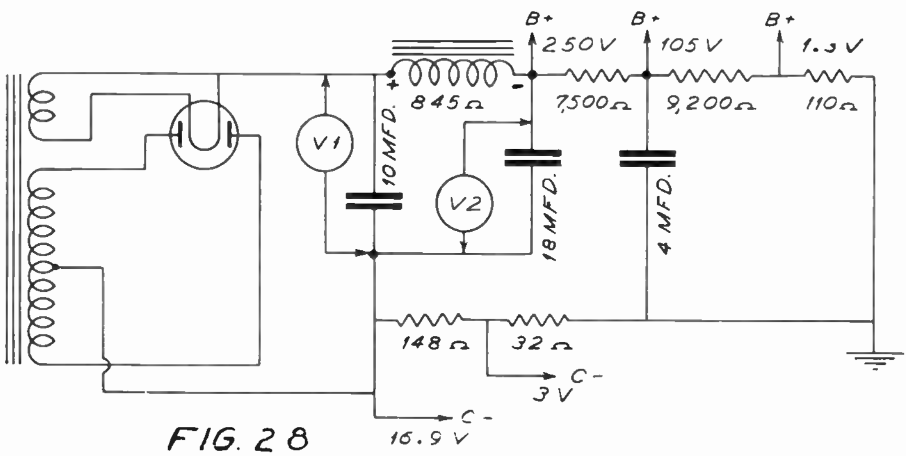


FIG. 28

Usually a filter system with a choke input is so designed that there will be minimum hum. However, if the input filter condenser of a *condenser input filter* system becomes open, excessive hum will result, since the inductance of the input is not designed to minimize the hum without the help of the condenser. This angle, then will give you another clue that the input filter condenser is open.

Another more positive way of testing any of the filter condensers in a filter system for opens, is to connect the DC voltmeter in parallel to the condenser suspected of being open. Then disconnect one of the filter condenser leads. If disconnecting the condenser *does not change the voltmeter reading appreciably*, then you may be sure the condenser is open. This test holds true for both paper and electrolytic filter condensers. In this connection, if the condenser is shorted, the voltage reading will increase considerably when the condenser is disconnected. The voltmeter test connection for opens and shorts of condensers is shown in Fig. 28 where the voltmeter (V2) is shown in parallel with the 18 mfd. condenser.

Bear in mind, however, that this test does not hold true for small bypass condensers in the receiver proper. It holds true only where the condenser regulates the DC voltage, and in most cases, the only place where this is found is in the power unit.

So much for the test on filter condensers. Consider next tests on the inductance or the iron core choke coil. This filter system (Fig. 26 or 28) uses only one choke coil, which is the speaker field. Many power unit filters, particularly in the older receivers use two or more chokes and often one of these is the speaker field. The choke may be connected in either the positive or negative lead of the filter. That is, most receivers have the choke connected as shown in Fig. 28. Other receivers have the choke connected between the high voltage center tap and ground. The same test principles apply in either case.

If the choke is in good order, there will be a voltage drop across it, however small it may be. Do not let a reverse reading on the voltmeter cause you to think you have no reading. Remember that it is absolutely necessary to *observe polarity* when measuring the voltage drop across receiver parts. The polarity of the filter choke is shown in the diagram of Fig. 28.

A short can exist across part of a choke coil and yet the voltmeter will show a reading. Thus the mere fact that you can measure voltage across a choke coil is not an absolute indication that the choke is in good order. You should remember, however, that ninety-nine times out of a hundred, the choke is not likely to be shorted internally. When there is a shorted filter choke coil, it is very difficult to determine it unless you know what its exact resistance should be. If you do know the rated value, you can measure the resistance of the choke with an ohmmeter.

The DC resistance of a choke, and the current flowing through it, determines the amount of voltage drop across the choke. This value will, as a rule, be low. The DC current through a choke might be 40 milliamperes. If the choke has a resistance of 200 ohms, the voltage drop across it will be 8 volts. Suppose a filter condenser shorts and causes an additional 40 milliamperes to flow through the choke. The voltage drop in this case would only be 16 volts. Therefore, you see it is important to use a low range accurate DC voltmeter when measuring the voltage drop across iron core filter inductances. On the other hand, a speaker field winding may have a resistance as high as 5000 ohms. In this case, the current through the winding is always low. A representative case is 16 milliamperes flowing in the 5000 ohm field. The voltage drop across the choke in this case will be 80 volts.

If a power unit filter choke coil is open there will be no DC voltage on any tubes of the receiver, and no sound from the speaker. If you suspect a choke of being open, connect the negative terminal of the voltmeter to the center tap of the high voltage winding (Fig. 26) and then connect the positive terminal of the voltmeter to first one terminal of the choke and then the other. A reading in one case, but not in the other, will indicate an open choke. By the simple tests described in the foregoing, it is possible to determine the condition of the parts in the power unit filter system up to the output of the filter or to the point where voltage is distributed to the various circuits by means of the voltage divider.

From the output of the filter to the plates and grids of the various tubes there are several parallel paths over which current will flow. Since current will be flowing in most of the various circuits, any receiver part having an appreciable DC resistance will probably show a voltage drop when the voltmeter is connected across it. This is an important point to remember, since it forms the basis of the multimeter method of testing. As long as you can measure a voltage drop across a receiver part, you can always form a fairly accurate idea of the condition of that particular part. This will become clearer as you proceed further with this study.

In using Fig. 26 as the example, all tests will be made assuming the range switch is turned to band A. Tests on other bands can be made in the same way. However, further details on testing the other circuits are left to a later lesson on all-wave receivers.

Suppose in your preliminary measurements, the voltmeter showed no plate voltage on the plate of the RF tube. Several things could cause this condition. For instance, the plate coil may be open or the plate by-pass condenser may be shorted. To locate the defect, connect your voltmeter between the plate and cathode circuits of the first RF stage as shown in Fig. 29. This circuit shows the first RF stage of Fig. 26. It is again repeated here so as to make the connections clear.

Now take a short piece of wire and short the range selector switch which connects this coil to the plate. If you now get voltage, this switch is not making contact. If it makes no change (no voltage registers), you can assume this switch is making proper contact between terminals.

Next take a short piece of wire, and short the plate coil for band A. If the voltmeter now shows normal voltage, the plate coil is open. If you still have no voltage, remove one lead of the .1 mfd. plate by-pass condenser, C12. If you get voltage this time,

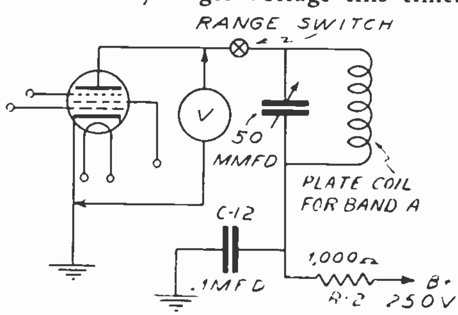


FIG. 29

it proves the plate by-pass condenser (C12, Fig. 26) is shorted and will, of course, need replacing. If, on the other hand, there is still no plate voltage, any part connected between the power unit and the plate by-pass condenser may be at fault. From Fig. 29 note that the only part between the plate by-pass condenser and the 250 volt B+ lead is the 1000 ohm resistor (R2). Shorting this resistor will indicate whether it is open by the fact that voltage will appear at the plate terminal if it is open.

Since you establish, by other tests, that the power unit is functioning properly, you will know when you have tested up to the 250 volt B+ tap, there is nothing wrong with the plate circuit from the power unit output to the plate of the tube socket under test. Therefore, the cause of no voltage has got to be in the cathode circuit. In Fig. 26 about the only thing that could cause no plate voltage in the cathode circuit is an open resistor between the center tap of the high voltage winding and ground (R15, R16), since the cathode is itself grounded at the tube socket. Shorting these resistors, one at a time, with a piece of wire will determine if they are open. and the cause of no voltage. Since these resistors are common for all DC voltages, you will not need to check them again. Remember any tube socket terminal may be open or not making contact (such as cathode to ground), although this is unusual.

Many circuits employ a bias resistor between cathode and ground. If this resistor is open, and the voltmeter return is connected to cathode. no plate voltage can be measured. Connecting the voltmeter negative terminal to *ground* will at once indicate that this resistor is open provided voltage is indicated. Therefore, it is recommended when making these tests you connect the voltmeter negative terminal to ground if the cathode is not directly grounded.

In connection with a lack of plate voltage, it has been pointed out the many places where *defects could exist.* Bear in mind, however, that the chances are you won't find it necessary to make all the tests which have been outlined, because defects as a rule exists at only one or two points. You can, therefore, readily see that by simply connecting your voltmeter between plate and ground, using a piece of wire to short-circuit parts and with the occasional use of the soldering iron, determine what part of the circuit is open or shorted. This, of course, is done *without having to disconnect parts,* and then making a detailed continuity test on parts to determine if they are defective.

You will find many circuits where some parts are common to several tubes. Thus an open in one part will cause a lack of voltage on several tubes. On the other hand, an open in another part may cause a lack of voltage on only one tube. An example of this is shown in Fig. 30. If R1 opens, no voltage will be measured on any of the tubes with the voltmeter negative terminal connected to the tube's cathode, but voltage will be indicated *when the voltmeter negative terminal is connected to ground.* If R2 becomes open, all voltages will be about normal except the screen grid voltage on the first and second tubes. If R3 becomes open, all volt-

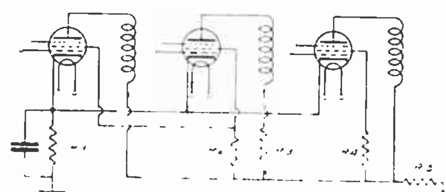


FIG 30

ages will be normal except the plate voltage on the second tube. Likewise, if R4 becomes open, all voltages will be about normal except the screen grid voltage on the third tube. If R5 becomes open, there will be no plate or screen grid voltage readings even with the voltmeter negative connected to ground.

There is a different way of making these same tests. Refer again to Fig. 29. Connect the voltmeter from ground to 250 volts B+. This should give a reading of 250 volts. Now leave the voltmeter negative terminal connected to ground, and move the positive voltmeter lead to the plate side of the 1000 ohm resistor. If the 1000 ohm resistor is normal, you will get a voltage reading somewhat lower than 250 volts. How much smaller will depend on the value of the resistor and the voltage drop across this 1000 ohm resistor.

In Fig. 26, this will only be a few volts. However, if the .1 mfd. condenser is shorted, excessive current will be flowing and a large voltage drop will exist across R2. Probably the 1000 ohm resistor would burn out and no voltage would be registered under this condition.

If all parts so far tested are in good condition, move the voltmeter positive lead to the plate side of the plate coil. If voltage is not registered, the coil must be open, or if there is a voltage reading, the 50 mmfd. trimmer condenser may be shorted, while the plate coil may be open. This, however, is very unlikely. Tests to check against this can be made by disconnecting one lead of the 50 mmfd. condenser.

It should be clear to you that these basic test principles do not apply to Fig. 26 only. All the tests described in this lesson apply to all receivers. The principles are fundamental; and are, therefore, of the utmost importance. Don't fail to get these test principles firmly fixed in your mind. If they are remembered, you will be well repaid for your study of this lesson.

Remember too, that this part of the lesson is not limited to RF plate circuits only. It applies to all plate circuits regardless of their type. All such circuits employ coils, chokes, resistances and condensers. Therefore, by using this basic method you can easily determine the condition of parts in the detector and audio plate circuits.

Other circuits can be tested in the same way. Simply trace out the individual circuits, test all parts through which current must pass to reach the elements of the tubes and check all condensers which may break down and short the DC voltage to ground.

Whenever an abnormal reading is indicated, study the diagram of the circuit, and try to reason what could cause this abnormal reading. It may be high, low or no reading at all may be noticed. However, a simple volt meter connection will indicate the condition of any individual part.

You will find cases of resistors in parallel which will give a misleading reading. Or you may find a condenser shorting so as to make a parallel path for the current. In a case like this, it will be necessary to break one of the parallel circuits in order to get an indication of the condition of the parts.

The general procedure you should follow when servicing a receiver by the analyzer and voltage or multimeter methods has been outlined. Specific applications of these methods on the many different types of receivers you are called upon to service will depend more or less on yourself. You should train yourself to apply the instructions of this lesson to your work.

Not every receiver you service will have the same circuit structure as the one you have studied in this lesson. Therefore, you are urged to learn the *test principles* thoroughly. It is the principles of the tests you study that you should strive to remember rather than the specific tests being described. Once you learn the principles, you will not have any difficulty in applying the knowledge you have gained from this or other lessons. For instance, you know that connecting your voltmeter across a resistor (which would normally have current flowing in the circuit) will indicate if the resistor is open. Such a measurement is fundamental. Therefore, do your utmost to remember and make use of these fundamental tests.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers.

QUESTIONS

No. 1 What is the purpose of the two section switch S3 in Fig. 8?

No. 2 If a point in a circuit measures positive with respect to ground, does this mean that it will be positive with respect to any other point in the circuit?

No. 3 In Fig. 22, if the first tube to the left was removed from its socket, would the cathode lug of the socket still be positive with respect to ground?

No. 4 If measurements show incorrect voltage at one particular socket, does this necessarily limit the defect to that circuit only?

No. 5 In Fig. 25, why should the sum of the readings of meters 1 and 2 be equal to that of meter 3?

No. 6 What important principles should you observe when connecting your DC voltmeter across any radio part?

No. 7 Suppose while making tests on a receiver, the voltmeter showed no plate voltage on a certain tube. How would you quickly determine whether or not the trouble was in the cathode circuit?

No. 8 How could you use your DC voltmeter to indicate whether or not a choke coil was open?

No. 9 State how the DC voltmeter may be used to prove that plate current is flowing in the plate circuit of the 6F6 output tube in Fig. 26.

No. 10 How would you measure control grid voltage on the 6F6 output tube of Fig. 26 using the external leads of your voltmeter?

CONTINUITY TESTING IN RADIO AND TELEVISION CIRCUITS

LESSON TV-3

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

RADIO AND TELEVISION CIRCUIT TESTING

As you become more and more familiar with radio and television circuits you will realize that both types of receivers are essentially the same from a testing and repair viewpoint. For instance both types of receivers employ similar power supply circuits—and the same is true for FM receivers. All such receivers follow the same general pattern. All have tuned input systems, an oscillator, a mixer, IF systems, second detector systems, AF systems, speakers, etc. Therefore, the only basic difference between AM-FM receivers and a television receiver is that the latter employs a picture or cathode ray tube. Even in this case, test principles follow the same general pattern. Where there are special conditions and tests to be made on television receivers later lessons in this special series will give them adequate treatment.

From this brief explanation you will realize that this lesson has an important bearing on the testing and adjustment of FM and Television receivers as well as for the common AM receiver. This lesson will give you important basic directions for tracing through and testing the component parts for all types of receivers. You will learn how to separate circuits to make it possible to test each and every part in a given circuit. By this means you may test individually every resistor, condenser, inductance, switch and other part in any receiver regardless of its type. Thus you can at once prove whether or not a part is at fault and this will enable you to pass on to the testing of other suspected parts.

So this lesson is extremely important in your progress of learning how to test and repair all types of receivers. Study it carefully and apply these test principles to all AM, FM and Television receivers you have for repair.

K9542M

This photograph shows an application of the continuity testing principle. The test instrument is of the combination type—one meter serving several functions. Test leads plug into the instrument panel, thus parts may be tested directly at the receiver chassis.

CONTINUITY TESTING IN RADIO AND TELEVISION CIRCUITS

Lesson TV-3

In previous lessons it was stated that the analyzer and multimeter test methods were in general *stage testers.* That is the meter of either type instrument will indicate if abnormal voltages or currents are present but this does not always indicate exactly which part or parts are at fault. For instance if an iron core filter choke or speaker field winding is open, a voltmeter will indicate this by showing voltage is available at one end of the winding but not at the other. This is called dynamic testing in that you make measurement while operating power is being supplied to the receiver or amplifier. By indirect measurements and supposition you can very often tell which part or parts are at fault by the dynamic testing method. However, in many cases after finding abnormal measurements by the dynamic method a still more detailed test is necessary to locate the actual defect. In this case tests are made *with no operating power supplied to the receiver.* This is called *static testing* in contrast to dynamic testing.

Static testing involves a careful detailed analysis *of each receiver part suspected of being at fault.* In other words the part is proven to be in acceptable or non-acceptable operating condition. Some few radio repairmen waste much time and use many new unnecessary parts by replacing parts merely because they happen to suspicion them to be at fault. This is a bad habit. No part should be replaced until it is proven beyond question of doubt to be at fault. If this is always made a rule by you, you will save much time and many parts and it will teach you to be efficient because it forces you to keep checking and testing until you actually do find the part which is at fault. This is the efficient scientific way to test radio circuits and if you use it as a guide you can not help but develop into an expert and efficient radio repairman.

Among static methods of testing are the oscilloscope. frequency measuring devices and the continuity method. Of these, the most practical and useful for the service and repair man is the continuity method. As you have no doubt learned from other lessons and from your reading, continuity testing consists of establishing whether or not a circuit or part will conduct current as intended by the designer. This current which the circuit or part must conduct may be either AC or DC. For instance a coil will permit either AC or DC to flow while a condenser in effect will only pass AC. Regardless of what type of current flow is involved a DC operated continuity tester is usually used. Some few AC operated continuity testers are used but they are limited in their applicatiton and. therefore, are not very practical.

The continuity tester may take several forms, but because of high value resistances to be tested it will be necessary to use an indicator of high sensitivity, at least when high resistances are involved.

A simple device of this type and one easily obtained is the *neon bulb*. A high voltage DC in series with the neon bulb is also required. This DC voltage is most easily obtained from the power supply of a receiver, although any other high voltage DC supply will be satisfactory.

Before going into this, consider a continuity tester in more detail. Such a tester may be any electrical device as long as *it will indicate through an electrical circuit*. Such testers are known as low and high sensitivity continuity testers. One requiring relatively high current for its operation is a low sensitivity tester. Examples of this type are the low voltage radio dial lamps, buzzer, 110 volt house lighting lamps, flashlight bulbs. etc. Examples of the high sensitivity type are the microammeter type of ohmmeter, headphones, neon bulb, etc. In other words, *the less current an indicating device needs for its operation when used in testing high resistances the better continuity tester it makes for radio circuits*. It is for this reason the neon bulb type of tester is recommended (in lieu of a meter) although there are special cases where a low sensitivity tester is desired (when it is desired that a circuit carry high values of current).

Figure 1 shows four examples of the low sensitivity type of continuity tester. At A, is an ordinary step-down transformer such as a 6.3 volt filament transformer. The secondary of this is in series with a 6.3 volt radio dial lamp. At B. a flashlight bulb is in series with a flashlight battery. A similar circuit is used at C with a suitable battery in series with a buzzer, such as the door bell type. At D, is an ordinary house lighting bulb in series with the 110 volt power line. This is the least desirable circuit

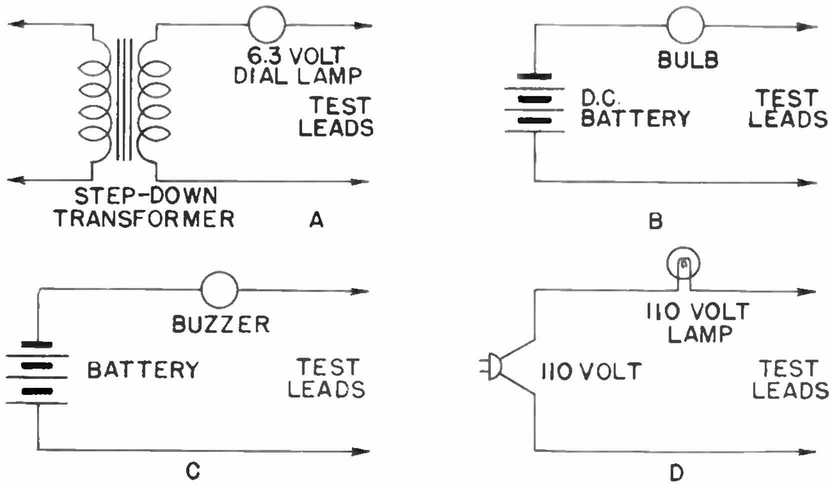


FIG. 1

among those of Fig. 1 because it is more dangerous since it is operated from the power line.

Figure 2 shows three high sensitivity types of continuity tester. At A, is the usual meter in series with a voltage source—this is commonly called an ohmmeter because its scale is graduated in values of resistance. At B, a pair of headphones is in series with a battery and at C, a neon bulb and a 150,000 ohm resistor is in series with a high DC voltage source. This will indicate through resistances of between 30 and 50 megohms.

Note particularly that all the circuits of Figs. 1 and 2 have three things in common, (1) a source of operating voltage, (2) an indicating device and (3) a pair of test leads. The test leads may be of the ordinary commercial type such as is usually obtainable from any radio parts jobber. However, you may use a pair of ordinary insulated wires (but bare at the ends) if commercial test leads are not available. Regardless of the type of indicator used, make sure that its operating voltage source does not exceed the safe voltage limits of the indicating device. For instance, in Fig. 1B do not use a 6 volt battery in series with a 3 volt flashlight bulb, etc. The reason for this is with little or no resistance across the test leads, the full force of the operating power is applied to the indicating device. Thus, with excess operating voltage, your indicator is likely to be damaged.

A continuity tester operates on the principle that with the test leads shorted (touched together) the indicator will denote a flow of current. But remember, this flow of current is from the power source which operates the indicator of the continuity tester. It does not indicate a current flow from the power source in the receiver you are working on. When using a continuity tester of the types described in Figs. 1 and 2, the receiver must be disconnected from its power source and all tubes of the receiver should preferably be removed from their sockets.

The type of continuity tester you use will of course determine what you are to observe to indicate continuity. For instance, in Figs. 1A, B and D, the lamps or bulbs will light when the test leads or touched together. In

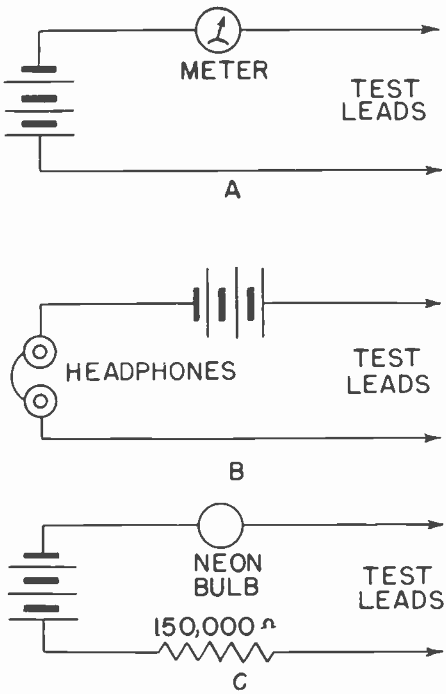


FIG. 2

Fig. 1C the buzzer will emit sound when the circuit is completed. In Fig. 2A with the test leads touched together, the meter needle will move. In Fig. 2 B, the headphones will click (sound) and in Fig. 2C the neon bulb will light.

The indicators in these various test circuits will produce evidence (light, sound, etc.) of a complete circuit when the test leads are shorted. When one test lead is placed at one point in a radio circuit under test and the other test lead is placed at another point in the same circuit, the continuity tester will show whether or not a circuit is complete. This is a most important principle and one which can be made very useful. However, in making use of this principle, the radio man must be careful to take into consideration the resistance of the circuit under test and the type of radio parts connected to the circuit.

In general, with a circuit consisting of wire connections only, any of the continuity testers shown in Figs. 1 and 2 may be used satisfactorily. However, as more and more resistance is included in the test circuit, the current from the tester circuit will become less and less with the result that when a certain resistance value is reached the tester will no longer indicate. When this happens, the tester is no longer useful and you must resort to a tester with higher sensitivity. Thus, you might as well use a high sensitivity tester to begin with, for then you can take care of all circuits with one unit. The circuit of Fig. 2C is therefore recommended, but a sensitive and accurate *ohmmeter* is even better.

The usual commercial multimeter includes several ohmmeter ranges and this is the preferred type of continuity tester to use since it is the only type of such a tester which indicates directly in resistance values. However, any of the types shown in Figs. 1 and 2 may be used in an emergency or where it is not important to know resistance values. *In the interest of accuracy and convenience for the student the instructions given in this lesson on continuity testing will be based on the ohmmeter.*

Since there are various types of ohmmeters in general use and since they employ different scales no detailed instructions on the operation of a certain type or make of ohmmeter can be given. Therefore, it will be assumed that the individual knows how to operate his own ohmmeter and that he can refer to manufacturers instructions for specific operating instructions. Thus, when reference is made to connecting the test leads across a given part or circuit for testing it should be understood that the student will connect his test leads to the proper tip jacks, he will set the range selector switch properly, and that he will use the right scale for the part to be tested.

There are seven basic test principles for you to remember and they apply to all AM, FM and television receivers. The first one has to do with part values. Except in the case of resistances, these do not change very often, and even in the case of resistances, the changing of a resistance value due to age or overload is rare.

It is safe to assume that in 99% of the cases the average receiver on the American market has the proper design—there are some few exceptions to this rule but they are of such minor consequence that you don't have to worry about them. If you recognize and accept this fact you don't need to worry too much about part values, etc., because if everything else is normal, you can assume these are about normal. *This is the first basic test principle.*

Now consider the radio or television circuit itself. Basically it contains nothing more than units of resistance, inductance, capacity and vacuum tubes. No matter how complicated the circuit, it can be resolved into these four basic items. Regarded in this way, an electronic circuit is a relatively simple device. Every time you have a seemingly tough problem just remember this primary fact —then stop and ask yourself, "why should this problem have me stumped?" Say to yourself, "this problem involves nothing more than the four basic items of radio," then ask yourself, "what basic principle have I overlooked?" If you will do this and stop to think over your problem carefully, you are sure to solve it. *This is the second basic test principle.*

Granted that an electronic circuit involves nothing more than resistance, inductance, capacity and vacuum tubes, it is well to remember how these react to the two basic forms of electrical power; namely, AC and DC. Resistance will pass both AC and DC, the current value being limited only by the resistance value. *This is the third basic test priciple.*

Inductance (which includes all wire leads and *all forms of coils* will also pass both AC and DC. But remember this important fact. Inductance does not react alike to both AC and DC. For AC inductance offers both reactance and resistance. These two terms are usually combined (reactance and resistance) and the effect of both of them is called *impedance.* Remember then for *alternating current* (AC) inductance offers impedance to the flow of current, and the value of the current is limited by the value of the impedance and frequency (for a given value of voltage). Remember too, an inductance may and often does carry both AC and DC.

For direct current (DC), inductance acts similar to an ordinary resistance. From a DC voltage and current viewpoint simply consider an inductance (no matter what its form) as you would any other resistance. *This is the fourth basic test principle.*

Now consider capacity (condensers in many forms). First, consider all forms of mica and paper dielectric condensers. These also have impedance but not in the same sense as inductance. While inductance will conduct DC, condensers *will not* (if they are in good condition). Every condenser no matter how good, has a minute DC leakage but until this assumes extreme values of current, this DC current leakage may be neglected entirely. Therefore, remember this important fact—for all practical purposes, a good mica or paper condenser will not pass DC. If it does, it is defective.

For AC, capacity or condensers will in effect conduct current. The amount will depend on the impedance of the condenser and the frequency. For practical test purposes you don't need to know the value of AC through a condenser but, if it passes DC, you do want to know it. *This is the fifth basic test priciple.*

One other common form of capacity is the electrolytic condenser. It is found in two forms: (1) using a liquid dielectric (called the wet type) and (2) using a thick paste form of dielectric (called the dry type). Both forms react alike to AC and DC. An electrolytic condenser (of the type used in radio receivers) will not operate properly when used on AC only. It is used in circuits having a high content of varying current but a DC is necessary to keep the condenser polarized and in operating order. Such condensers, therefore, have polarity, and the positive of the condenser must be connected to the positive or high potential side of the circuit with the negative of the condenser connecting to the negative or low potential side of the circuit. As compared to other types of condensers, the electrolytic types have high DC leakage current but, due to large values of capacity, the normal leakage current is not bothersome and is neglected. When an electrolytic passes abnormally large values of DC under normal voltage values, it is no longer useful and must be discarded. *This is the sixth basic test principle.*

The remaining basic unit in a radio receiver is the vacuum tube. Several different types may be used in one receiver. They are designed to accomplish different things, and therefore, do not all react alike. Assuming everything else in the receiver is normal, there are various ways to determine the condition of tubes. The basic fact here is that with all other things in the receiver normal, the substitution of a good tube for a bad one will correct the trouble. Later on in another lesson, you will be shown how to prove that a given tube is abnormal. As for the assumption that every other thing in the receiver is normal, tests to be described later will fulfill this requirement. *This is the seventh basic test principle.*

First, you observed that four basic items make up a radio or television receiver. Namely, these are resistance, inductance, capacity and vacuum tubes. Second, these four items, for practical test purposes, operate under seven basic principles as mentioned. If all of the foregoing is *clearly understood and* memorized, then the test procedure to be outlined makes the testing and repair of radio and television receivers comparatively simple.

The type of continuity testing to be considered in this lesson is a method which is sound in principle, simple to operate, and is the method which is used to actually determine which part in a particular circuit of the receiver is defective. With this method the chassis must be removed from the cabinet and supported on your bench in such a way to allow for easy access to the tube sockets and wiring under or on top of the chassis. The serviceman will need to be thoroughly familiar with the tube pins of each socket type for both the top and the bottom views of the socket. A tube manual identifying the pin numbers for any tube used by the receiver under test should be handy if you are not familiar with them.

Continuity testing consists of *resis-*

tance measurements of all the parts within the receiver and noting that *continuity is present* in circuits using transformers, resistors, chokes, etc., and absent in circuits where condensers alone are used.

These tests are all made directly at the points or parts in question. Other methods may be used to isolate the receiver defect to some particular stage but the continuity test is used to locate exactly which part is at fault.

As stated the best instrument for continuity testing is a good ohmmeter with low and high resistance scales. The ranges of the meter should be such that resistance of less than one ohm and as high as 15 megohms can be measured with fair accuracy. There are many good ohmmeters available. Most of them combine voltage and current measurements. The more sensitive ohmmeters are of the vacuum tube voltmeter type. Other continuity testers can be devised for simple short and open tests. See Figs. 1 and 2. Do not test for continuity through delicate units where very small wire is used with a large current consuming bulb. The large bulb will cause a high current to flow and may damage the part due to the heat generated by this high current.

How to Make Continuity Tests On Radio Parts and Circuits

When making continuity tests on a receiver, the procedure is much simplified by selecting each circuit of the receiver and treating it as a separate circuit. An easy way to do this until you get experience is to make a simple pencil sketch of the circuit you are checking, placing all the resistors, condensers, coils, etc., involved in this circuit in the drawing but leaving out all parts that do not have any bearing upon the circuit under test. If a diagram of the receiver under test is available the drawing won't be necessary. You can use the diagram itself and mentally separate the circuit in question, from the rest of the diagram.

When you have gained considerable experience with receiver continuity testing and also with receiver circuits in general, a diagram of the circuit won't always be necessary. The continuity method of testing is a static test (the receiver in a non-operating condition). Where the defect is due to thermostatic conditions (caused from normal operation of the receiver) some method must be used to simulate the operating condition during the continuity test or your tests may fail. If the failure of a part comes about due to the operating temperature of the receiver, this condition can be simulated by artificially heating the parts during the continuity test. One way to do this is illustrated in Fig. 3. Do not get the heating element of the electric heater too close to the part or the wax or other insulating material on or in the part may be melted. This method can be used to heat the entire receiver. If only the part you are testing is in question, you may be able to heat it separately with your soldering iron. If this method is used, it is advisable to cover the other nearby parts with an asbestos cloth so that only the one part receives the direct heat from the iron. If the faulty unit part is ther-

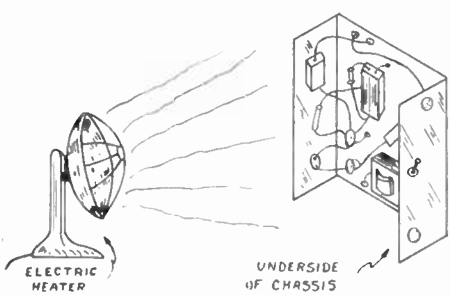


FIG. 3

mostatically intermittent, this test will usually simulate actual operating conditions and allow you to find the defect. Coils, resistors, and condensers may develop defects due to thermostatic conditions. If the resistance of a part changes considerably upon heating, the unit should be replaced. This heating should not be so intense as to damage the parts.

If the condition of the receiver will permit it to operate, it may be operated from twenty to thirty minutes which in general will bring all parts up to operating temperature. Then if suspected parts are tested before they cool, the same effect is obtained as artificially heating parts.

There are many complicated arrangements of the voltage dividing resistance network supplying voltage to all the tubes. For example a resistor in the power supply may be shunting the resistor you wish to check which may be in the RF amplifier, on the opposite side of the chassis. With complicated circuits, tests are made much quicker and easier if a diagram is available. From the diagram you can trace the resistors or coils involved with any test points you wish to observe and with the aid of simple arithmetic you can, if you wish to do so, calculate the value of the resistance in this circuit. When you make a check, if it does not agree with your calculations, provided you haven't made an error, there is an abnormal condition within that particular circuit. Many diagrams of different receivers include a resistance chart of the receiver circuit giving the resistance values between the different tube pins and also between many points in the receiver. This information aids considerably in checking the receiver if an ohmmeter only is available.

When checking the resistance value between two points of a complex circuit, always trace out the circuit making sure that there are no other parts such as resistors, coils, or transformer windings connected in the circuit.

If the parts are in series add the separate resistance values to find the total effective resistance value. This, of course, follows ohms law for resistors in series. When they are in parallel or in a combination series-parallel arrangement other methods must be used. It is assumed in this lesson that the student understands ohms law and can apply it to resistor combinations. For more information see lesson ND-6.

The practical radio serviceman does not have much time to make extensive calculations so the better solution for testing involved and complex circuits is to reduce them to more simple circuits. This can easily be done by unsoldering one or more parts in a circuit. Often the disconnection of one part (only one lead of it need be disconnected) will reduce a lengthy complex parallel circuit to a simple series circuit. This should be done in all cases where it is possible to do so for it saves time and simplifies the testing work.

Circuit Continuity Testing

Now that you have a general outline of continuity testing, a more detailed discussion of the individual circuits to be tested will be given. The first thing to do before making a continuity test on a receiver is to disconnect the power line cord from the power outlet, making the receiver inoperative. Antenna circuits will be considered first. It is, of course, impossible to give a description and continuity testing information for all makes of receivers but consideration will be given to some of the more complex circuits; and if you understand these circuits, the more simple circuits should cause you no trouble, Many receivers use a built-in loop or antenna. There are many variations of this system. In some cases all or a part of the loop acts as the input RF coil for the broadcast band of the receiver. When the high frequency or short wave bands are used another type of antenna is usually provided—such as, a foil antenna which is usually in the form of tinfoil fastened to the side of the receiver cabinet. In other cases an outside antenna is used for the short wave bands.

A circuit using a foil antenna for the short wave bands is shown in Fig. 4. To check this circuit an ohmmeter connected to various points should reveal any abnormal condition of the circuit. The equivalent DC circuit in Fig. 4 is shown to the right of the actual circuit. This circuit equivalent shows the values the continuity tester would indicate if the ohmmeter were connected across the circuit. As far as the ohmmeter is concerned the coils are just a length of wire offering a certain amount of resistance to the circuit as indicated.

If the leads of an ohmmeter are connected between points (1) and (2) with the band switch in the B position, the resistance indicated should be 34 ohms. When switched to band A, the reading between (1) and (2) should be 31.4 ohms. Measuring between point (1) and the chassis or ground should indicate 2.7 ohms and from point 2 to ground should indicate 31.3 ohms. These values may vary slightly and if they are not appreciably different from the rated values, the unit parts in the circuit are probably in good condition and properly connected. There is one condition which probably would not be indicated (unless a very accurate ohmmeter is used) with this test, and

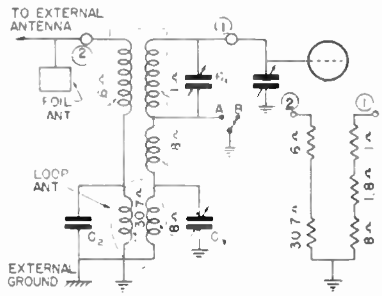


FIG. 4

that is *shorted turns* within the winding of one of the coils. As you see from Fig. 4 the coils are shielded and if you are suspicious of them and the continuity test doesn't reveal correct or normal values, removing the shields and making a visual check of the coils should reveal any short circuit which is present.

When you find no continuity (no reading on the ohmmeter) or very much lower resistance than there should be between the different points, you have found a defect within the circuit and by eliminating the different coils one at a time, the defective one can soon be found. When testing the secondary circuit as in Fig. 4 and there is no continuity between (1) and ground, note there are three coils to check and each in turn should be checked separately. An uninsulated connection is not always available for every part of a circuit. For this reason, it sometimes becomes necessary to use a *sharp pointed* test lead (a phonograph record needle is good for this purpose) that will penetrate the wire insulation allowing for a continuity check without damaging insulation on the wire.

With circuits of the type shown in Fig. 4 where there are variable condensers involved, disconnect one terminal of the condenser and rotate the condensers while making the test (connect the ohmmeter between the

Above is shown a Jackson Model 643 multimeter. It has the usual AC and DC voltage and current ranges as well as several ohmmeter ranges. This tester is typical of those used for radio circuit continuity testing.

stator and rotor terminals) to determine if there is a short between the plates of the variable condensers, within the range of rotation. Many times, dirt and other objects get in between the plates of these condensers and cause a short. Any reading on the ohmmeter while checking a disconnected tuning condenser is an indication the condenser is shorted. Either the plates should be cleaned and the plates made true or the entire tuning condenser should be replaced.

Shorted condensers in a circuit will cause a considerable change in the resistance value of the circuit. Condenser C2 in Fig. 4 is usually a mica condenser and very seldom do mica condensers break down. Condenser C3 in Fig. 4 is an antenna trimmer condenser and often dirt and tiny foreign objects become lodged in between the plates and may cause a short. When this condenser is shorted, it will make but little difference upon the continuity test due to the low resistance of the coil it is connected across. When this condenser has little or no effect upon the signal when being adjusted and the receiver output is low, it should be checked separately by disconnecting one of its leads and connecting a continuity tester directly across it. This same disconnecting procedure must be followed in any radio circuit where such a parallel connection exists. This example of Fig. 4 is used to illustrate the importance of a thorough understanding of more or less complex circuits in a receiver and to give you a detailed test procedure that will aid you when making receiver continuity tests.

Without sufficient knowledge of the circuit being tested, the best test equipment built is worthless. On the other hand, if you have a thorough knowledge of a particular circuit, very meager test equipment can, in many cases, reveal the defect.

Many receivers use a single or combination tube for the first detector and oscillator functions. When this is done a complicated circuit is usually the result—especially if the receiver has more than one tuning band. Figure 5 shows a typical oscillator-mixer combination using a 6K8 tube. Only the parts for one tuning band are shown. This is done to avoid confusion. What is said about one band, however, is true of the other bands and tests on the other bands should be made in the same way.

Most of the parts are used for all of the tuning bands and once these parts are tested and their condition determined, no further testing on them is necessary. The coils and their trimmer condensers are usually the only parts changed from one band to the next. Many receivers use separate sets of coils for each band, while others may use one large coil with taps for the higher frequency bands. It is an easy matter to determine which method is used from a visual observation of the chassis or from a diagram of the receiver.

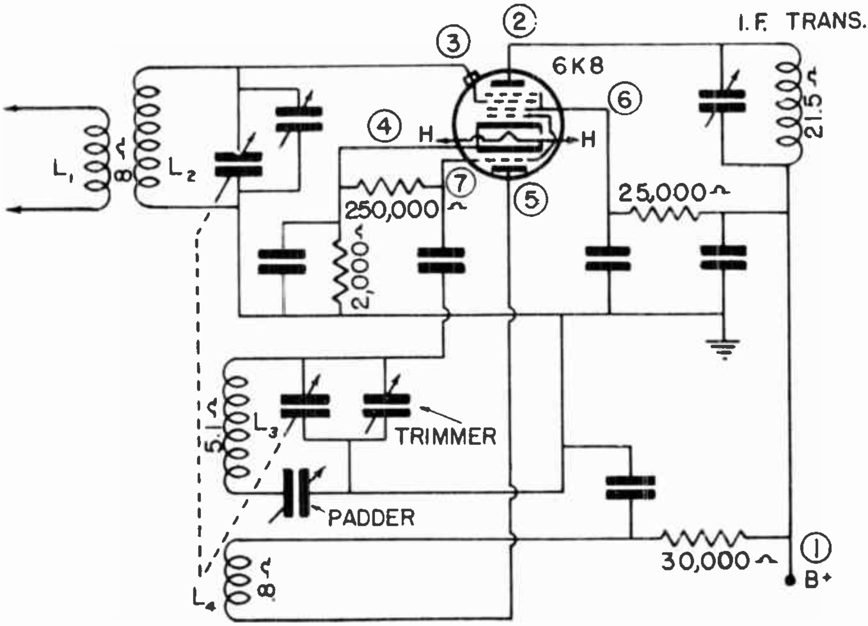


FIG. 5

Referring to Fig. 5 and using it as an example for continuity testing should bring to light the most important tests to make and also how these tests can be used to identify any defective part.

Circuits involving RF current and voltages, should in general be tested under a dynamic operating condition. However, there are many tests that can be made upon the circuit with a continuity tester that will aid in locating any defective part in the circuit. The dynamic operating condition of the oscillator can be determined by the use of *signal tracing* equipment which will be discussed in a later lesson of your SAR course. When it is found by other means that the oscillator is at fault, it should be an easy matter to locate the defective part by the continuity tester. Assuming the tube is good and that it has been removed from the circuit, a continuity test should reveal any weak or defective parts within the circuit.

With the tube removed from the circuit of Fig. 5 continuity between the different points should indicate resistance values as follows: From point 1 to 2, 21.5 ohms; from 3 to ground 8 ohms; from 4 to ground 2000 ohms; between 4 and 7, 250,000 ohms; and from 5 to 1, 30,000.8 ohms. As the resistance of coil L4 is so small in the circuit between 5 and 1 compared to the 30,000 ohm resistor, it will not have any noticeable effect upon the total resistance unless L4 is open or a high resistance develops. Thus L4 should be given a separate check. When the oscillator refuses to oscillate, it could be due to shorted turns within one of the coils. However, a coil is not likely to develop an internal short but a condenser connected across the coil may short and this, of course, would short the coil. If this is the case, each coil will have to be disconnected, checked separately, and the resistance of the coil measured accurately to determine if such a short exists. Many times a continuity check cannot positively determine this and a visual inspection of the coil will have to be made to positively confirm your diagnosis. In continuity testing, the accuracy of your tests depend upon the accuracy to which your ohmmeter is calibrated. Continuity testing with a poorly calibrated ohmmeter will not always give you the necessary information for locating the defective parts—especially if they are of low resistance. This is true in the case of RF and IF coils since many of them have low resistance.

Referring again to the circuit of Fig. 5, the resistance between points 6 and 1 should be 25,000 ohms. The tuning coil L3 of the oscillator has no continuous DC connection to the rest of the circuit. Therefore, it will have to be checked separately. One end of the coil in this circuit connects to the gang tuning condenser and the other end connects to the padder condenser. By using these two points as a reference you can test for the continuity of the coil. It should be 5.1 ohms in this particular circuit. As mentioned previously, when making tests on coils where variable condensers are used across the coil, disconnect one side of the condenser in order that any defect in the condenser cannot have its effect on the coil—the condenser should, of course, be tested separately while one side of it is disconnected. The padder and trimmer condensers are usually of the mica variety. Thus any dirt collecting upon these condensers is not likely to cause a low resistance short but may cause a high resistance leak across the condenser plates. This will change the efficiency of the tuned circuit and in turn may cause low sensitivity and selectivity of the receiver.

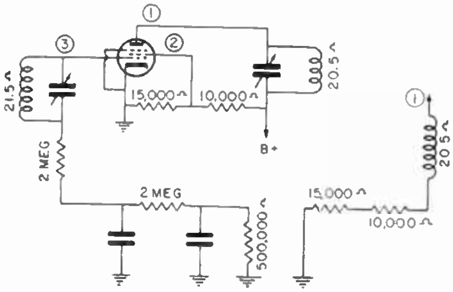
The values of resistors usually have a tolerance of plus or minus 20%. If your measurements show no more than this, the value is within the tolerance limit. After continuity between the elements of the circuit which should possess continuity has been established, tests should be made between other points to ascertain if continuity exists where it should not.

In Fig. 5 assuming that there are no resistance paths in other circuits of the receiver which connect the B+ to ground, points between 2, 5, 6 and ground should show *infinite resistance* (no reading on the ohmmeter) unless there is a leaking condenser or other high resistance leak in the circuit. This, as you see, affords an excellent check upon the condition of the condensers within the circuit under test.

This example of a mixer-oscillator tube circuit is just a typical example of circuits of this type. You will find many receiver with combination oscillator-mixers which will vary considerably from the example given. The circuit, resistors, condensers, and coils will all have different values from those given in Fig. 5. The values used in any receiver depend upon the tube and also the type of oscillator used. The basic continuity test procedures, however, are the same for all circuits of this type.

Figure 6 shows a typical RF or IF stage in a receiver. It includes the AVC circuit which is actually located in the 2nd detector stage but to complete the continuity testing on this stage, it must be considered since it is directly connected to the RF and IF stages of the receiver.

Considering the circuit of Fig. 6 as it is drawn with no other external connection to the power supply, the circuit analysis involves nothing more than a group of series resistors from point 1 or the plate of the tube to



(A) (B)

FIG. 6

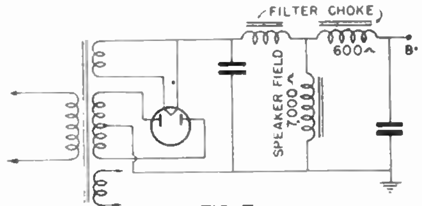


FIG. 7

ground. There would be as indicated in Fig. 6B, the 20.5, 10,000 and 15,000 ohm resistors all added in series giving a total of 25,020.5 ohms. Now if this same circuit is connected to a power supply where the speaker field is connected directly across the B+ feed line to ground the continuity measurement will be considerably different. Figure 7 shows a typical power supply with the speaker field connected from B+ to ground. With this power supply connected to the B+ terminal of Fig. 6, the circuit changes considerably as it introduces a parallel circuit to ground. Figure 8 shows the equivalent circuit of Figs. 6 and 7. Instead of the series combination of Fig. 6B there is a series-parallel combination. Adding these resistors in the proper manner gives an effective resistance value for the group of 5848.72 ohms.

This is the resulting resistance of the series-parallel combination of resistances. This is considerably different from the value of resistance without the power supply connected to the circuit.

Consider the resistance between point 2 of Fig. 6 and ground *with the power supply connected.* With this combination the 15,000 ohm resistor is shunted by the series combination of 10,000 plus 600 plus 7000 ohms or a total of 17,600 ohms. This gives an effective resistance value of:

$$\frac{15.000 \times 17.600}{15.000 + 17.600} = 8098.15 \text{ ohms}$$

between point 2 and ground with the power supply included. With it disconnected the resistance between point 2 and ground in Fig. 7 is 15,000 ohms.

The resistance values between other points of Fig. 6 can easily be calculated by the same procedure. Between point (3) and ground there is a series combination of two 2 megohm resistors plus a 500,000 ohm resistor giving a total of 4.5 megohms resistance. If either condenser in this circuit becomes shorted or develops a leak, the effective value will be changed considerably from what it should be since a parallel circuit to ground will be formed.

The foregoing examples bear out the fact that you must consider every unit part in a circuit that is related to the circuit you are testing in order to eliminate the possibility of false readings. If, for example, the effect of the power supply as indicated in Fig. 7 was neglected when you made your continuity tests, you would, no doubt, suspect a condenser in the circuit of having a leak (forming a high resistance parallel path) and much time would be wasted in trying to lo-

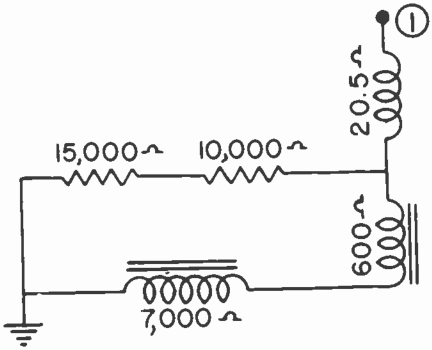


FIG. 8

cate a faulty condenser in this circuit when one did not exist.

On the other hand, do not assume that there is a resistor in some other circuit causing a change in resistance between the measured value and the calculated value. If you cannot trace the circuit wiring from the stage you are testing to other circuits, it will save time if you disconnect the leads you are not certain about and in this way eliminate any possible interference from other circuits.

All of this simply means for you to be on the alert for parallel circuits having their effect on the circuit you are testing. Busy repairmen do not have time to stop and make extensive calculations relating to parallel circuits. Such calculations in general are only made to get a check on the overall effect of a circuit. For instance your check on the unit parts of a circuit may show no defects yet you may have a suspicion that some part of it or another parallel circuit is at fault. Thus, to get an overall check it might be necessary to measure the resistance of a circuit with an ohmmeter. To check the measurement it would be in order to calculate the overall resistance of the circuit under test. If there should be a material difference between the measured and calculated values it would offer a clue as to the possible source of the defect. In all other instances it is better to break long and involved circuits into short simple series circuits. This can easily be done by testing across one part at a time or by disconnecting part of a circuit to eliminate a parallel branch. For instance in Fig. 8 to eliminate the parallel effect disconnect the 10,000 ohm resistor where it joins the 600 and 20.5 ohm resistances. Then connect one test lead to ground and connect the other one to the free end of the 10,000 ohm resistor. This would give a reading of 15,000 + 10,000 or 25,00 ohms. Then move the test lead to point 1 of Fig. 8 and take another reading. This should equal 7,000 + 600 + 20.5 or 7620.5 ohms. In this way both circuits may be tested without calculation. When finished testing reconnect the 10,000 ohm resistor exactly like it was connected before you disturbed it.

Figure 9 shows a typical 2nd detector and 1st audio amplifier stage. The IF transformer secondary is connected to the diode section of the tube. The diode rectifies or detects the IF signal and changes it into a pulsating DC which is made to drive the grid of the triode section through R and C. The AVC voltage for the receiver is also developed in this stage. With no resistance network of the rest of the receiver connected, the circuit is very simple and a continuity test of this circuit is very easy to make. If, how-

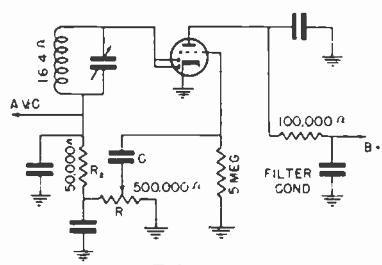


FIG 9

ever, the power supply or some other part of the receiver involves the parallel path principle as explained for Fig. 8, then a more complicated network will result. One common defect encountered with the 2nd detector which causes the receiver to act very peculiar, with noise, poor reception, and the AVC action ceases, but still the receiver operates is an open secondary in the IF transformer. This defect can be established by a continuity test across the coil winding. When trouble of this type is observed and you find that the adjustment of the trimmer condenser across the secondary of the last IF transformer has no effect upon the output of the receiver it is a sure sign that the secondary of this transformer or its circuit is open.

The audio system of some receivers where phase inversion is used may be somewhat complicated and confusing when observed in the receiver or on the diagram. However, by drawing such a circuit separately from the rest of the receiver circuits, it seems fairly simple and a continuity test is very easy to follow. Figure 10 shows such a circuit.

In a phase inverter circuit, the value of the resistors used is critical and if they are not closely matched one tube of the push-pull output will be driven to a larger voltage value than the other. This will cause a non-uniform output voltage resulting in considerable distortion in the output of the receiver. The operation of a phase inverter is simple and should be thoroughly understood by the serviceman. The tubes used in a phase inverter, like those used in the push-pull output stage, should be matched in order to give best results. This is more true with some types of phase inverters than others. There are usually a number of resistor networks involved in a phase inverter as you can see from the circuit of Fig. 10 and to make a

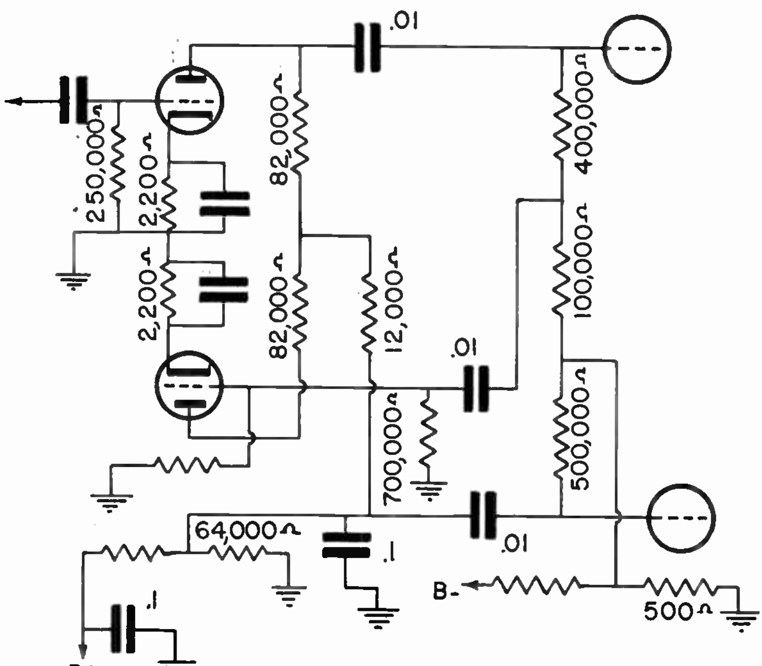


FIG. 10

thorough test of this circuit, it is necessary to measure the resistance of every resistor making sure that the value measured is within the tolerance allowed for that resistor. In such circuits, there are usually combinations of series and parallel resistors and these are often combined with other circuits. In Fig. 10 this is true when the B+ lead is connected to a power supply such as the one in Fig. 7.

The condensers in phase inverter, AF and second detector circuits are just as vital as the resistors. Often it is required that they be tested for shorts. When an ohmmeter is connected across such a condenser no reading should be obtained and if the slightest leakage is shown the condenser should be replaced.

Phase inverter circuits are used to take the place of a push-pull input transformer. When the circuit of the phase inverter becomes defective the proper relationship in phase and amplitude of the voltage fed to the push-pull stage will not be correct, hence there will be distortion.

Many times due to the large number of resistors used in these stages, noise is developed. This noise may be due to a faulty resistor and unless this resistor is located and removed, the noise will continue. Usually resistors that are noisy have at sometime or another been overheated and in many cases this causes the resistance value to change. In most cases a continuity test is not sufficient to locate the noisy resistor and other methods will have to be used. The methods of locating noisy resistors will receive detail treatment in later lessons since this lesson is concerned mainly with continuity testing.

The phase inverter circuit of Fig. 10 may be used to drive a push-pull system such as that shown in Fig. 11. Since Fig. 11 is typical of AF output circuits it may be used as an example of how such circuits should be tested for continuity. *When testing in actual practice you will not have to test each and every part in the circuit.* However, tests will be described for each of the parts in Fig. 11 and you should be able to duplicate these same tests on any other receiver.

First consider the condensers in Fig. 11. There are six of these in the circuit. Normally all you have to do to test these is to connect your ohmmeter test leads across the terminals of each condenser. This is a satisfactory test provided no conductive parallel circuit exists across the condenser. Such a conductive circuit is often hard to recognize in a complete complex circuit. So the safest procedure is to disconnect one side of the condenser to be tested. This removes all doubt about a parallel circuit. With this done set your ohmmeter selector switch to the highest range and connect or touch the test leads across the condenser terminals. If a reading is obtained the condenser under test is defective and requires replacing. This is a general test which you can make on all condensers of the non-electrolytic type. Each of the six condensers shown in Fig. 11 should be tested as described. When you are through testing a condenser be sure to reconnect or resolder the lead you have disconnected.

To test the resistors in Fig. 11 begin by connecting one of your ohmmeter test leads to ground. Next connect the other test lead to the control grid of tube V1. You should obtain a reading of 600,500 ohms made up of 400,000 + 100,000 + 100,000 + 500 ohms. No reading means at least one of the resistors is open. To find which one is at fault merely con-

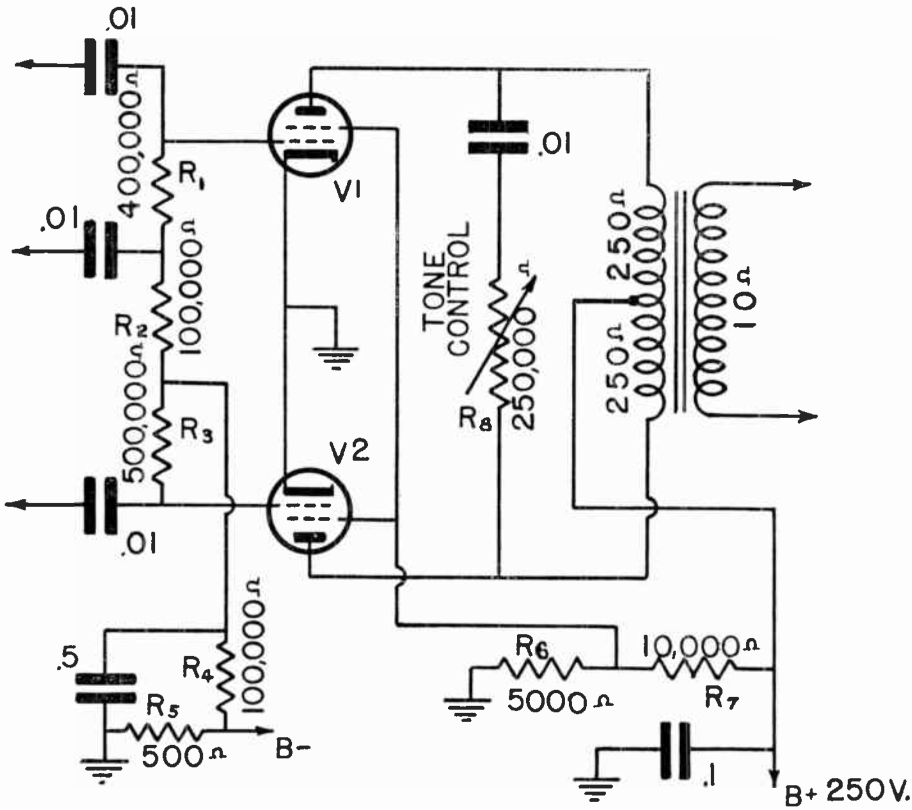


FIG. 11

nect your test leads across each of the separate resistors.

With one test lead still connected to ground move the other one to the control grid of tube V2. Again the reading should be 600,500 ohms but note a new resistor R3 is involved. Also note this second reading gives a recheck on R4 and R5. If in the first test on V1 you obtained no reading and on the second test on V2 you do obtain a reading it means either R1 or R2 must be at fault. Be on the alert for double checks of this kind for often by a process of elimination you can tell which resistor or part is at fault without having to test the parts individually.

With the one test lead still connected to ground, connect the other test lead to first the screen grid of V1 and then to the screen grid of V2. In each case a reading of 5000 ohms should be obtained. If no reading is obtained either R6 is open or the wire leads to the screen grid terminals of tubes V1 and V2 are open.

Next connect the test lead first *to* the plate of V1 and then to the plate V2 with the other test lead being grounded. Since other parallel circuits may exist in the power unit it would be well to temporarily disconnect the B+ connection in Fig. 11 from the rest of the B+ circuits. With this done the reading at the plate of V1 should be 15,250 ohms, made up of R6, R7 and one half of the

This photo shows a modern multimeter as made by Simpson. A selector switch at the right is used to select the various AC and DC ranges of the meter. Such an instrument makes an excellent continuity tester.

output transformer primary. The same approximate reading should be obtained at the plate terminal of V2. (A small variation of the two readings at the plate terminals of push-pull tubes is permissible because the two half windings of the output transformer primary have unequal resistance values in most practical circuits). If no reading is obtained at either plate terminal in Fig. 11 the primary winding is at fault or R6 or R7 is open (burned-out). If you establish that proper values exist between the plates of V1 and V2 reconnect the B+ connection to restore normal continuity.

The remaining element in Fig. 11 for which directions have not been given for testing is the tone control. If you have previously tested all condensers you will only have to test the tone control resistor. Since no parallel circuit can exist for it (unless the .01 condenser is shorted) all you need to do is to connect your ohmmeter leads across its terminals. With this done rotate the control throughout its path of travel to be sure there is no interruption of the resistance element. If the meter needle is *jumpy* while you do this, the resistance element is probably worn and needs replacing.

Remember other AF output circuits are likely to be widely different from Fig. 11 as to values and arrangement of circuits. However, this should cause you little trouble if you will use the test principles outlined in the foregoing.

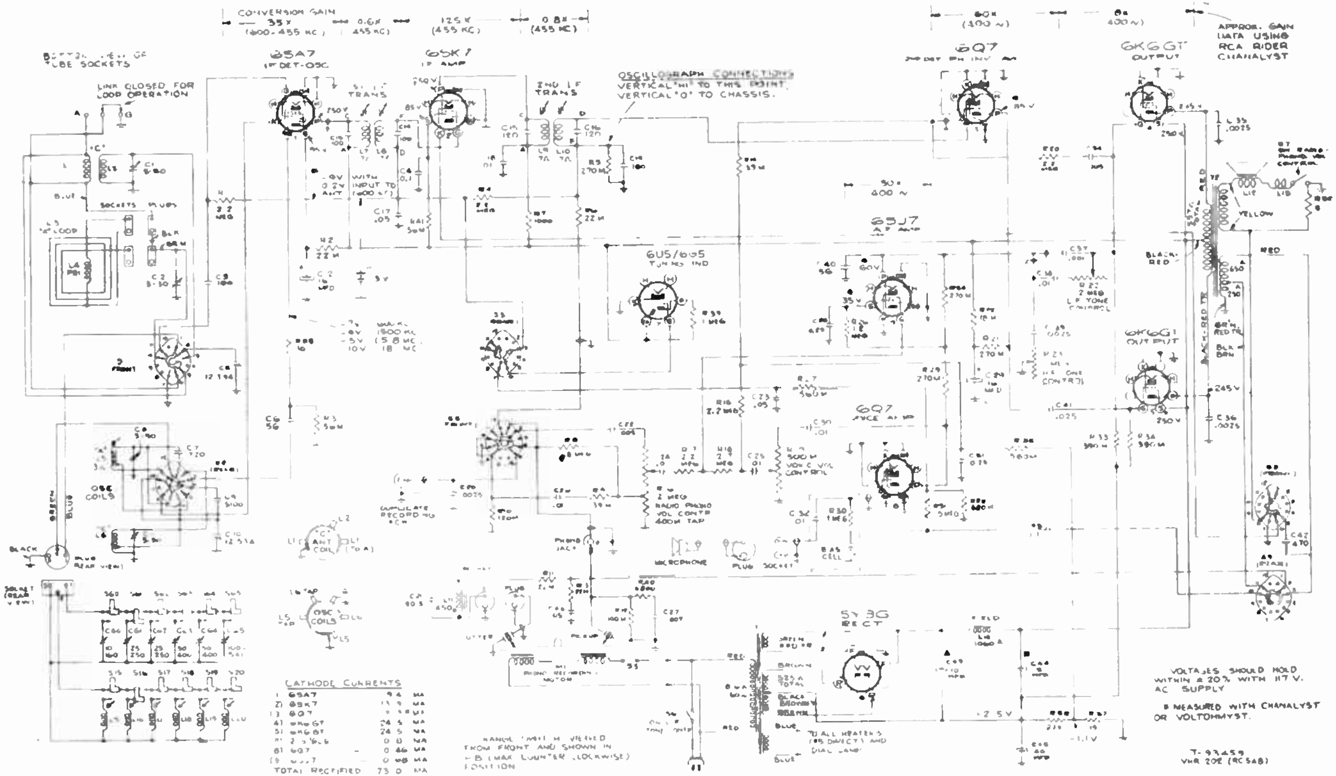
The secondary circuit of the output transformer in Fig. 11 will connect to the voice coil of a speaker. To test both windings disconnect one lead from the secondary winding and give both secondary and voice coil a separate check for continuity.

A Detailed Receiver Test

One of the most important things for you to learn from this lesson is *continuity test principles*. It will not do you much lasting good to learn how to test just one type of receiver. So as you study the next few pages, it is important that you understand each test as a principle which you can apply to other receivers.

As an example of a complete complex receiver, the circuit of the RCA model VRH 202 will be used. It is shown in Fig. 12. This circuit is a good example to use as a basis for continuity testing because it includes most of the features you will encounter in practical work. It employs two tuning bands and in addition it includes recording and record reproduction facilities.

The antenna circuit employs a loop which acts as the RF or antenna coil for the broadcast band. For short wave reception the loop is not used. Note the push button tuning system is a separate unit which can be disconnected from the rest of the circuit by removing the plug from the socket into which it fits. Note there is no separate RF amplifier stage. The 6SA7 acts as the RF amplifier, 1st detector and oscillator tube. Only one



Model VHR-202

FIG. 12

stage of IF is used, a 6SK7 tube being used for this purpose. The second detector and AVC functions are contained in the diode section of the 6Q7 tube. The triode section of the 6Q7 acts as a phase inverter.

The 6SJ7 is the audio amplifier tube and is used for radio, phonograph reproduction and recording. The 6U5/6G5 tuning indicator serves a dual purpose. It operates as a tuning indicator when using the radio section of the receiver and as a volume level indicator when recording. The triode section of the second 6Q7 tube is used as a microphone amplifier and one section of the duo-diode is used as a rectifier for rectifying the output of the audio amplifier. This rectified voltage which is taken from the output of the amplifier is fed back to the 6U5 indicator tube. This voltage operates the 6U5 tube in such a way that the eye of the 6U5 tube indicates the correct volume level when using the microphone in making a record.

This extra stage of amplification is necessary when using a microphone due to its low output. The cutting head and phonograph pick-up is also shown on the diagram. The power supply is a conventional type using a 5Y3G tube as rectifier.

The general procedure followed by most servicemen when checking a receiver is to start with the power supply which is the most common source of trouble and working forward. In this analysis of the circuit in Figure 12, the same procedure will be followed.

The tubes are checked separately and as they have no special effect upon the circuit in or out of their sockets it may be advisable when removing them for testing to leave them out of their sockets until the continuity tests are made. In this way it is usually easier to get at inaccessible places on the top of the chassis with the tubes out of the way. Also you may want to make a measurement between the tube socket pins on the top of the chassis and if the tube is removed this is possible by inserting your test leads into the correct tube pin hole in the tube socket.

One of the first continuity checks, especially if the rectifier tube appears to be overloaded or if a low plate voltage is indicated, is between the cathode of the rectifier tube and ground. After thoroughly tracing the circuit, you can see there are no DC paths to ground from the cathode of the rectifier tube. In other words, there should be an infinite resistance indicated on the ohmmeter assuming that all the condensers in the circuit are perfect. Now from a practical viewpoint this is not possible for the electrolytic condensers in the filter circuit of the power supply will have some leakage even when they are in good condition. As you will remember from previous lessons, dealing with electrolytic condensers, these have a peculiar characteristic and act considerably different from the solid dielectric type of condenser. As these condensers are polarized when testing circuits containing electrolytic condensers, the polarity of your ohmmeter should be the same as that of the condenser under test. Most ohmmeters are so arranged that the polarity of the test leads are indicated in the same manner as those for measuring voltage and current—red for positive and black for negative.

When you first apply your ohmmeter test leads across a condenser of large capacity, the condenser will offer little resistance to the charging voltage allowing a momentary current to flow depending upon the capacity of the condenser but as soon as the condenser obtains a charge, there is almost an infinite resistance unless there is a leakage path through the condenser. In the case of electrolytic condensers there is a leakage path which depends upon several factors; the capacity of the condenser, the voltage used to test the condenser and the condition of the condenser are the main factors affecting the leakage resistance.

With an ordinary ohmmeter using a meter having a sensitivity of 1000 ohms per volt, the leakage resistance of an electrolytic condenser should be practically infinite after the condenser has reached full charge if the condenser is in good condition. If an electrolytic condenser under test indicates less than this value, it should be given a separate test. The detailed testing procedure for electrolytic condensers will be given in a later lesson.

Referring again to Fig. 12, now that the effect of the electrolytic condensers has been explained you can see what will happen when your ohmmeter leads are applied between the cathode of the rectifier tube and ground. Assuming the condensers are all in good condition, the moment you apply the test leads to the circuit the meter of your ohmmeter will immediately show low resistance and then as the condenser charges, it will rapidly indicate high resistance. If any of the condensers connected to this circuit are leaking, the meter will not increase to a high value, thus indicating that a condenser in the circuit is at fault. If you find a low resistance exists between these points, it should be corrected before making any further tests. Many times there is more than one defect in a receiver and even after a defect has been found the receiver should be given an actual operation check to make sure all defects have been corrected. Many times the rectifier tube is found to be faulty and if without any further tests upon the circuit a new tube is inserted, and if the original trouble was due to a short in the B+ line, the new tube will be damaged from the overload placed upon it. Therefore, when a rectifier is found defective before replacing it with a new tube, give the B+ circuit of the receiver a thorough continuity check to make sure the failure of the tube was not caused by a defect within the receiver circuit.

The next point to check in the power supply is between the center tap of the high voltage winding of the power transformer and ground. In this receiver, the chassis is 21.5 volts positive in relation to the center tap of the high voltage winding on the power transformer. This is done to provide bias for the different tubes in the receiver. Resistors R36 and R37 are placed between the center tap and ground and the voltage drop across these two resistors gives the correct bias for the tubes. From the center tap to ground there should be a resistance value equal to the sum of R36 and R37 or 285 ohms.

A shorted or leaking condenser connected across this circuit will be indicated by a lower reading on the ohmmeter. An open resistor will be indicated by an infinite or no reading value. When there is a defect in the bias circuit, it is usually indicated by a noisy and distorted output. It is a very common defect for the resistors in this type of circuit to burn out or become open. A short occurring within any tube where the B+ is connected will cause excess current to flow through resistors R36 and R37 and if it isn't removed in time these resistors will be damaged. Many times their resistance value will change due to the high temperature caused by the overload. This is another case of where a defective tube can cause resistors to be damaged. After the tube has been replaced, the receiver will not operate properly until the damaged resistors have been replaced.

The only other continuity test to be made upon the power supply is to check filament and high voltage windings of the power transformer. Methods for testing transformers will be given in detail in a later lesson. However, you should realize that a transformer winding has DC continuity and is therefore subject to both open and shorted conditions which will be indicated by the ohmmeter.

The next stage to check in Fig. 12 is the audio amplifier and speaker system. Note it employs two 6K6GT tubes in a push-pull arrangement. The output transformer of this particular receiver is somewhat more complicated than most other receivers due to the recording feature. However, it presents no special difficulties in continuity testing. It consists of coil windings, a resistor and switch. If the ohmmeter test leads are connected across the switch contacts of S7 with it *open*, a reading indicates continuity and no reading means one of the parts is open. An ohmmeter test of each part of the output secondary circuit will indicate which part is at fault. To test the primary of the output transformer for continuity merely connect your ohmmeter leads between the plate terminals of the push pull tubes. A reading of approximately 537 ohms should be obtained. No reading means an open winding. The other parts of the AF system are easily tested with the ohmmeter. To test the condensers (except those shunted with resistors) merely connect your ohmmeter leads across the condenser terminals. No reading should be obtained for paper and mica type condensers. A reading means a defective condenser and a replacement should be made.

The resistor elements in the AF system should be tested just like the condensers. However, watch for parallel circuits and when in doubt disconnect the parallel circuit so you can get a positive check on each unit in the circuit. Unlike condensers, resistors should show a reading on the ohmmeter when tested. The values as read on the ohmmeter should be within 20% or less of the rated value. With these brief instructions you should be able by means of an ohmmeter to determine the condition of any part in any AF system similar to Fig. 12.

The various functions of this receiver such as recording, sound reproduction, etc., are controlled by the selector control knob on the receiver front panel. It controls four switches S3, S4, S8 and S9 (Fig. 12). All of these switches are mounted on the same shaft—four positions being provided.

Figure 13 shows the circuit involved when the control knob is in position number 1. This permits (1) recording of voice or music through microphone, (2) recording of other records through use of a separate turntable and (3) recording of records with voice or music through microphone.

Figure 14 shows the circuit for position number 2 of the selector knob. This permits (1) record reproduction, (2) recorded selections with voice or music through microphone and (3) microphone only—an effective PA system.

Figure 15 shows the circuit as arranged in the 3rd position of the selector control knob. This is another recording position for (1) radio programs and (2) recording of radio

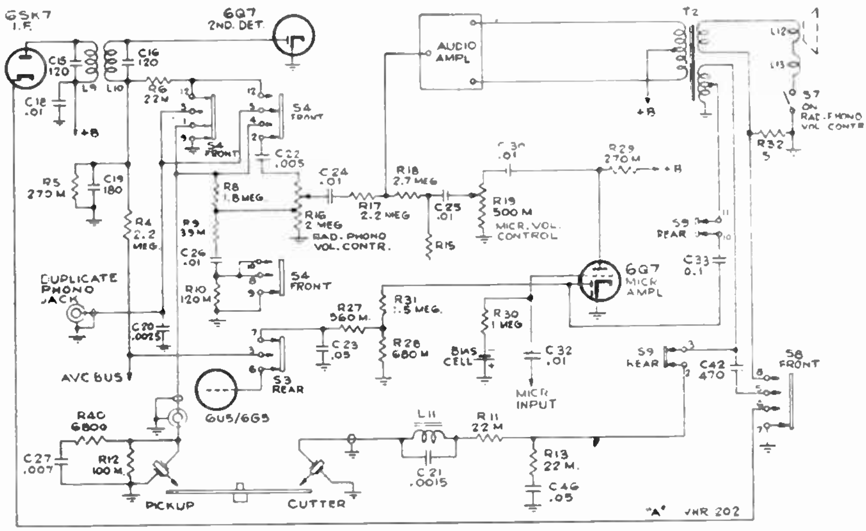


FIG. 13

programs with voice or music through use of the microphone.

Figure 16 shows the circuit as caused by the 4th position of the selector control knob. It permits (1) the reception of radio programs and (2) radio programs mixed with voice or music through use of the microphone.

Study Figs. 13, 14, 15 and 16 and note how the circuits can be traced and checked for continuity through the various switch contacts. In Fig. 13 notice how the switches S3, S4, S8 and S9 arrange the circuit. Assume for this first position of the selector knob that recordings can not be made. A quick continuity check on the vital parts of the circuit will most likely enable you to find what is wrong. The procedure would be about as follows:

One of the first tests should be on the cutter. From a continuity standpoint, it is a condenser. So an infinite reading should be obtained when the test leads are connected across it. A reading through it would indicate the need of a replacement. Next clip one test lead to the ungrounded side of the cutter and connect the other test lead to ground. This tests continuity of L11, R11, terminals 2 and 3 of S9 and the lower secondary on the output transformer. If everything is normal the reading should be 23.350 ohms as noted from the values of the parts involved in Figs. 12 and 13. If the reading is widely different from 23,350 ohms make a separate check on each item involved. In addition check all condensers connected from the circuit to ground. In Fig. 13 only one condenser is involved (C46) and it is in series with R13 of 22,000 ohms and it is not likely to be at fault since the condenser is not subject to DC.

The secondary side of T2 can be tested by connecting one test lead to terminal 8 of S8 and the other test lead to the upper terminal of S7. The exact resistance values for the upper secondary of T2, L12 and L13 are not available as would be the case for many receivers. If a reading is obtained it indicates the circuit has continuity and very likely is in good condition. While testing the output circuit R32 should be checked. This can be done by connecting one test lead to ground and the other one to terminal 8 of S8. The reading in this case should be 5 ohms.

Next connect one test lead to ground for the time being and then check as many other parts as possible with the other test lead—moving it from part to part as required. If a reading should be obtained C33 is shorted. Next move the test lead to the diode plate of the 6Q7 microphone amplifier tube. The reading should be 2,180,000 ohms through R31 and R28 to ground. No reading means at least one of these resistors is open. Next move the test lead to the grid of the 6U5/6G5 tube. The reading should be 1.240,000 ohms through 6 and 7 of S3, R27 and R28. Note this gives a double check on R28 for in the previous test it was also tested along with R31. If in testing from the grid of the 6U5/6G5 a very low reading is obtained. it means the terminals of S3 are grounded or that C23 is shorted with the latter being the most likely defect. A continuity test of each unit would prove which one was at fault.

In the foregoing described tests for Fig. 13 not every possible test has been described to indicate to you how the remaining parts should be tested. Again you should remember that it is the principle of a given test you should keep in mind and not so much the specific test itself as it relates to this one receiver.

Now consider Fig. 14 wherein the switches are turned differently from Fig. 13 to expose still other parts which may be tested by the continuity method. This is the phonograph record reproducing position for the selector knob. As for Fig. 13 certain continuity tests will be described for this circuit—not every possible test you might make—but enough tests will be described to enable you to

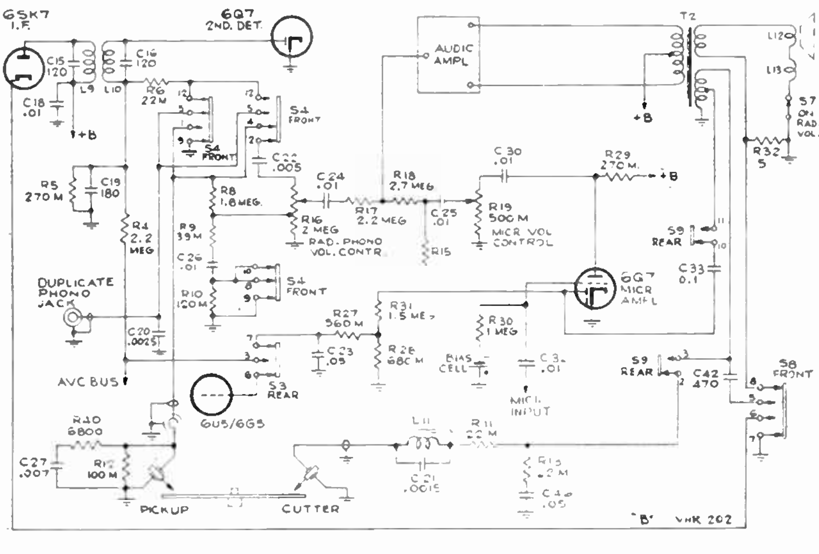


FIG. 14

make full tests on all similar circuits.

Tests may be started at almost any point in the circuit. However, all such tests should have a purpose and should proceed in a logical manner. So assume the complaint is *no record reproduction* and again it will be assumed that the tubes are in good condition. Begin at the pick-up and note it, like the cutter, is a crystal and therefore should act like a condenser from a DC continuity viewpoint. Also note R12 is in shunt with the pick-up. So the first thing to do is to disconnect one end of R12. Since there is a parallel circuit through R8 and R16 to ground the upper end of R8 should also be disconnected. Now connect one test lead to the chassis and leave it connected there for the time being. Connect the other test lead to the ungrounded end of the crystal (note a connection to terminal 1 of S4 or to terminal 4 of S4 is the same thing as connecting to the ungrounded end of the crystal). With these connections made there should be no reading on the meter. If a reading is obtained, the crystal is shorted, C27 is shorted, the wire lead from the crystal is grounded (possibly through the shielded braided wire) or there is a ground at one of the switches. In cases of this kind where a reading is obtained where none should be the best procedure is to check each part in the circuit separately. Where a condenser like C27 is in series with a resistor and not subject to DC it is not likely to develop a full short but it may develop high resistance leakage. With all parts in the pick-up circuit tested and proven fit to be used, the other parts disconnected should now be restored to their original connections.

With the one test lead still grounded in Fig. 14 touch the other one to the diode plate of the 6Q7 second detector tube. This will give a reading through L10 and through R6 and S4 for one parallel path and through R5 as another parallel path (assuming the AVC buss lead is disconnected). Since R6 is 22,000 ohms and R5 is 290,000 ohms it is clear from observation that the parallel effect of these two resistors is going to be less than 22,000 ohms. Calculation shows the effective value is 20,343 ohms. So if your ohmmeter reads in the neighborhod of this value, the two branch circuits are probably all right. Note this as a principle—where two branches are involved, you know the effective resistance value should be less than one branch circuit so you can with practice almost guess what the effective value should be.

As a test principle, note it is often possible to select two convenient test points easily accessible between which a unit part can be tested. For instance consider C33 in Fig. 14. By placing one test lead on 10 of S9 and the other test lead on the diode plate of the 6Q7 microphone amplifier tube C33 is tested. In like manner with one test lead on the triode plate of the same 6Q7 tube and the other test lead on the ungrounded end of R19, a test for C30 is provided.

Another similar test in Fig. 14 is from 3 of S9 to 5 of S8. This will give a test on C42. With experience you will soon learn to pick out such test points and thus save time.

Note the use of the bias cell in Fig. 14 for the control grid of the 6Q7 tube. The proper way to test this or a similar control grid circuit is to remove the bias cell from its clip, measure the voltage of the cell with a very high resistance voltmeter and check the resistance of R30 with the ohmmeter. If all is in order the cell

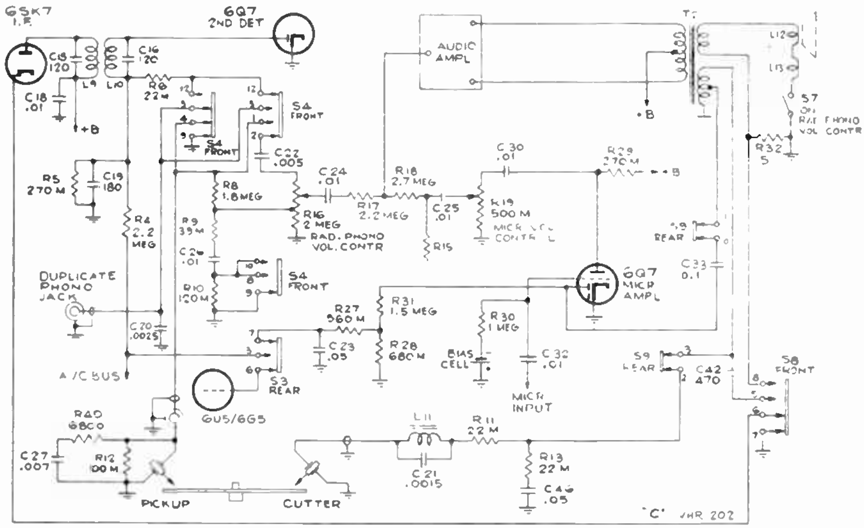


FIG. 15

should then be replaced in its clip. This description for Fig. 14 should be sufficient to enable you to test each and every unit in it or in a similar circuit.

Now consider Fig. 15. This brings still more parts of Fig. 12 into use. Directions will be given for testing a few of the parts in this circuit. To test the cathode circuit of the 6SK7 IF tube connect one test lead to ground and the other one to the cathode of the tube. A full scale reading should be obtained. No reading means the circuit is open. This could be an open at the cathode terminal of the socket, an open along the wire lead to S8 or S8 itself could be open.

With the one test lead still grounded, touch the other one in turn to 8 of S4, to 7 of S3, to 3 of S3, etc. Now trace these circuits and determine what the readings on the ohmmeter should be. If it is not clear which units are under test draw the circuits separately. This is one good way to develop a technique in continuity testing.

Now for tests on some of the units in Fig. 15 which cannot be tested so readily without disconnecting. It is desired to test R9, R8, R16, R17, R18, R15, R19, and R29. R8 and R9 may be tested together for a total reading of 1,839,000 ohms. R16 is the volume control and its terminals should be readily available for testing. Connect the ohmmeter leads across the end terminals of R16. A reading of 2 megohms should be obtained. Move one test lead to the center terminal of the volume control. Then turn the volume control knob throughout its path of rotation. There should be steady increases and decreases in the reading except where the taper takes a sharp effect. To tell the difference between an erratic effect and taper effect, turn the volume control knob very slowly. If the meter needle gradually follows the turning of the control knob, it is probably in good condition. A double check on an erratic control is actual operation —the control will cause noisy operation as it is moved—the remedy is to replace the control.

Resistors R17, R18, R15, R19 and R29 in Fig. 15 are best tested separately. No parallel path exists across them to ground so merely connecting your test leads across them is a sufficient test. R17 should test 2,200,000 ohms. R18—2,700,000 ohms, R15—2,200,000, R19—500,000 ohm tapered control, and R29—270,000 ohms. These are the rated values you should measure but you should keep in mind that a 20% tolerance is allowed. In the case of no reading for one of these resistors it means the resistor is open and needs replacing. The other resistors and condensers not mentioned in the foregoing tests should be tested in the same general manner as outlined for the others.

Next consider Fig. 16. This shows the use of the circuit for radio reproduction. It is not greatly different from the other figures (13, 14, and 15) and the same types of continuity testing are involved. In all of these figures the small squares at the top center of the diagrams labelled "audio ampl" represents the triode grid of the 6Q7 second detector tube and the 6SJ7 AF amplifier tube. The details of this amplifier stage can be seen in Fig. 12. It does not involve any switching and can therefore be represented as a block diagram. Its parts, however, are subject to the same types of defects as are encountered in the switching circuits. Thus it should be understood that if no defects are found in the switching circuits the same similar tests should be made on the other AF parts.

In considering Fig. 16, again assume the tubes are in good condition and that a defect is to be found by continuity testing. First test the 6SK7 IF stage. A test between cathode and chassis will establish if this circuit is complete through S8 to ground. Next connect your test leads across C18. Assuming no parallel path exists through the B+ lead, no reading should be obtained on the meter. If a reading is obtained, C18 should be replaced. Next test L9. This can be done by placing one test lead on the

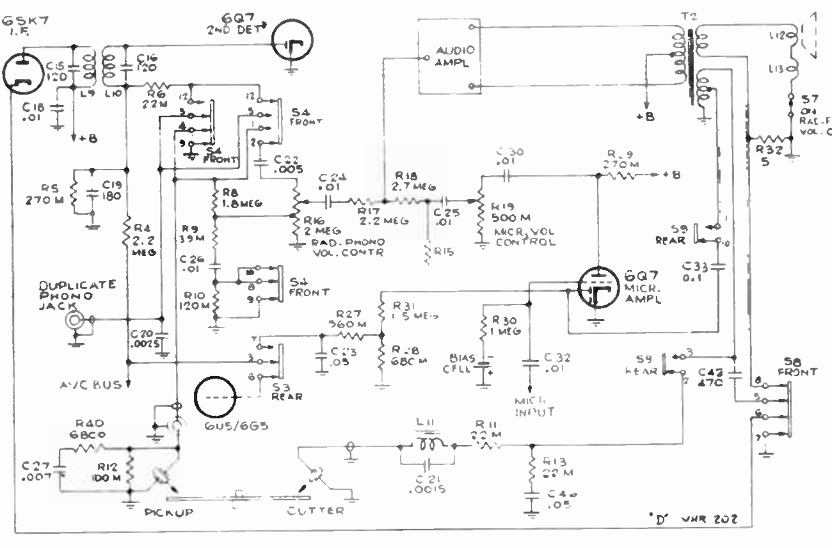


FIG. 16

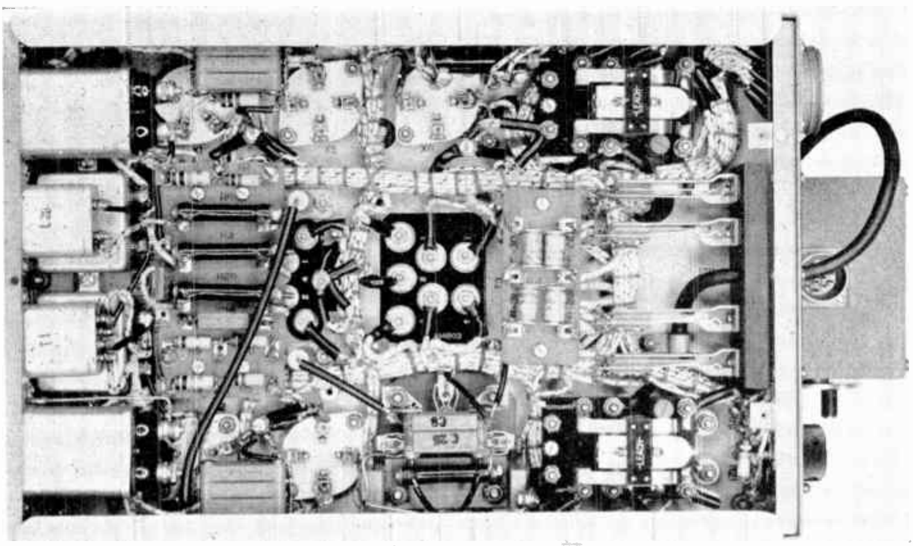
plate of the tube and the other one at the B+ connection. Normally a reading of 7 ohms should be obtained. No reading means an open coil or open wire lead. The coil should be replaced if found open.

Next pass on to the 6Q7 second detector stage. Place one test lead on the diode plate and the other one on the grid of the 6U5/6G5 tube. This will give a reading through L10, R4 and S3 for a resistance value of 2,200,000 ohms neglecting L10. Next move the one test lead from the grid of the 6UG/6G5 tube to ground. This will give a test on R5 and the reading should be 270,000 ohms. If it is considerably less than this amount give C19 and C17 in Fig. 12 a separate test for at least one of them will have developed an internal short to ground.

Note in Fig. 16 the signal is transferred from the second detector through R6, S4, C22, R16, C24 and R17 to the grid of the 6SJ7 AF tube. A test from the diode plate of the second detector to 2 of S4 should show a resistance of 22,000 ohms through R6. Next to test C22 leave one test lead on 2 of S4 and connect the other one to the ungrounded end of R16. To test C24 connect the test leads across it. A reading for either C22 or C24 indicates a replacement is necessary. This leaves R17 to be tested which should read 2,200,000 ohms. Next if you will refer to Fig. 12 the remainder of the circuit for the triode grid of the 6Q7 second detector stage may be seen. In the foregoing tests you will have tested the signal circuit through R17. Now note in Fig. 12 that R18, R15, R14, R35 and R37 is also involved in the triode grid circuit. A test from the junction of R17 and R18 to the triode grid of the second detector stage will test R18, R15 and R14. The value should be 4,939,000 ohms—a value difficult to read on the average ohmmeter. Thus, it would be better to test each of these resistors separately. To test the remainder of the grid circuit, leave the one test lead on the triode grid and connect the other one to ground. This should complete a circuit through R37, R35 and R14 to show a total value of 599,015 ohms. Here again note 15 ohms (R37) is small as compared to R35 and R14. A reading, however, indicates continuity. Note if R37 was open and if C31 was shorted practically the same effect would be obtained as if R37 was not open. So to be sure separate tests should be made on R37 and C31.

In the foregoing tests have been described for Fig. 16 on the signal circuits from the output of the IF to the input of the audio amplifier. In this series of tests the possibility of defects in the parts used have been eliminated. There remains the phase inverter and push-pull functions to be tested. Parts making up these stages consists mainly of a network of condensers and resistors. They would be tested exactly in the same way as described for the other parts. You would proceed to eliminate the possibility of a defect in each part, passing from one part to the other. In this way you would prove each part to be good or defective as you made progress. Thus, the defect or defects would soon be found.

You should remember in a given receiver, not all of these tests would have to be made. You would have certain clues to go by such as a lack of voltage or current in certain circuits as established by use of your multimeter under dynamic operating conditions. With this as a clue you would then use your ohmmeter to



This shows an under-chassis view of parts arranged in neat order. This view is typical of many receiver circuits and shows the parts just as they appear for testing. Thus it is seen that a schematic diagram is very desirable when tracing and testing circuits—it helps to avoid mistakes.

determine under static conditions just which parts would be at fault.

The RF section of Fig. 12 is typical of those you will be called upon to test. The push button system and the loop antenna can be disconnected from the circuit by simply removing the plug from the socket which connects them to the circuit, disconnecting these parts from the circuit allows an accurate and easy method of checking these units separately. The push button system often needs repairs and as it can be disconnected, the checking and repairing of defects is made fairly simply. Figure 17 shows a drawing of switches S1 and S2 of Fig. 12. These two switches are mounted on the same shaft along with S8 and S9 in Fig. 12.

The arrows indicate the terminals upon the switch slip rings; if the arrow is touching the ring, it indicates a contact and as these terminals are solid metal when any two of the arrows touch the same solid metal ring, they make contact with each other. Thus in the diagram of Fig. 17 arrows 1, 11, and 10 of S1, are connected together through the metal slip rings of the switch, also arrows 5 and 6 of this same switch are connected together. If the switch is rotated one position in a clock wise direction (only the metal terminals move not the arrows), arrows No. 2, No. 11, and No. 10 are connected—No. 1 being disconnected because the arrow isn't long enough to reach the terminal. Note also that 5 and 6 are connected.

In the next position in the clock wise direction, arrows No. 3 and No. 11 are connected and arrows No. 6 and 7 are connected.

From this discussion it should be an easy matter for you to follow the rotation of switch S2 through the three positions.

Referring again to the circuit of Fig. 12, the switching arrangement can now be followed. The position

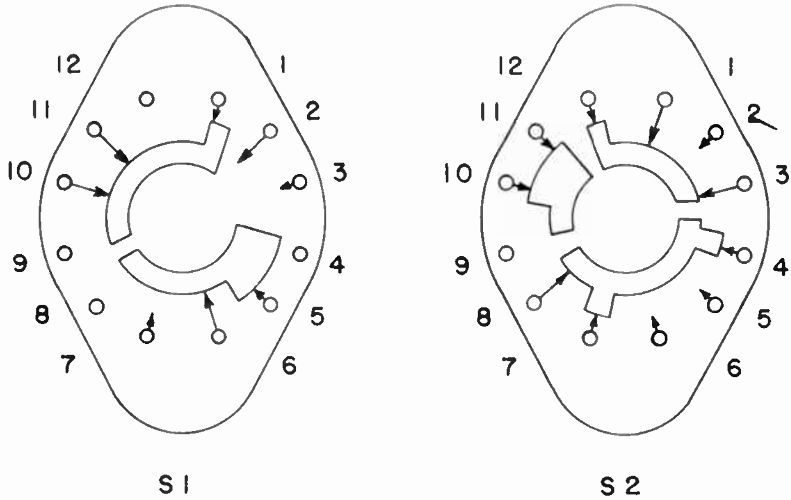


FIG. 17

for the switches as indicated on the diagram is for *push button operation* and by following the switch contacts it is obvious how the circuit is connected.

Following the connections of the switches as indicated in the preceding discussion of the switch terminals, it is found that at position 1 of the range switches (S1 and S2) that a continuity test of the push button circuit can be made. In this position continuity between the terminals of the switch and different push button circuits can soon be found. Between terminals 1, 3, and 12 of switch S2 and ground will give a continuity check of each coil in the push button circuit by pressing the buttons down one at a time. The continuity shown when the button is down is the resistance value of the coil associated with that button. Each button should be depressed to give a complete continuity test of the push button coil system. Between terminals No. 1, No. 11 and No. 10 of S1 and ground, there should be an infinite resistance (no reading on the ohmmeter) if the circuit has no defective condensers when any of the push buttons are depressed. Again to get a complete picture, each button should be depressed for this check.

These two continuity checks should indicate any defects within the push button system. Other receiver push button systems may vary considerably from this circuit. However, by following the selector switch system, the points for making the continuity tests upon the circuit can soon be located.

The continuity test of the receiver for the next switch position is just as easy to follow. Continuity between terminals No. 2, No. 10 and No. 11 of switch S1 and ground will indicate the resistance of the loop antenna. Between terminals No. 5 and No. 8 of switch S2 and ground will give the continuity between the tap on coil L5 and ground. The value found will be less than one ohm. Between terminal 7 of S2 and ground will give the total resistance of coil L5 or 3 ohms.

In the third position between terminals 3 or 11 of S1, the continuity of L2 can be secured. The continuity of L1 can be checked with the switch in position 3 between terminals 6 and 5 of switch S1. Continuity of coil L2 can be checked between terminal No. 3 of switch S1 and the receiver chassis.

The motor for the recorder and phonograph turntable can easily be checked as the only continuity test will be the motor windings.

To get an accurate picture of the operation of the switches and controls of the receiver refer to Fig. 18.

The service selector control operates switches S3, S4, S8, and S9 changing the circuit as shown in Figs. 13, 14, 15 and 16.

The Power-Bass and Treble tone controls operate the potentiometer as indicated in the diagram. Resistor R22 is the power-bass control. Resistor R23 is the treble tone control.

The push buttons are shown in Fig. 18 between the two tone controls. One button changes two circuits as shown in Fig. 12, that is, the first button operates S60 and S15, the second button operates S61 and S16, etc.

The control labelled volume control in Fig. 18 operates the main receiver volume control which is variable resistor R19 in Fig. 12. The

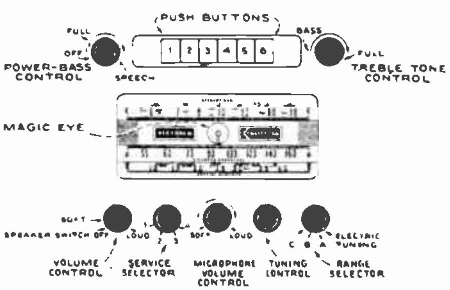


FIG. 18

microphone volume control operates the variable resistor R16. This control affects the volume of the receiver when the microphone is used. The tuning control of course is to change stations manually and controls the variable condensers in the RF and oscillator circuits of the receiver. The Band Selector Control operates switches S1 and S2. The three positions as indicated are for push button operation or electric tuning. The other two positions are for the broadcast band. manual tuning. and the short wave band. The 6U5 electric eye indicator is shown in the center of the receiver dial plate.

There are several service notes made upon the circuit diagram of Fig. 12 for making an analysis of this receiver with other types of test equipment. The significance of these notes will be clearer to you after you have studied some of the SAR service lessons to follow. All the information given by these notes aid the serviceman considerably in locating the defective stage or stages of the receiver.

The continuity test procedure as explained before is only an example for you to follow. The basic tests described here will be the same for any receiver regardless of its make or model. The actual circuit and also the arrangement of parts and other special features of the receiver may vary considerably from this example. If you have grasped the basic ideas given here, you will be able to apply the same type of analysis to any circuit.

In continuity testing. the accuracy of the results depends upon the interpretation of the readings taken. Guess work should be entirely eliminated and the reading taken should be carefully analyzed as to the condition of the circuit; keeping a sharp lookout for abnormal resistance values at all

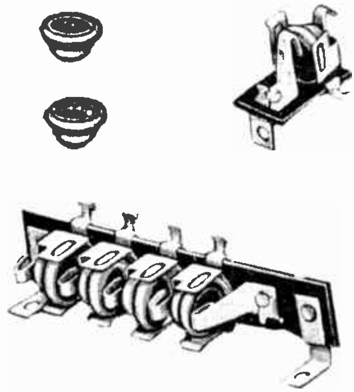


FIG. 19

times, taking care that the circuit under test is not affected by other circuits not directly under test. Many times one may be mislead by the resistance of the hands across the test leads. Little insignificant things of this nature can often cause a false reading and much time can be wasted in trying to locate a fault that doesn't exist.

Electrolytic condensers often cause misleading readings if the ohmmeter leads are placed across them with the wrong polarity. Bias cells used for obtaining grid bias can give puzzling readings if you are not familiar with these units. Fig. 19 shows some typical bias cells. The voltage of these cells can only be measured with a high sensitivity type voltmeter. If you attempt to measure the voltage of these cells with a low resistance meter, a false reading will be indicated. If you are making continuity tests of a circuit with a cell of this type (not aware that the cell is used) your ohmmeter will probably read off scale due to the added voltage in the circuit. So be on the alert for such units.

Practice and good judgment are always essential when making any receiver test. Don't jump at conclusions, take your time, don't hurry through a circuit, or you may miss the clue to the defective part.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 Name three simple but sensitive continuity testers.

No. 2 Describe what is meant by a continuity test.

No. 3 Name the units in a receiver which should show continuity and name those which should not show continuity.

No. 4 Why is it sometimes necessary to disconnect a part from the circuit before making a continuity check of this part?

No. 5 In Fig. 9 what resistance value should a continuity test show between the diode plates of the tube and ground?

No. 6 In Fig. 11 what is the resistance between the center tap of the output transformer and ground?

No. 7 What precaution must be taken when making a continuity test across circuits where electrolytic condensers are used?

No. 8 What effect will be noticed on an ohmmeter when it is placed across an electrolytic condenser?

No. 9 Can all sizes of condensers be tested with an ohmmeter?

No. 10 If a 1000 ohm resistor and a .05 mfd. condenser are Connected In Series and the ohmmeter test leads are connected across them what will be the reading on the ohmmeter?

THE VACUUM TUBE VOLTMETER FOR RADIO AND TELEVISION CIRCUITS

LESSON TV-4

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

THE TESTING OF TELEVISION HIGH IMPEDANCE CIRCUITS

In the early days of radio the sensitivity of meters used for testing was not too important because high resistance values were not often encountered and very wide tolerances in part values and in voltage values was common. Thus the early type meters often employed a sensitivity of less than 1000 ohms per volt. Such meters were standard for a long time and it has not been until recent years that manufacturers have learned to build meters with sensitivities up to 20,000 and 50,000 ohms per volt. Today a meter with a sensitivity of 25,000 ohms per volt is considered high indeed. However, such a meter no longer is 100% applicable to modern day AM, FM and Television receivers. This is especially true in FM and television receivers where resistance, impedance and frequency values are so extremely high. For these special conditions, ordinary meters, even with high sensitivities, can no longer be relied upon where accuracy in measurement is so important.

To overcome this lack of sensitivity in ordinary meters, vacuum tube circuits have been adapted to be used in conjunction with meters which increase their sensitivities tremendously. By this method the sensitivity of an ordinary meter can be increased from 20,000 to 50,000 times. Such a measuring instrument is very useful in all kinds of receivers but particularly is it true with reference to television receivers. These instruments are called vacuum tube voltmeters and the abbreviation VTVM is usually used to describe them.

This lesson includes a study of the different types of VTVM so that you will understand how they operate. Also you are shown how to apply the VTVM to practical problems. So give this lesson your complete attention, for later on you will find that you can apply these test principles to many of your FM and television repair problems.

K3552M

THE VACUUM TUBE VOLTMETER FOR RADIO AND TELEVISION CIRCUITS

Lesson TV-4

Those with radio and television experience know that the ordinary meter having an internal resistance of from 1000 to 5000 ohms per volt is not satisfactory for voltage measurements in high resistance circuits. To the student, however, it may not be so apparent why such meters are not satisfactory. The chief reason why a better meter is required is because the lower resistance voltmeters are not sensitive enough to measure voltages accurately — that is they draw too much current for full scale deflection. To overcome this deficiency the vacuum tube voltmeter (VTVM) has been developed. It is especially useful when measuring negative grid bias voltages, AVC voltage, bias cell voltage, determining receiver gain (overall or single stage), oscillator voltages and all other voltage measurements in high resistance circuits. This includes uses for both the AC and DC types of the VTVM as will be explained later on.

In order for you to fully appreciate the need for a VTVM consider Fig. 1. This shows a two stage amplifier using a 6F5 at the input and a 6F6 at the output.

Assume that this amplifier is not operating correctly, and that the defect is not at all obvious. One of the principle indices that may give a direct clue to the defect or defects is the measurement of voltages at the tube

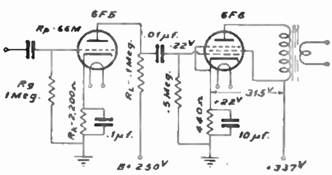


FIG. 1

socket terminals. A resistance test and a capacity test or a tube test may disclose the defect, but these tests require much more time and every part may have to be tested to localize the defect. Moreover, all of these tests may not disclose any source of defect, as the tests are not made under operating or dynamic conditions.

Assume further that you have an ordinary DC voltmeter having a sensitivity of 333 ohms per volt (a type often used by servicemen). The grid voltage of the 6F6 tube in Fig. 1 should be —2 volts. Now if you connect this meter (0—3 milliampere movement) used as an 0—5 voltmeter (by selecting the proper multiplier for this range) to the grid and cathode terminals of the 6F5 tube in Fig. 1 the following results will be obtained.

The circuit will be analyzed thoroughly, so that the error in reading and the reason for it will be clarified. For convenience in noting exactly how the voltmeter is related to the circuit, the parts of the circuit are redrawn which are primarily involved. The new circuit is given in Fig. 2. Each of the resistances in this drawing are the same as in Fig. 1, and there is an additional resistance Rm (that of the meter) introduced when the meter is connected for a reading. Its resistance at 333.3 ohms per volt for a 5 volt scale would be 333.3 × 5 or 1666.6 ohms.

Before the meter is added there is no current flow through Rg in Fig. 1 as its upper end connects to the grid which is negative with respect to the cathode. As in Fig. 2, however, the meter and Rg are in series and both are

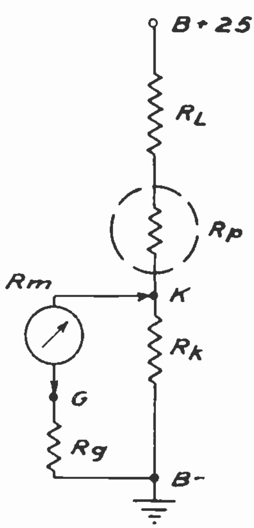


FIG. 2

across the cathode resistor Rk. In parallel with Rk the sum of the two resistances Rm and Rk reduce the total resistance, from cathode to ground, by about 1 ohm or somewhat less than .05 of 1%. The voltage at the cathode is reduced accordingly but is entirely negligible. The meter will normally read closer than 2%, so 1/20 of 1% may be entirely ignored. You may, therefore, assume *the voltage from cathode to ground,* across Rk, has been virtually unchanged by this meter connection. For proper operating conditions this would be 2 volts. This voltage is impressed across the meter resistance Rm and Rg in series, having a total value (Rg + Rm) of 1,000,000 + 1,666.6 ohms or 1,001,666.6 ohms. Since both carry the same current, the actual voltage across each member will be proportional to its resistance. In other words the voltage must be divided in the same ratio as the resistors. Since the meter resistance bears the same relation to the total resistance as the meter votage (Vm) does to the total voltage, you may correctly write—

$$Vm = \frac{-2 \times 1666}{1,001,666} = .0033\text{volt.}$$

This would be the actual reading of the voltmeter *if it were graduated finely enough to read this value.* The reason for this is that it is in series with resistance Rg. The current flow through Rg brings about a voltage drop from +1.9967 volts at G to zero volts approximately at B negative. Thus .0033 volt is, of course, the true voltage at these points (K to G) with this connection, but its reading has utterly no value in this circuit, for as soon as the meter is removed, the voltage at the grid end of the resistor drops from +1.9967 volt to zero. It is made almost 2 volts positive by the meter, which you will note. connects it (through Rm) to the cathode.

Many radiomen know that such a measurement has no value, but not so many know why this is so. That is why it would be well to dwell on this subject a little more, considering it in still another way.

In order to correctly measure any voltage, the terminals of the ordinary voltmeter must be connected directly across the source of voltage or across the two points where the voltage is available. Exact and precise resistances are used in the meter itself, so that its readings will be accurate as intended. If resistance is added *externally* in series with the meter, the meter cannot distinguish this from that used in its construction, and *such resistance will multiply the effective range of the meter.* Thus note you can double the range of any voltmeter by simply doubling its total resistance.

In the case just illustrated, *600 times as much* resistance has been added externally to the meter than it had already, and hence it would require 600 times as much voltage to make it read full scale as required originally. From a 0-5 voltmeter, its range has actually been multiplied to 5 × 600 or 3000 volts approximately. *Carefully note that a reading of 2 volts on a 3000 volt scale is equivalent to a reading of .0033+ volt on a 5 volt scale* as 600 × .0033+ equals 1.98 or approximately 2.

It was soon learned that the best way to get a fair reading of grid voltage was to read the cathode voltage and simply check the continuity of the circuit from grid to ground to make sure that this voltage was being applied to the grid. Now you will see if this method is practical with such a meter.

Using the same simplified circuit structure, note the meter is connected for this measurement in Fig. 3. Here the meter resistance Rm directly shunts the cathode resistance Rk, reducing the total resistance from cathode to ground (parallel effect). The new value is simply the value of the two resistances in parallel or:

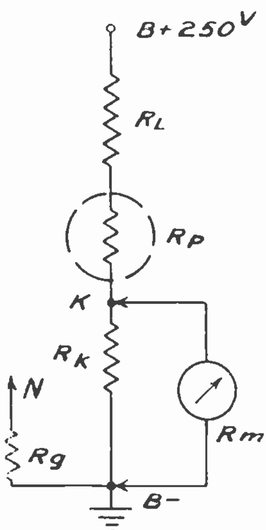


FIG. 3

$$Rt = \frac{2200 \times 1666.6}{2200 + 1666.6} = \frac{3,660,000}{3,866.6}$$
= 945 ohms approximately.

To determine what this has done to the original voltage at the cathode, you must first understand how this voltage occurs as *a voltage drop across a voltage divider.* The plate-cathode circuit is supplied with 250 volts, and carries .9 milliamperes. This means that its total resistance (plate-cathode circuit) is 250/.0009 or 277,777 ohms, of which RL is 100,000 ohms and Rk is 2200 ohms, leaving 277,777 − 102,200 or 175,577 (175,600 approximately) ohms for Rp. Bear in mind that this latter value is the instantaneous DC plate resistance of the tube.

With the meter connected as in Fig. 3 there is a total resistance (B + to ground) of 100,000 + 175,600 + 945 or 276,545 ohms approximately, of which 945 ohms is the cathode section. Thus 250 × (945/276,545) = .855 volt approximately as the cathode voltage. Formerly there was a total of 277,777 ohms, of which 2200 ohms was in the cathode circuit. This gives 250 × (2200/277,777) or 550,000/277,777 which amounts to 2 volts approximately. For simplicity, it is assumed the plate current will remain approximately constant and consideration has not been given to the lowered biasing effect in Fig. 3 of adding the meter.

Thus even with this connection, the reading of the voltage will be considerably off from the correct value. *The meter still reads the correct voltage of the terminals across which it is placed,* but this is by no means the same voltage that was there before the meter was connected.

One more measurement will be described before considering what changes in the meter arrangement will provide a more accurate reading. Suppose you attempt to read the plate voltage with this 333.3 ohms per volt meter. The meter will, of course, be connected between the plate and ground. An equivalent circuit would be as in Fig. 4.

You would expect to read a rather high voltage, and so would use a much higher scale of the meter than 5 volts. If it had a 300 volt range, you would probably choose that one for the measurement. Other ranges such as 250,300,350, etc. would do as well. For a 300 volt range, the meter resistance must be increased 60 times the value used for a 5 volt reading, because this is 60 times as much voltage. Thus 60 × 1,666.6 is equal to 100,000 ohms, which is the Rm in Fig. 4 in this case.

Without the meter connected, the total resistance as before is 277,777 of which the part from plate to ground or Rp + Rk = 175,600 + 2200 = 177,800 ohms. Now 250 × (177,800/277,777) = 160 volts approximately, which is the value of the actual calculated plate voltage.

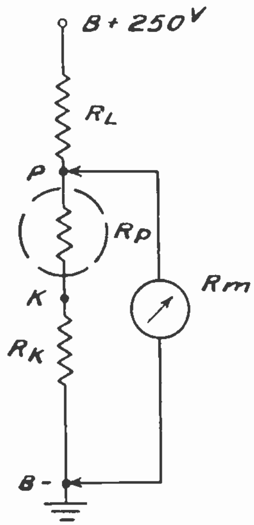


FIG. 4

When the meter is added, the total resistance from plate to ground will be the value of Rm *in parallel* with the sum of Rp and Rk. The latter sum, as you know is 177,800 and Rm for this case is 100,000 ohms. From the rule of parallel resistors, the total Rt converted to megohms is:

$$Rt = \frac{.1778 \times .1}{.1778 + .1} = \frac{.01778}{.2778}$$

= .064 megohm or 64,000 ohms.

This brings the total circuit resistance down from 277,777 ohms to 64,000+100,000 or 164,000 ohms. The voltage btween P, and ground in Fig. 4, will therefore be 250 × (64,000/164,000) which is 97.5 volts. You see, therefore, from these figures that the meter will record only 97.5 volts whereas the actual voltage is 160 volts.

The drop of voltage at the plate occasioned by the meter connection has been due to the value of Rt (the parallel value of Rm and Rp + Rk) being less than Rp + Rk alone.

Now suppose, you could change the resistance of the meter without changing its scale reading (0-300 volts)—that is, increase its sensitivity, make it deflect the same degree for lower values of current through it or voltage across it. A number of values of sensitivity (ohms per volt) and readings obtained are shown graphically in Fig. 5, for the circuit in Fig. 4. There is much information in this graph, and it should be studied closely.

At the left is the column of plate voltages up to the actual value of 160, which is the correct normal voltage for Fig. 4. For various total meter resistance values, Rm from 10,000 ohms to 10 megohms, the exact voltages recorded by the meter are shown by the curve. For example, with a 100 ohm per volt meter, having a

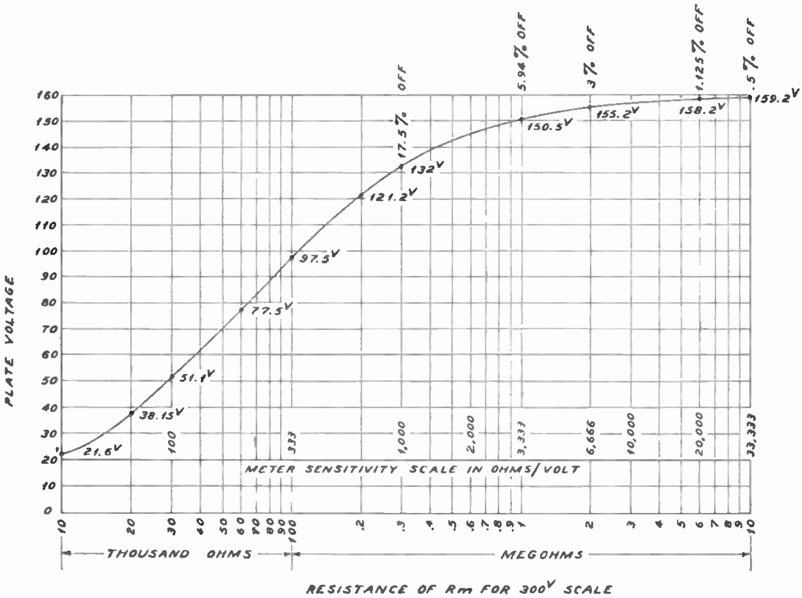


FIG. 5

range of 300 volts and a total resistance of only 30,000 ohms, the reading as described for Fig. 4 will be 51.1 volts. If the meter sensitivity is changed to 333 ohms per volt, the reading will be 97.5 volts as you have seen in the former example. If you use a 1000 ohm per volt meter, you will get a reading of 132 volts, which is 17.5% off. Using a 20,000 ohms per volt meter, you will get a reading of 158.2 volts, which is only 1.8 volts short of the correct value, or only 1.125% off. This is considerably more accuracy than is needed as the meter itself will usually be less accurate than this.

The curve of Fig. 5 distinctly shows the advantage of using a meter with the highest possible sensitivity for the most accurate reading. To cover this particular case, there are practical meters which will make very accurate measurements, but this case only shows the relations involved in this problem, and not in very much more difficult cases.

There are cases where the 20,000 ohms per volt sensitivity is as inadequate as the 1000 ohms per volt sensitivity is for the cases illustrated.

These are the commonly used AVC and AFC circuits. In most AF bias circuits, and many oscillator circuits, there are similar problems.

The entire problem is then resolved into one of obtaining a meter having the highest possible sensitivity. Such a meter need not have either a greater or a smaller range, and it need not have any larger scale or need other changes as long as its sensitivity is high.

Now, there is a practical limit to the construction of a reasonably priced portable or shop instrument. The size of wire used on the meter movement cannot be made smaller than a limiting size, and due to the requirements of meter construction, there are other limiting factors in the problem. Ultimately the current which drives the meter movement must be very much greater than the permissible current drawn from the point at which the voltage is measured. This is merely another way of looking at the idea of sensitivity. An instrument is most sensitive when it will deflect a given amount, using the least possible current.

How a Tube Improves The Sensitivity

The vacuum tube was early recognized as a suitable means of controlling relatively large currents by means of extremely small currents. One of the early applications of this principle is shown in Fig. 6. This circuit represents the basic idea used in most of the *vacuum tube voltmeters* in common use today. With this circuit, *the maximum sensitivity is attained when the resistance R across the grid circuit is as large as possible, and also when the change in plate current is greatest for a change in grid voltage.* Both will be observed as the essential requirements of a good power amplifier. This *ratio* of change in plate current to change of grid voltage may be recognized as the transconductance or mutual conductance of the tube.

A practical example can now be shown of how the sensitivity of the instrument as a whole has been increased over that of a meter alone. Assume the use of a 2 megohm resistor for R (Fig. 6) and assume that the tube is biased practically to plate current cut-off. If a tube is chosen that

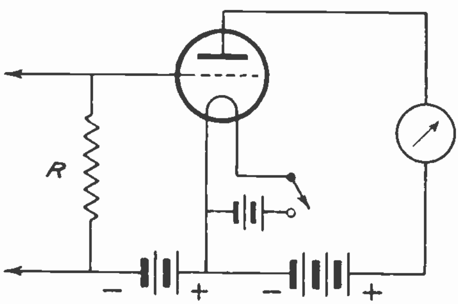


FIG. 6

has a range of 10 volts from zero grid to cut-off bias, it is obvious that the grid voltage can be increased 10 volts before it will draw current from the cathode. However, the 10 volts applied is placed across R, which means that there will be a 1 volt drop across each 200,000 ohm segment of it. The total current through R with 10 volts impressed is 10/2,000,000 = .000005 ampere, which is 5 microamperes. *The resistance is used only because of the necessity of closing the grid circuit of the tube.* It is as high a value as possible without causing instability of the tube.

The maximum value of resistance which can be used here is determined by the type of tube and the conditions under which it is operated. One result of too high a value of R will cause the commonly known *motorboating effect as observed* in audio amplifiers. If it were not for this, you could put from 20 to 50 megohms in the grid circuit and raise the sensitivity to many megohms per volt.

Some tubes can operate with these high values of grid resistance, but under these conditions the grid bias values are usually only 1 to a fraction of a volt and the plate voltage is only a few volts. The plate current would be so low that it would require a sensitive microammeter to read it. Obviously there would be little use for the tube in such a case.

Now, if the plate current of the tube chosen in Fig. 6 were 50 milliamperes for zero grid voltage, and a 0-300 volt scale were used on the meter, its actual sensitivity would be only 20 ohms per volt. Thus in simply using the tube the sensitivity of the instrument has been increased from 20 ohms per volt to 200,000 ohms per volt or 10,000 times.

The circuit of Fig. 6 is, of course,

not the final form of the vacuum tube voltmeter. Some refinements were necessary at the very beginning of practice with it. For example, it is known that near the cut-off bias of any tube its Eg-Ip characteristic bends considerably. This means that the grid voltage changes are not proportional to the plate current changes in this region. Figure 7 illustrates this difficulty. For this example a tube has been chosen which draws 10 milliamperes at zero grid voltage and having a —10 volt plate current cut-off point. When +1 volt (a voltage being measured) is applied to the grid in series with the bias (across R), Fig. 6, the total bias will be reduced by 1 volt or to —9 volts instead of —10 volts. This will cause somewhat less than .5 milliampere of current to flow in the plate circuit as indicated in Fig. 7. Assuming that the meter is made to coincide in current with the tube, that is 0-10 milliamperes for zero grid to cut-off, its scale will have to be marked as in scale 1, Fig. 7. The number 1 which on most DC meters is 1/10 of the spacing from 1 to 10, is now less than 1/20 of this distance. Likewise, 2, 3 and 4 are crowded at the lower end of the scale. Obviously this means that *unless there is some other means of using the meter, a new scale must be made in accordance with the curve of the tube being used.*

To avoid this, use is made of only that portion of the Eg-Ip curve for which the grid voltage and plate current are reasonably proportional, just as for a class A amplifier where the same thing is done to obtain as little distortion as possible. The portion of the curve lying between —6 and zero volts of the grid is reasonably straight for this purpose and the scale marked (2) of Fig. 7 can be used. Note that this evenly graduated scale is the type found on all D'Arsonval type DC meters.

There is one more difficulty which you will note. The meter must carry a little more than 2.5 milliamperes at —6 volts bias according to the tube curve, and yet it should start with this as zero. This is the current which flows before any external voltage is applied, and if the meter does not start at zero, it will be necessary to subtract some odd figure from each measured value.

Instead of doing this, some means is always used to apply an equal and opposite voltage across the meter so *that for no measurement it will read zero.* The meter is usually placed in the cathode side of the plate circuit so that this *cancelling voltage* may be applied more easily. It is done as in Fig. 8. At Fig. 8A there is obviously a bridge circuit in which the IR drop or voltage across R1 is equal to that of R2 for no test voltage ap-

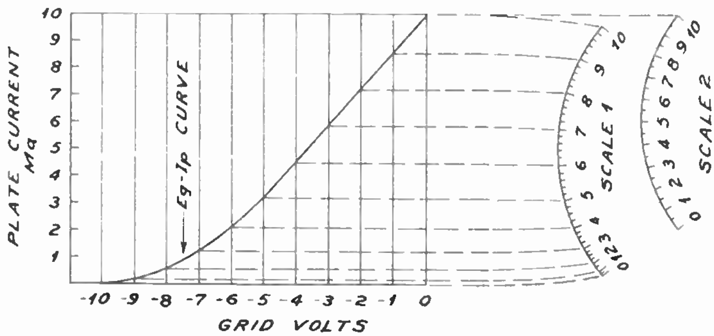


FIG. 7

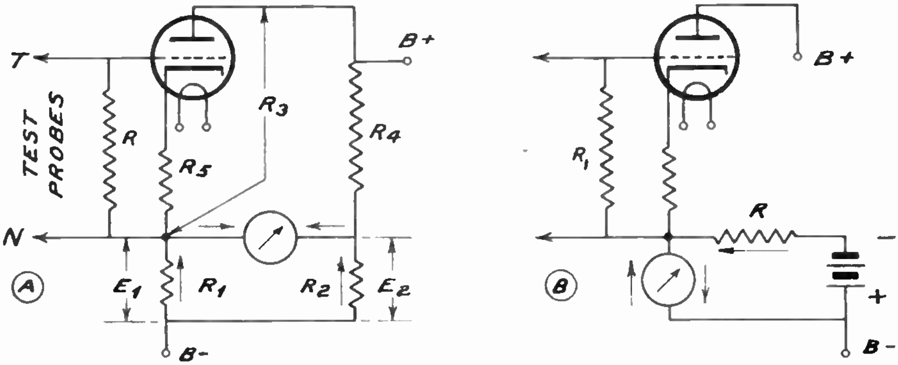


FIG. 8

plied to the test leads. When a DC test voltage (with + to the grid) is applied the IR drop of R1 will exceed that of R2 because the plate current of the tube will increase and a current will flow through the meter in proportion. R5 in Fig. 8A is to automatically bias the grid at the proper place in the lowest part of the straight portion of the Eg-Ip curve of the tube. A somewhat similar method making use of a battery is sometimes used as in Fig. 8B. These two methods are practically in universal use. The voltage supplied by the battery (or from a resistor net work in an AC operated unit) through resistor R is exactly equal to the drop across the meter due to plate current flow but opposite in polarity —thus the meter reads zero.

It is apparent that a mid-point of the Eg-Ip curve could be chosen as the grid operating point and a zero center scale reading meter used, permitting a reading of both positive and negative values.

It would appear that the voltage limit which a VTVM could handle would be simply determined by the total grid range from the most negative point on the Eg-Ip curve to zero grid voltage. If the grid becomes positive the instrument becomes useless as a VTVM for two reasons: (1) The grid resistance across the test leads reduces greatly, sometimes as low as a few hundred ohms per volt due to grid current. (2) The grid voltage and plate current will no longer be proportional.

It is possible to not only increase the voltage range of the VTVM, but likewise its sensitivity almost without limit. For example, suppose the total grid range is only 10 volts in Fig. 8A and the grid resistor R, is 2 megohms. For 100 volts you would still need only 10 volts across the grid resistor, so you simply add a multiplier resistance of 18 megohms as in Fig. 9. A resistance of 20 megohms total will carry the same current at 100 volts as 2 megohms will carry at 10 volts. In other words, you can multiply the scale reading just as for the meter alone. This, of course, will not change the sensitivity of the meter.

The main reason why higher ranges are not practical is because high values of resistance, such as above 10 meg-

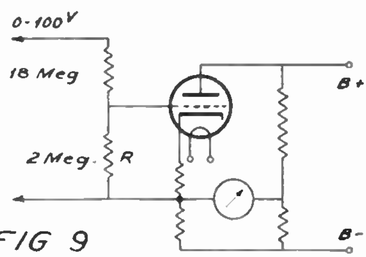


FIG 9

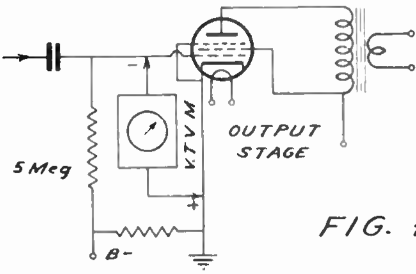


FIG. 10

ohms cannot be guaranteed as to value. No process has yet been developed to make such resistors that are dependable at reasonable cost and within reasonable size.

When a value of resistance as high as possible is used in the grid circuit, the only way the sensitivity can be increased beyond this is to choose a tube with the smallest possible *grid swing* and the largest possible Gm.

With this instrument, Fig. 9, suppose you wanted to read the grid bias of the circuit in Fig. 10 directly. The grid test lead would be placed at the grid while the other test lead would be connected to the cathode of the output tube.

From B negative to ground by way of the meter there would be a total resistance of the grid resistance (500,000 ohms) and the VTVM resistance (20,000,000 ohms) in series with it or 20,500,000 ohms, which will be identified as 20.5 megohms. Now 20 megohms of this total of 20.5 megohms is supplied by the meter and hence 20/20.5 of the total voltage will be dropped across the meter. This amounts to .975 or 97.5% of the actual voltage at the grid before the meter was added.

If the actual grid voltage is 16.5 volts, the meter will read 16.5×.975 or 16.1 volts, while if the voltage is originally 60 volts, the meter will read 60×.975 or 58.5 volts. These readings are but 2.5% off and are regarded as fairly accurate. If the grid resistor is .25 megohm, the accuracy would be increased to 1.25%.

In Fig. 9, it is obvious that there is 2 megohms per 10 volts or 20 megohms per 100 volts either of which would give 200,000 ohms per volt as the sensitivity of the meter.

A problem which presents great measurement difficulties in radio is that of AVC and AFC. An AVC problem is pictured in Fig. 11. The voltages directly at the grids within 2% accuracy under any conditions of operation are desired, with the meter connected as shown. Just the series conductive AVC circuit is shown in Fig. 11 and it is immediately realized

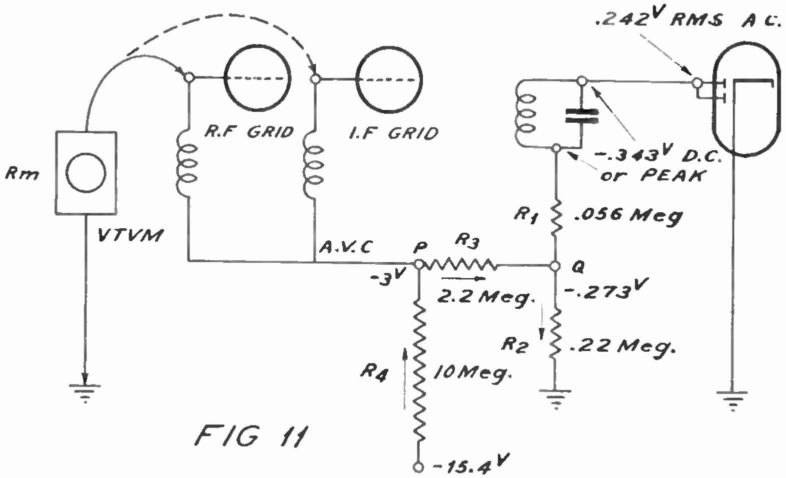


FIG 11

that the DC resistance of the grid coils is so small that they do not enter the problem in any essential way (assuming they are not open).

The AVC voltage from control grid to ground may increase to as high as 40 or 50 volts in many receivers and a 0-100 volt scale would be needed. Connected as shown in Fig. 11 the meter circuit actually may be regarded from P to ground, for measurement of either of the grid voltages shown. However, there is added value in measuring directly from the grids to avoid the possibility of coil or grid cap or wire leads being open. Resistance Rm would be in shunt with the sum of R3 and R2 which have a total of 2.2+.22 or 2.42 megohms.

Now measurement of the voltage from P to ground means that *some load or resistance must be placed across R3 and R2. The larger this resistance, the less will be the decrease of the total including R2 and R3 and the more nearly will its ratio to R4 remain the same.* This time it has been calculated that in order for the voltage at P not to fall more than 2%, the added resistance from P to ground must be 95.4 megohms. Suppose this is increased to 100 megohms still more decreasing the reading error and having a range in round numbers, which is easy to deal with.

Moreover, as mentioned, the AVC voltage could attain 40 or 50 volts, and so a range of 0-100 volts for the meter would not be excessive. While you are not as yet prepared to investigate all details of the VTVM, Fig. 12 shows how the grid section of this unit could be wired. There are 100 megohms in the grid or test circuit, 10 of which are across the grid-cathode circuit. This circuit's full range is 10 volts and the meter perhaps an 0-1 milliampere type is made to read on a 0-100 volt scale, and show full

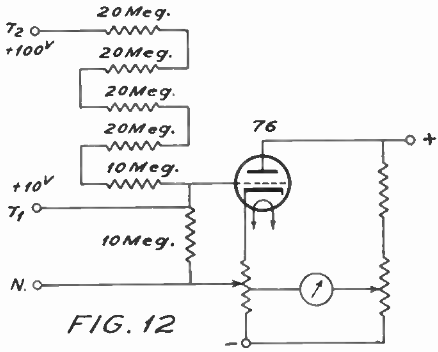


FIG. 12

scale deflection for 10 volts impressed on the grid. At 10 megohms and 10 volts, naturally the sensitivity is 1 megohm per volt.

The characteristics which would make a tube more or less suitable for adaption to VTVM purposes have been described. In the first place, the total grid voltage should be low—that is, a low grid range is advantageous because it increases the sensitivity ratio as indicated by the following:

$$\frac{\text{grid resistance required}}{\text{grid voltage range}}$$

Next, the Gm of the tube or the change in plate current resulting in a change in grid voltage should be as high as possible. The AC plate resistance should be as low as possible and the grid-plate (Eg-Ip) curve should be as straight as possible.

Now, as any tube chart will show, these desirable qualities do not all exist simultaneously in any one tube. For example, the 25L6 has a high Gm of 8200 micromhos, and the 6L6 has a Gm of 6000 micromhos. Neither of these tubes are suitable, however, because of their Eg-Ip curvature. For amplification this may be corrected as the correction is made dynamically, while the tube is in operation. If it is made statically, the value of the high Gm will be lost.

Another tube with a high Gm is the 2A3, which has both high Gm and straight Eg-Ip characteristics. On the other hand, it has a large grid swing (60 volts or more) and requires a lower than usual grid resistance. The filament with no indirect cathode and the plate drain constitute other practical difficulties.

The reasonably good Gm values of the 57, 6C6, 6J7, etc. are far outweighed by their undesirably high AC plate resistance values. Likewise, you could go through the entire tube list and show why each tube is undesirable on one account or another. Two tubes which have the best average of good characteristics are the 6C5 and 56. The 6C5 is usually preferred because of its 6.3 volt filament. Otherwise, these two tubes are alike. The 37 tube is also popular for VTVM use.

Nothing will so clearly demonstrate the action and specifications of a good VTVM as the actual design of one simple type.

Suppose a start is made with a 6C5 tube. So that a very high grid resistance may be used, it is by far advisable to use a low plate voltage. This reduces ionization tendencies, secondary emission, etc., making it possible to use grid resistor values which would be unstable otherwise. At 100 volts on the plate, the normal class A bias is -5 volts and with these voltages the normal plate current will be 2.5 milliamperes. As the grid is brought to zero voltage, the plate current increases up to 13 milliamperes. An increase of $13 - 2.5$ or 10.5 ma. This latter figure, 13 milliamperes, is obtained from the Eg-Ip family curve for the tube.

To take advantage of the full grid range from -5 to zero volts, a meter is required in the plate circuit with a maximum scale deflection of 10.5 milliamperes. Then when the grid is at -5 volts, the meter will be biased to zero and with 13 milliamperes in the plate circuit, it will carry only 10.5 milliamperes, the balance flowing in the meter biasing circuit.

Meters are not made with any definite odd sensitivity such as 10.5 milliamperes and so a multiplier must be used. No matter what the original range of the meter in milliamperes or volts, as long as its maximum scale deflection falls below 10.5 milliamperes it can be used. It is far preferable to have its scale marked in 5 major divisions rathet than 1.5 or 3, or even 2.5 as many meter scales are divided. It does not matter whether the scale markings are 0-5, 10, 15, 20, 25, or 0-1, 2, 3, 4, 5, or even 0-10, 20, 30, 45, 50, or 0-50, 100, 150, 200, 250, etc. Furthermore, it does not matter whether these were originally milliamperes or volts.

Suppose you have a meter with a basic full scale deflection of 2.7 milliamperes after removing all shunts. You must further assume for this example that the metet has a certain resistance, for example, 37 ohms.

Now in multiplying the range of the meter, it will be increased an amount equal to 10.5/2.7 or 3.89 times; or by a factor 3.89 above its original reading. Thus, the meter resistance of 37/3.89 gives 9.5 ohms as the total meter and shunt resistance and the shunt resistance will then equal:

$$\frac{9.5 \times 37}{37 - 9.5} \text{ or } 12.8 \text{ ohms.}$$

The meter with this shunt is placed in the plate circuit and its five major

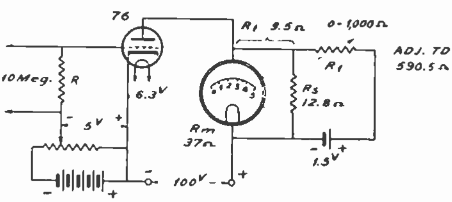


FIG. 13

divisions are simply five voltage divisions. See Fig. 13.

For this operation, note that the grid is externally biased, which is essential for such a high grid resistor value. Note also, that the meter balancing circuit is a small local circuit. The effective total of Rm and Rs in parallel is 9.5 ohms, and the 1.5 volt cell must tend to drive a 2.5 milliampere current through the meter in the reverse direction from that carried by the tube plate circuit. Thus, 1.5/2.5 x 1,000 or 600 ohms is needed, of which 9.5 is already in the circuit. An additional 590.5 ohms is needed and a variable resistor R1, 0-1000 ohms may be adjusted to this value.

Now consider what this VTVM will do. The meter itself is a 10.5 milliampere unit, which means that it has 1/.0105 or a 95.25 ohm per volt sensitivity. From the point of view of the modern meter, this is very low indeed. In the grid circuit, however, there is a total range of 5 volts with a resistance of 10 megohms, giving a sensitivity of 2 megohms per volt. Thus through the use of the tube it is possible to increase the sensitivity of the meter 21.000 times.

You can multiply this to any value in the grid circuit simply by adding 2 megohms of resistance for each volt added in the voltage range.

Before going into the AC vacuum tube voltmeter and practical applications, there are a few other points in connection with the DC instrument which you should study.

From Fig. 13 it should be obvious that the sensitivity of this type of circuit can only be improved upon by increasing the grid resistance, and where possible, operate the tube in such a way that this may be done. Now, if voltages within the primary or normal grid range of the VTVM are to be measured, *the grid resistance R in Fig. 13 may be omitted as the*

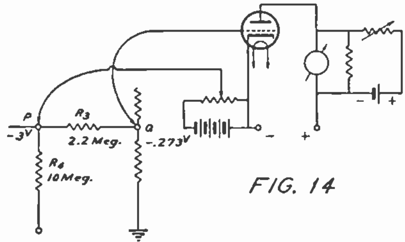


FIG. 14

circuit across which the voltage is measured becomes the grid load. This is illustrated in Fig. 14 where it is used across the resistor R3 of the same circuit as shown in Fig. 11. Resistor R3 in Fig. 14 becomes the grid leak, and *since the grid of the VTVM requires no grid current, the sensitivity is infinite.* The exact voltage, therefore, can be read directly from the meter in this case. For voltages in excess of 5 volts or, whatever the normal grid range of the instrument may be, this arrangement cannot be used. A grid resistor must be used as a section of a voltage divider for higher voltages.

This brings up the important low voltage applications of the DC vacuum tube voltmeter. While the number of precise voltage measurements that need be made under 5 volts are somewhat limited, there are a great number of readings which fall below 15 volts, and yet above 5 volts. The resistors across which these voltages may be measured are considerably below 10 megohms so that it is possible under these conditions to use a higher plate voltage on the tube and still permit infinite sensitivity of any of these readings with an extended grid voltage range. At a higher plate voltage, the bias recommended for class A operation of the tube is nearly correspondingly higher and inasmuch as there is no need to worry about the permissible grid resistance, perfectly accurate measurements may be made.

For example, if the oscillator grid circuit of a superheterodyne is ar-

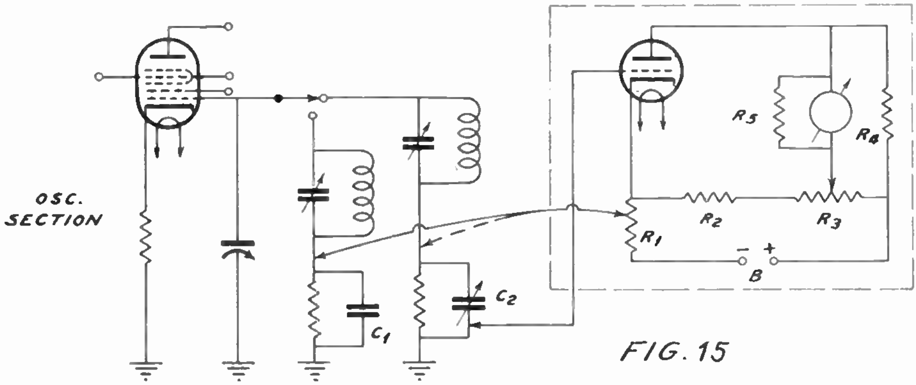


FIG. 15

ranged as in Fig. 15, the DC grid voltage while the tube is oscillating can be measured as shown. This voltage will vary anywhere from a fraction of a volt to minus 15 to 18 volts, in extreme cases. It will normally vary throughout the tuning band, usually rising with frequency from, 3 to 5 volts to 10 or 12 volts. No voltage here indicates no oscillation. This measurement will show whether or not the tube is oscillating at every frequency in every band. That is about all the value it has.

In some cases the connection of the VTVM test leads may stop the oscillator tube from oscillating in which case, the use of high series resistance in the cathode or bias lead or a choke coil in this band will prevent this difficulty.

Note in Fig. 15 that the VTVM circuit has been *revised* for full AC operation. The grid bias is obtained from a voltage divider and the balancing network for the plate meter is also derived from the main power supply without batteries.

For this circuit, the meter must read 5 milliamperes maximum, requiring a shunt R5 of 43.4 ohms. R4 may be 1000 ohms; R 3, 1000 ohms; R2, 25,000 ohms and R1, 2000 ohms. The voltage at B+ will be 250 volts.

Inasmuch as it is possible to use a meter with a sensitivity below 100 ohms per volt in the plate circuit, there obviously would be no need for amplification in any DC vacuum tube voltmeter unless to drive a power meter of very low sensitivity or for picking up an extremely small voltage and feeding it into a VTVM.

As a VTVM instrument is used more and more, the emission of the tube it uses naturally decreases and hence while the Gm of the tube may not change proportionately, the meter zero adjustment must be continually made. Finally, there comes a necessary drop in Gm with reduced emission at the same grid signal and the tube is no longer useful to fit the meter scale. True, you could increase the meter shunt to compensate for this, but there is a better way (Fig. 16) to do this so that no adjustments need be made, making appreciably no difference from one tube to another. Furthermore, the effective Eg-Ip characteristics are more nearly straight and the grid range is greatly increased.

The only way in which it differs from the usual circuit is in the addition of the cathode resistor Ro (Fig. 16). The combined DC resistance values of the plate circuit of the tube and Ro form a total value R1, which

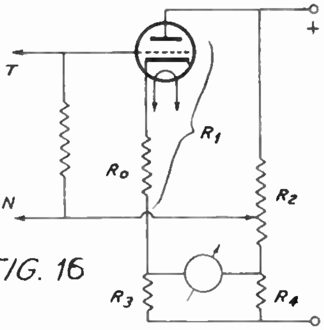


FIG. 16

acts as one arm of a bridge circuit R1, R2, R3 and R4. R2 is a potentiometer, so that a bias value may be chosen to fit the tube.

Measurements of the operation of this circuit will show that the ratio of change of grid voltage to change of plate current is much more nearly constant than for any class A amplifier. Since the cathode voltage rises and falls with the grid voltage, making the total grid-cathode voltage difference small, the grid voltage may change a much greater amount than for the other type of meter. Its sensitivity may thus remain quite high for a much larger range of voltage.

By means of a bridge system, such factors as tube emission and Eg-Ip characteristics may be cancelled out of consideration. Figure 17 shows an early type commercial VTVM using the bridge principle.

A test voltage is introduced at Ex with the polarity shown across the 3 megohm resistor. The cathode voltage then follows this almost precisely as the net voltage difference between the grid and cathode is of no importance. Voltage Ex is thus added to that across the 5 megohm resistor as E1. Before the test voltage is applied, the 10,000 ohm resistor in the 76 tube cathode is adjusted for a balance of the bridge circuit, consisting of two 6000 ohm resistors, one 40,000 ohm resistor and the plate circuit of the 76 tube.

The voltage added to E1, of course, reduces the plate resistance of the 76 tube and unbalances the bridge, indicating a bridge current flow through the galvanometer. During this time, R1 is adjusted to zero resistance, so that E2 will be zero. To rebalance the bridge, the movable element of

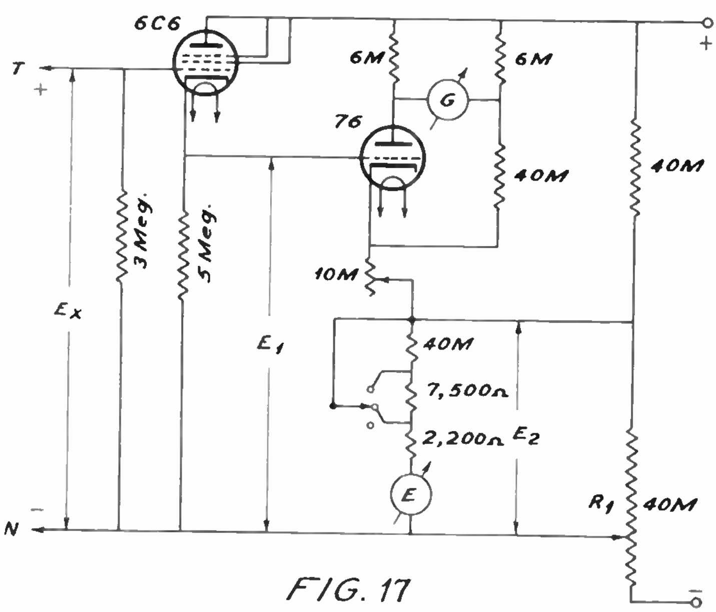


FIG. 17

R1 is moved down, giving rise to an increasing voltage E2. Note that E2 subtracts from E1, and eventually when E2 equals exactly the increase of E1, the bridge will be balanced and the galvanometer will read zero. The voltage E2, therefore, which has been necessary to balance the bridge is equal to the increase of E1, and hence to Ex which has been added to E1.

In this way it is possible to construct a meter of very high sensitivity which will not be dependent on the tube's life. No matter what the emission or Gm of the 76 tube falls to, as long as the bridge can be balanced at the 10,000 ohm resistor the results will be accurate.

It will, therefore, be just as accurate with the tube almost dead as for a new tube. The same is substantially true of the 6C6 tube, as its plate current is extremely low at all times. This has the disadvantage of complications, difficult to operate correctly and uses two meters. It is, therefore, not a direct reading instrument.

Typical DC Vacuum Tube Voltmeters

There are several very good vacuum tube voltmeters on the market today, some are designed to measure both AC and DC, some just DC or AC. The DC type will be considered in this section of this lesson.

A very popular vacuum tube voltmeter among servicemen is the RCA Voltohmyst. This meter has several features besides the DC vacuum tube voltmeter as you can see from the diagram of the unit in Fig. 18. Most present day meters are of a multi-range variety. By designing an instrument to measure several quantities it allows servicemen to acquire equipment for making most measurements at a much lower cost than if each meter is purchased separately. The Voltohmyst is a special designed meter of this type.

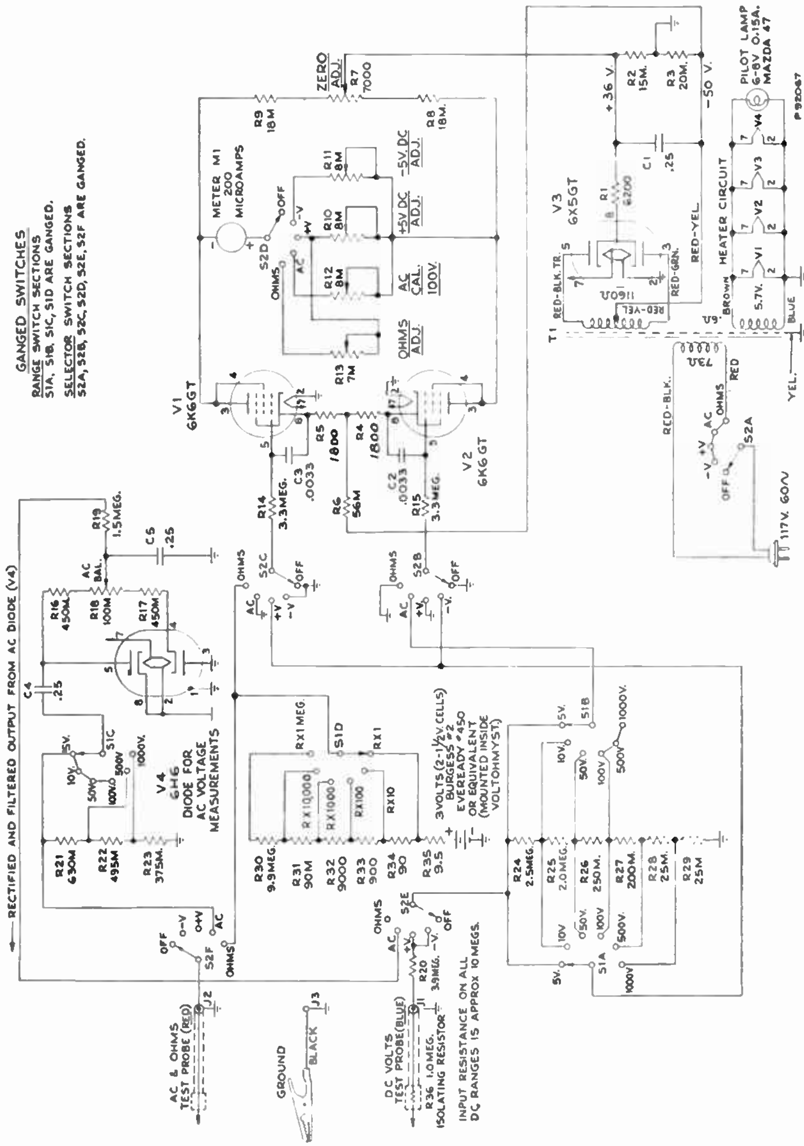
The circuit diagram of Fig. 18 is a complete diagram of the RCA Junior Voltohmyst. The vacuum tube voltmeter of this unit operates on DC only. The AC meter as you can see by following out the circuit is not of the vacuum tube voltmeter type. However, the rectifier for this meter is a vacuum tube. The DC vacuum tube voltmeter of this instrument uses a push-pull differential vacuum tube bridge circuit.

As the two 6K6GT tubes are linked by means of a common high resistance (R6) and because of this coupling between tubes any change in the input voltage to the grid of one tube changes the cathode bias of the other and as a result the change in the plate current of one is accomplished by a simultaneous opposite change in the plate current of the other.

This differential in voltage developed across R8 and R9 in Fig. 18 is applied to the meter which is calibrated in terms of the voltage applied to the grid. When the instrument is being used as an ohmmeter the scale of the meter is calibrated in the terms of resistance. The input resistance of this meter is the same for all voltage ranges and is 9.9 megohms. This high value of input resistance makes this instrument a valuable meter for measuring the tube bias or any voltage in a high impedance circuit.

There are 6 ranges from 5 volts up to 1000 volts in steps of 5, 10, 50, 100, 500, 1000. Because of the special circuit, line voltage variations have little effect upon the meter readings.

The ohmmeter of this instrument also uses the vacuum tube voltmeter arrangement, allowing a very wide range of resistance measurement from



Schematic Circuit Diagram

FIG. 18

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.1 ohm up to 1000 megohms. The high resistance ranges are possible because of the vacuum tube meter circuit employed in this instrument.

Another modern vacuum tube voltmeter type is shown in Fig. 19. This is the Precision model EV-10-S. The meter ranges and the number of different measurements available with this instrument are similar to the RCA Voltohmyst. It is designed to measure DC up to 6000 volts in 8 ranges—3, 6, 12, 60, 300, 600, 1200 and 6000. The zero of the meter is in the center of the scale when making measurements with the VTVM thus making polarity switches unnecessary. The input resistance of this meter is 13.5 megohms on the first six lower ranges; 26.6 megohms on the

1200 volt range and 133.3 megohms on the 6000 volt range.

The vacuum tube voltmeter of this instrument is a stabilized bridge type employing a 6C5GT as a voltage amplifier, a 6X5GT as a power supply rectifier and a VR 150 as a voltage regulator. The VR 150 holds the plate voltage to the amplifier tube constant regardless of variations in line voltage.

The ohmmeter associated with this instrument has 6 ranges—0 to 2,000; 200,000; 2 megohms, 20 megohms; 200 megohms and 2000 megohms. The ohmmeter of this instrument like the Voltohmyst is used with the vacuum tube voltmeter. The other

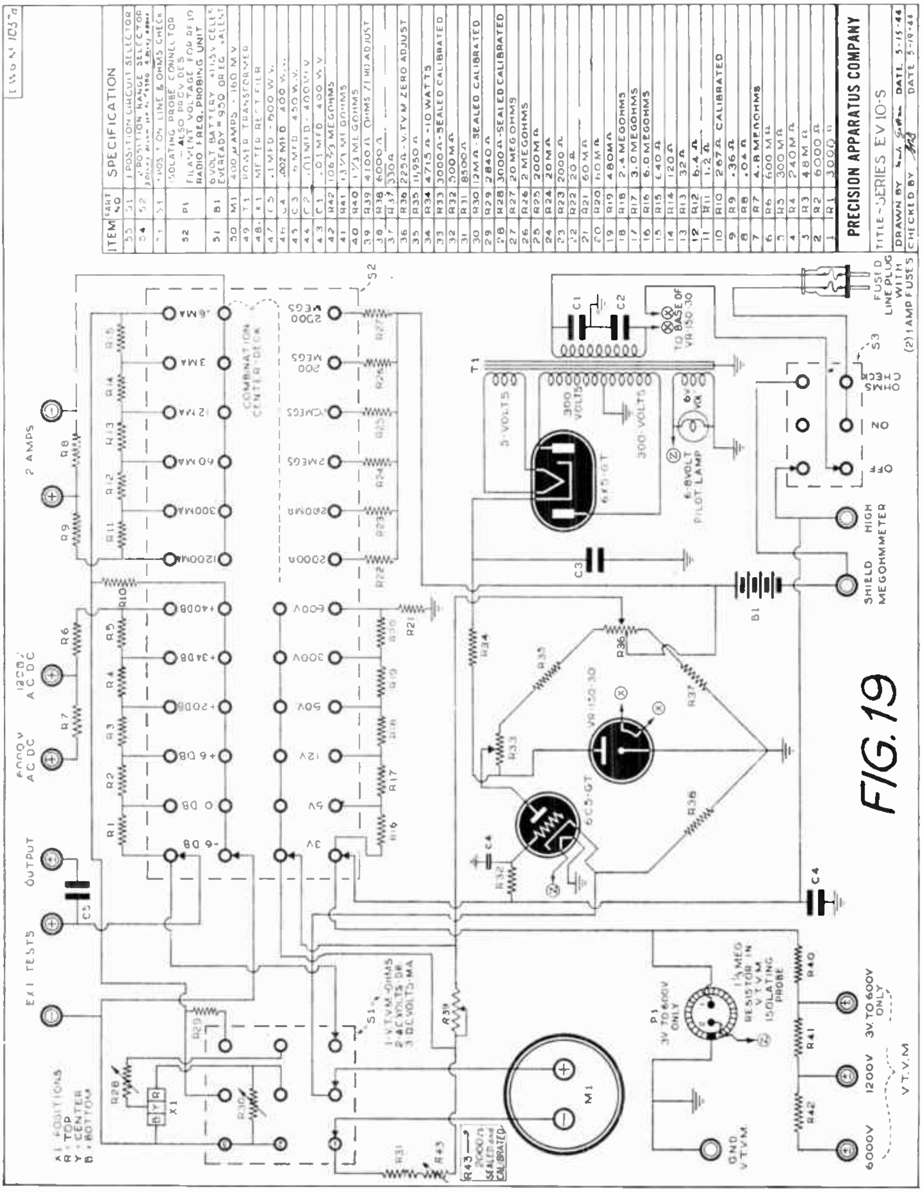


FIG. 19

available measuring circuits are not associated with the vacuum tube voltmeter.

Both of the foregoing described instruments are so designed that damage to the meter from overload is almost impossible. This is a good feature as meters are often damaged from unintentional overloads.

There are many other vacuum tube voltmeters manufactured by other companies each having their own special circuit design which will vary from the circuits given here as examples.

The design of each unit is different and the range of measurements that can be measured with each instrument varies depending upon the design of the instrument. One instrument may be especially designed for one thing and another for an entirely different purpose. Usually the ranges used by these instruments are within the ranges of the units discussed in this lesson.

In some instruments the tubes and the components used are not standard types. Any variation in part values in case a replacement is necessary may cause serious trouble and inaccurate readings will be the result.

The VTVM For AC

The use of the VTVM for alternating current voltage measurements has a somewhat wider application than for DC. The ultimate meter for an AC vacuum tube voltmeter is always a DC meter so that it may be understood at the outset that some type of rectification of the voltage to be measured, takes place. This rectification may take place in the regular measuring instrument, in a tube or in an auxiliary circuit. Later developments favor using an auxiliary circuit for several important reasons.

First the self-rectified type of VT VM will be considered as in Fig.

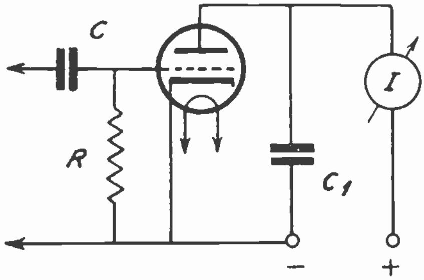


FIG. 20

20. Note that this is simply a grid leak condenser detector circuit, which as you know, converts AC to DC. In this case, the meter is chosen with a sensitivity which permits a full scale reading with no test voltage applied. Then when an AC voltage is applied at the test leads, the rectification of the grid-cathode circuit produces a negative charge on the grid very nearly proportional to the voltage applied. This reduces the plate current also. in proportion, until it gets near the *cut-off region*.

Obviously the main difficulties here are the reverse graduation of the meter, the dependence on the uniform emission of the tube and the partial scale inaccuracy. Without multipliers it has a very limited voltage range.

The plate circuit type of detector-rectifier AC vacuum tube voltmeter is shown in Fig. 21. This is just like the DC type with the exception for adjusting the meter to zero as described formerly. In the case of AC input, a plate filter condenser C1 is also advised. The addition of the

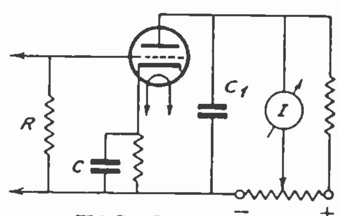


FIG. 21

condenser does not prevent the use of this instrument for DC and in addition the resistor R may be removed for low DC voltage measurements within the class A bias range of the tube.

Before the development of the electric eye or other tuning indication methods the meter tuning indicator was used. It was usually connected in the cathode circuit of one or more tubes and was simply a type of VT VM.

Of course, there are two common values of an AC voltage, which can be read and these are the *peak value* and RMS values. The meter may be graduated or adjusted to read either. Having one of these values it is quite easy to find the other and so the adjustment is used only to avoid calculations and to read direct values. However, there are VTVM *peak meters* which owe their operation to the peak voltage value, although they are sometimes calibrated for RMS values.

Such a voltmeter is shown in Fig. 22. A test voltage is introduced into the grid-cathode circuit with R1 adjusted at the cathode so that the bias voltage reading (E) will be zero and R3 is adjusted for zero plate current indication. Naturally a reading at meter (I) will show the presence of plate current, but no attention is paid to the exact value here. The movable element of R1 is then moved toward B—until the meter (I) reading reduces to zero as it was before the test voltage was applied. The reading at (E) is thus required to prevent any plate current flowing for the amount of AC applied to the grid. It is, therefore, the peak value of the AC applied.

It makes little difference whether the AC being measured is 60 cycles or 465 KC or even more if short leads are used. The reading will be accurate.

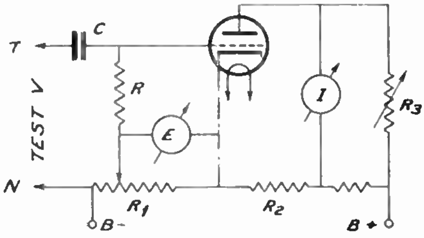


FIG. 22

Vacuum tube voltmeters of special design can handle equally well any AC from 20 cycles to 100 megacycles. This is not possible with any other type of instrument.

This circuit may be used with an initial bias, using a cathode resistance without showing any reading at (E) so that the entire operation may be accomplished with less plate current.

If the voltmeter (E) measures 10 volts, this means that the positive peaks of the test voltage are 10 volts. The RMS value is, of course, 7.07 volts. Accordingly, the meter may be calibrated to read 7.07 volts when 10 volts are applied if desired. This is done by simply increasing the multiplier resistance value 41.4% for this voltage range. If it is a 1000 ohm per volt meter reading on a 15 volt scale, it will have 15,000 ohms resistance. Now $15{,}000 \times .414 =$ 6,220 ohms approximately, which must be added in series with the meter. Its actual scale has been increased to $15 + 6.22$ or 21.22 volts (peak), but when this voltage is applied the meter only reads 15 volts RMS.

Since the voltmeter (E) reads across a fairly low resistance value, and not in the test circuit, its sensitivity has no effect on the measuring circuit. Because of the *sliding back* of potentiometer arm R1 in Fig. 22 to zero plate current, the instrument is commonly called a *slide-back VTVM*.

In an AC vacuum tube voltmeter the sensitivity is determined by the

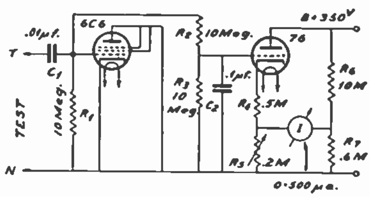


FIG. 23

impedance of the input circuit in ohms per RMS volt. Entering into this impedance value are the input coupling condenser reactance, the grid external resistance and the ohm value of the tube's input impedance. This latter term includes the total grid capacity of grid to all other elements, the grid shunt leakage resistance and reflected reactance values as for regeneration or degeneration.

Mention has been made of the external rectifier as applied to an AC vacuum tube voltmeter. A circuit of one popular type is shown in Fig. 23. The positive alternations applied across the grid-cathode circuit of the 6C6 connected as a diode are rectified. In the process, the grid becomes negative and the rectified current flows through R1, R2 and R3; the latter two being in parallel with the former. At the grid of the 6C6 AC is impressed, but the filter action of R2 and C2 is such that almost pure DC is impressed on the 76 grid. During operation, the voltage across R3 and C2 (one-half of the peak voltage from grid to ground of the 6C6) is measured by reason of the VTVM section, which is the 76 tube and its circuit. The customary bridge meter connection is used here. A 6C6 is used rather than a diode for high impedance rectification and to prevent saturation conditions where added input voltage will not increase rectified current.

Now the combined load on the AC source is the total resistance from grid to ground, which is—

$$\frac{10 \times 20}{10 + 20} = \frac{200}{30} = 6.66 \text{ megohms.}$$

The total input grid capacity of the 76 is of no concern, as it is supplied with DC. The input capacity of the 6C6, of course, is in shunt with the total resistance (6.66 megohms), making the total impedance equal to the *product of the resistance and capacity reactance at the frequency being measured, divided by their series impedance* at the same frequency. The reactance of C1 is part of the total impedance, but its value is so small that it need not be considered above 60 cycles. Neglecting it at 10,000 cycles the input impedance is a little below 3 megohms (2.87 megohms approximately).

Not until a high value in the KC spectrum is reached will the capacity reactance of the tube's grid input be low enough to seriously load the circuit under measurement. However, it is very obvious that if a long shielded lead is used for the test circuit, its shunt capacity may be very large. Also, at high frequencies it begins to express its transmission line characteristics, making the load on the circuit being tested very considerable. If, for example, it was rated at 2 megohms of impedance, it would have an input impedance of only a few hundred ohms at the higher frequencies.

This is completely avoided in a well designed unit by placing the rectifier tube at the end of the test lead so that it may be as close to the tested circuit as possible. In this event, the test lead simply carries DC. An example of this application combined with the degenerative feature is shown in Fig. 24. Note in Fig. 24 the grid resistance of the VTVM section has been omitted. In Fig. 23, R3 may be omitted if R1 and R2 are made small enough.

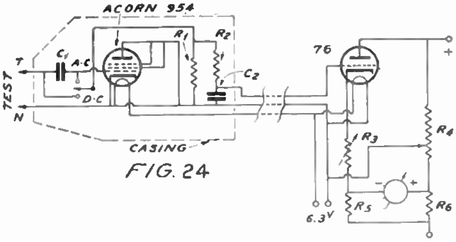


FIG. 24

For compactness of the test lead, Fig. 24, an acorn type 954 pentode tube is used for the rectifier. The use of a pentode rather than an ordinary diode as explained before has definite advantages inherent in its characteristics. The measuring circuit is, of course, just like the one in Fig. 16, the details of which have already been covered.

In common with the other types of cathode bridge circuits, such as in Fig. 16, this circuit as in Fig. 24 has a very great advantage which has not been described.

Measurement of DC voltage at points remote from the source through high resistance involves both *positive* and *negative* values. It may have occurred to you that the VTVM does not have the flexibility in the way of changing its polarity that an ordinary meter would have. For example, if it is an ordinary plate circuit type, as in Figs. 6 or 13, it is designed to read only when the grid is made more positive. True, you may reverse the input leads but this has two important disadvantages. (1) It will usually by-pass and stop any RF or IF or even AF which must be preserved to produce the very voltage being measured. For example, if you stop the signal at an IF tube in order to measure the AVC produced, the AVC will not be produced as it depends on the signal. It is created from the signal. (2) Even where pure DC is being measured, there is a high probability that the leakage of the large ground or chassis system of the instrument would destroy the high sensitivity of the VTVM. So for either polarity, the grid terminal of the VTVM should connect to the ungrounded terminal of the voltage being measured.

Moreover, this suggests that all voltages should be measured with respect to ground which is recommended. Now the advantage mentioned here is that in the cathode bridge circuits of Figs. 15 or 24, the *meter* terminals may be reversed for reading either positive or negative grid voltages without reversing the test lead terminals.

For AC readings, of course, the grid readings will all be negative in proportion to the AC voltage applied and for equivalent negative DC voltages introduced at the 76 grid, Fig. 24, the meter is not changed. For readings where a positive DC is involved on the grid, the meter is reversed. Better yet, is the use of a zero center scale meter which will read either polarity without change of the circuit. Even if the meter is not a zero center scale type, it may be adjusted to half scale deflection while in the circuit and thus be made to read either positive or negative voltages with the meter dial calibrated with zero at the center.

A circuit of this character is shown in Fig. 25. The group of resistors (R1) are multipliers for various ranges of the instrument. With this

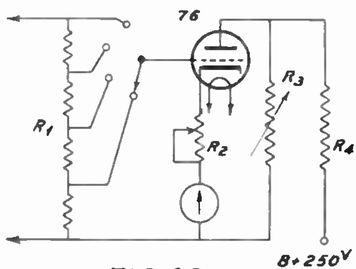


FIG. 25

arrangement the sensitivity is, of course, maximum at the lowest voltage range, decreasing as the range is increased, R2 is to provide the normal class A bias so that the same accuracy can be obtained for both positive and negative potentials on the grid. R3 and R4 comprise a voltage divider, the former for stability of the voltage supply and the latter for the positive divider section. Either may be variable or they may form one potentiometer from B+ to ground with the plate connected at the movable element. The ranges can be extended indefinitely for both positive and negative polarities and no attention need be given the polarity during measurement.

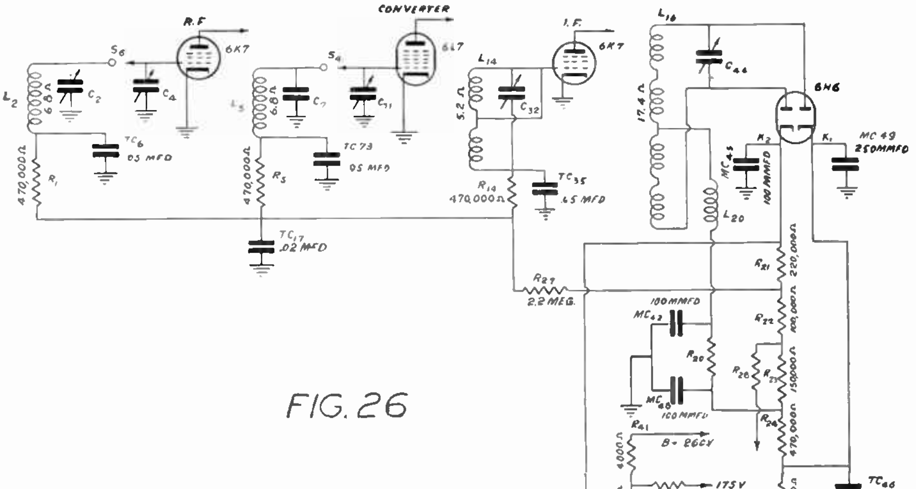
Uses of the VTVM

Like any other electrical instrument, the interpretation of the VTVM readings is very important. Getting a reading from any desired point in the receiver is one thing but determining whether or not this reading is correct by reason of the circuit operation is quite another. Here is a good example of the value of correct interpretation of readings. Suppose you measure the plate voltage of a resistance coupled amplifier with a highly sensitive VTVM and find it to be 75 volts. You may also notice that a manufacturers voltage table gives a value of 11 volts, for example, for the same reading. However, the latter reading was taken with a meter having only 1000 ohms per volt sensitivity. Also the voltage table may specify the volume was full on or off when the reading was made, which may or may not affect this reading. Moreover, if you have no chart to refer to and the tube in question is rated to operate at a much higher voltage, how are you to know that 75 volts is correct even if you can easily read this value to better than 2%? This is where your experience with circuits and their elements will be of great assistance. The theoretical knowledge of the circuit operation permits you to take such things as this into consideration.

One of the best ways to understand the practical uses of the VTVM is to study how it may be applied to an actual receiver. For this purpose *a portion* of the GE receiver model E-126 has been chosen. The essential circuit is shown in Fig. 26. This is a typical circuit employing high value resistances and is representative of circuits on which you are likely to be required to make voltage measurements.

The circuit affords a great number of possible uses for the VTVM in connection with voltage analysis of the circuit. While you could just as well measure all voltages of the receiver with the VTVM, the greatest concern will be with measurements through high resistance and high impedance circuits which will give little or no response on the usual meter.

The first measurement to be considered will be for the control grid of the 6K7 RF tube. The grid lead of the VTVM will be identified as *T* (for test lead) and the cathode or ground of the VTVM lead will be *N* for negative test lead. Any of the DC bridge type vacuum tube voltmeters described in this lesson will do for this work. An ordinary meter in a bridge vacuum tube voltmeter circuit like Figs. 15, 21 or 24 may be adapted for reading either polarity of the input in two ways: (1) A reversing switch may be provided and set for the correct reading. (2) The circuit may be adjusted so that the meter will remain at half scale for no test voltage and the scale of the meter regraduated for zero center scale reading. Thus it can read up scale for a positive test voltage and down scale for a negative test



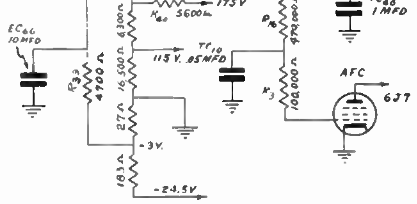


FIG. 26

voltage. The test lead *T* is placed on the control grid cap and test lead *N* is placed on the cathode of the RF 6K7 tube in Fig. 26 with the receiver and VTVM turned on. Now, if the antenna is detached and there is no signal, you would expect a minimum bias to be applied to the grid. You can trace the grid circuit of the RF tube in Fig. 26 back through the tuned circuits L2-C2. etc.. through R1 (470.000 ohms), R27 (2.2 megohms), R21 (220,000 ohms) and R39 (4700 ohms) to a point on the voltage divider marked —3v. Since there is no current flowing through any of the resistors mentioned. there is no voltage drop across them and they are at the same potential at every point. This, of course. is —3v. They total 2,894,700 ohms exclusive of L2. It represents a series circuit to the grid and, this total resistance can very well act as a grid leak. Therefore, the grid resistor of the VTVM should be removed for a reading within 2% of the correct value. For this low range (0-5. for example) no input voltage divider is needed and the regular circuit resistance is used. If the 10 megohm grid resistor is used, the accuracy will reduce to

$$\frac{10}{10 + 2.8947}$$

or .7755124 which would be approximately 77.6% of the correct value. Thus the meter would record $3 \times .776$ or only —2.33v instead of —3v.

Measurement of this potential across the 27 ohm section of resistor R41 in the power unit voltage divider from the —3v tap to ground would not tell if it were applied to the grid. There are at least a dozen places where condenser leakage, a short, or an open might prevent it reaching the grid. (While adjusted for the RF measurement it would be well to apply the *T* terminal to the IF tube, as the same results should be obtained).

Now suppose you attach the antenna and tune in a local station or otherwise the strongest signal possible. The signal rectified at the second detector will cause current to flow through R20, R23, R22, and R21 and through R24 due to the action of the other diode plate and cathode of the 6H6 tube. The junction of R23 and R24 is the most negative point in the circuit and R23, R22 and R21 act as dividers for this voltage. At the point where the resistor R27 (2.2 megohms) is connected to the divider only 46.8% of this total voltage can be developed as it embraces only 46.8% of the total resistance. Now the voltage at the grids of the RF and first IF tubes cannot exceed a total bias value in excess of —52 volts, because at this bias they have no essential amplifying power and a signal would be unable to reach the second detector. You could expect something under 45 volts at this point for the strongest signals. Therefore, the VTVM remaining connected to the control grids for the test is set for a range as near 50 to 60 as possible and the full voltage (AVC plus the minimum bias voltage) is read. Such a reading may be accurate to 5% or better. The advantage of the degenerative type VTVM should be apparent here. It should be remembered that you must preserve the highest possible sensitivity and yet the range must be high as well. In this instance, as well as the former, a reading across R21 for the AVC voltage would not be an index necessarily of the actual voltage on the grid of the RF or IF tubes. For example, if the first IF AVC filter condenser TC35 were shorted to ground, it would not appreciably affect the voltage across R21, but of course it would cause zero reading at the grid of the IF tube.

Following are two suggestions which you will find valuable in connection with this work. Direct connection of a test lead to a control grid which is attempting to handle a signal at the same time will reduce the signal to some extent. This, of course, will reduce the AVC developed and the voltage will be lowered. It will still read the voltage accurately, but under false operating conditions. The introduction of RF into the VTVM may cause adverse effects and an RF choke of good quality made with multiple sections should be placed in series with the test lead (*T*) to the grid.

Even with this choke attached, if a change in volume is at all noticeable, it would be well to make measurements *at the grid return circuits in Fig. 26 such as across TC35 or TC6 where practically no RF exists.*

A test of voltage across R1 or R14 in Fig. 26 with the grid resistor removed from the VTVM with test lead *T* toward the grid end adjusted to its lowest range, will disclose any gas in the RF or first IF tubes or an AVC filter leakage. Leakage up to 50 megohms may be detected in this way. If a negative voltage at *T* is indicated, it shows the presence of gas, while if positive, AVC filter leakage is indicated.

Next for Fig. 26 attach test lead *N* to the chassis and test lead *T* to the cathode K1 of the second detector diode. At exact resonance the reading should be exactly —3v. The lowest scale of the VTVM should be used, and the grid resistor should be removed or switched out of the VTVM circuit if convenient. When the silent tuning and AFC switches (not shown in Fig. 26) are set to the off and on positions respectively, the cathode K1 of the 6H6 tube may change potential in accordance with the tuning. As the receiver is tuned off resonance, this voltage at the cathode K1 will rise to 7 or 8 volts or reduce to —4 or —5 volts, depending to which side of resonance the circuits are tuned. When the receiver is tuned perfectly to resonance, the silent tuning switch

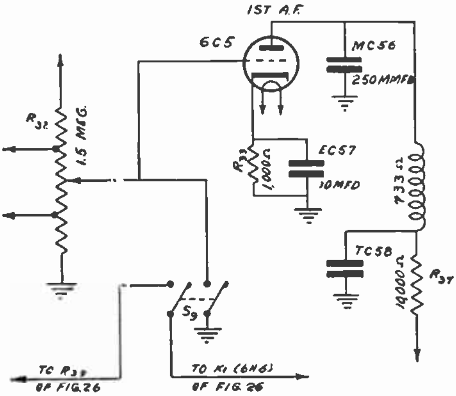


FIG. 27

may be turned off or on and it will make no change in the VTVM reading at the cathode K1.

Now to be sure that this voltage is being impressed on the AFC control tube (6J7) grid in Fig. 26, attach test lead *N* to ground and test lead *T* to its grid. The same readings as at the cathode K1 should be obtained and this will show that R3, TC10, R16, TC46 and R24 are in good condition. If not, there is leakage or a short in one of these units or gas in the AFC control tube.

The next measurement may be for the first AF 6C5 tube bias voltage as in Fig. 27—this is for the same GE 126 receiver the essentials of which are shown in Fig. 26. Test lead *T* is attached to the grid and test lead *N* to ground. The reading should not exceed −6v, so the range of the meter may be selected accordingly. With the antenna shorted or grounded, the reading should be 6 volts for any position of the volume control. The grid resistor in the VTVM may be removed or switched out if desired for the measurement although it will cause no serious error in reading.

The signal and other AC and high frequency or RF voltages may be measured by means of the VTVM shown in Fig. 24. It must be remembered that this device will not read in terms of microvolts or millivolts, so no values can ordinarily be read in the RF first detector or first IF stages. It may be possible to read the input to the last IF in many cases, while all second detector and AF voltages with strong signals may be easily read.

The output phase inverter introduces some measurement problems which can be solved only with the VTVM. For this detailed study, a typical circuit as used by the Emerson Radio Company in their DLW chassis has been chosen. It is shown in Fig. 28.

First note you can read the bias voltage of the 6F5 by connecting the test lead *T* to the grid and test lead *N* to ground. The 6F5 is used as a class A voltage amplifier for which the bias voltage should be approximately 2 volts. Measure this also with test lead *T* at the cathode as +2 volts so as to be sure that it is not caused by a gassy tube. If an AC measurement at the 6F5 cathode in Fig. 28 discloses any signal voltage, the condenser across the cathode is likely to be open. The same is true of the 6F6 cathode circuit to ground.

Now with 2 volts DC across the 3500 ohm resistor in the 6F5 cathode, a current of .000571 ampere will flow in the entire plate circuit, creating a voltage drop across the plate resistor (250,000 ohms) of 142.5 volts. This means the remaining voltage from a B+ of 250 volts would be 108.5 volts from plate to chassis. With test lead *T* connected to plate and test lead *N* connected to chassis, it should be possible to read this accurately within 3 or 4%.

Next consider the grid resistor feeding one of the 6F6 tubes and the 6C5 tube. Its tap at 80,000 ohms is 13.8% of the total of 580,000 ohms

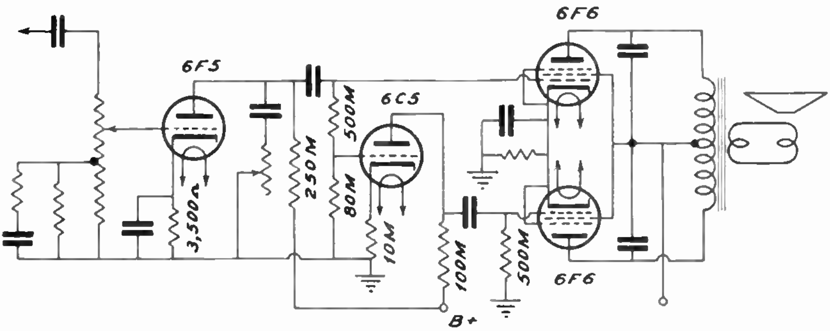


FIG. 28

and obviously with a peak signal of 16.5 volts on the 6F6 grid as maximum—the maximum peak signal on the 6C5 grid cannot exceed 13.8% of 16.5 or 2.275 volts. At any signal strength the signals to the two grids should bear this ratio of 13.8% or 7.25 times. That is, the 6F6 signal should be 7.25 times as high as that for the 6C5, or that of the 6C5 only 13.8% of that for the 6F6. If you set an audio signal generator for a 1 volt reading at the 6C5 grid you should get a 7.25 volt reading at the 6F6 grid.

The DC grid voltage at either grid must be measured with respect to cathode. Attach test lead *N* to the cathode and test lead *T* to the 6C5 grid. The reading should be approximately 5 volts. Placing the test lead *N* terminal on the 6F6 cathode and test lead *T* on the grid (either tube), the reading should be 16 or 16.5 volts. Be sure also that the plate voltage of the 6C5 is between 100 and 150 or even up to 175 volts. The value is not critical but should fall within these limits.

Now with the AC vacuum tube voltmeter you can measure the AC *signal voltage* at any plate or at practically every grid. You can estimate the gain or loss of each stage or section and thus tell if amplification is taking place. For example, it has been shown that the gain of the 6C5 must be 7.25 times because from its grid the signal must be amplified to equal that of the directly fed 6F6 grid for the inverter tube. You know further that the gain of a pentode output stage is rarely more than 1/8 to 1/10 of the amplification factor of the tube used, because of the use of a small plate load in comparison with the AC plate resistance of the tube. You, therefore, cannot expect a gain of more than 20 or 25 from grid to plate of the 6F6. If the AF signal generator is again adjusted for 1 volt output as read at the 6F6 grid with the VTVM, the plate signal voltage will be between 20 and 25 volts.

Less known in receiver analysis are the signal and other voltages in the oscillator, IF amplifier and second detector because there has been no way to measure them before the introduction of the VTVM.

A circuit typical of hundreds of receiver types is shown in Fig. 29. It must be understood at the outset that unless considerable gain is present preceding the grid of the 6A8, you cannot take a reading of the signal voltage at this point. It may range from a few microvolts to a few millivolts. You can, however, read the bias voltage within or below the AVC action range as described in the foregoing.

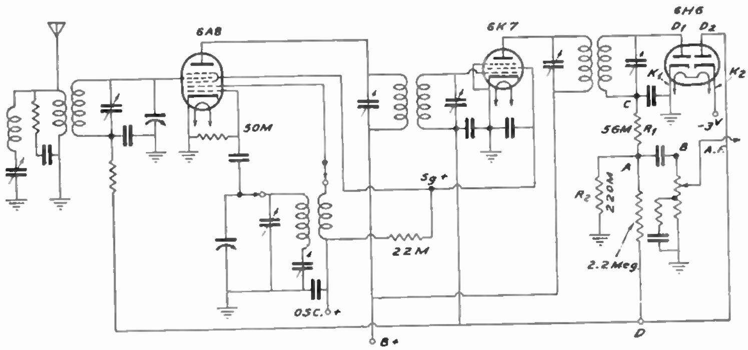


FIG. 29

The first reading of importance, in Fig. 29, is that of the oscillator grid voltage. While oscillating, the grid of the 6A8 oscillator section will have an *average* value although to be oscillating there must be an RF voltage on the grid amounting to several times this bias value. With a 50,000 ohm grid resistor as shown in Fig. 29, there will be anywhere from 2 to 15 volts negative on the grid. This bias voltage will vary with the tuning of the oscillator, in general increasing with frequency but not necessarily so. Any negative voltage on the grid is proof that the oscillator is oscillating.

A DC type VTVM with the shortest possible test leads should be used with test lead *T* to the oscillator grid and test lead G to the chassis. It is not necessary to read the RF voltage on the grid as its value is of no importance and you know that it must exist to be rectified and produce the negative DC grid bias. Under practically any condition of oscillation the oscillator produces many times more power than is actually needed in the process of mixing.

Moreover, if the oscillator is functioning there is no need to read the value of RF on the oscillator plate, as you already know that this must be sufficient to sustain oscillation. The DC grid test is simply to determine if there is any oscillation.

Now it may be possible to read the IF signal voltage at the plate of the 6A8 as it will have from 50 to 75 times the signal strength at this point. Of course, if the receiver is picking up a signal as low as 300 or 400 microvolts, this measurement may not be possible without amplification. If no measurement can be made, do not suspect difficulty with the circuit. Take a reading of the screen grid voltage of the 6A8 and the 6K7 (one operation with test lead *T* to the screen grid and test lead *N* to the chassis). You do not need a VTVM to read the DC plate voltage of either of these tubes.

Now at the plate of the 6K7 in Fig. 29 you should be able to read the IF AC signal value, as it will be from 60 to 100 times as high as the grid input signal. A high impedance VTVM must be used here so as not to seriously load the plate tuned circuit. Its shunt resistance at resonance will be from 75,000 to perhaps as high as 300,000 ohms and the load on it for measurement purposes must be as many times this value as possible. For the AC vacuum tube voltmeter, test lead *T* is placed on the plate with a series capacity in the *T* lead not exceeding 5 mmfd. with test lead *N* to chassis as usual. The range will probably be the lowest provided.

but for strong local signals a higher range may be needed.

Little can be said of the value of the IF at this point. It may not even be readable, or it may be .5 volt or as high as 20 or 30 volts. However, a comparison of this voltage with that on the diode plate (D1) of the 6H6, Fig. 29, should reveal something definite in the way of how the circuit is behaving. These voltages should be very nearly the same. If the latter is considerably lower than the former, there is some defect in the second IF transformer, or its load circuit. Due to the possibility of a smaller load (higher impedance load) on the diode including the meter circuit, *it is possible to get a higher IF reading here than at the 6K7 plate.*

If you can put a signal from a signal generator or a local station into the receiver so that you can read 20 volts at D1, you would expect to read this voltage also at C and a little below 16 volts at A, because of the values of R1 and R2 and above 15 volts at D, the AVC feed line. All of these voltages are negative with respect to ground.

With the volume control set at maximum, the AF signal would have a peak value of 7 volts. This, however, may overload the first AF tube. Potentials at D1 and B must be read with an AC vacuum tube voltmeter connection, whereas those at C, A, and D may be read with DC connections. Either may be used at A, as both AC and DC may be found there.

There are, of course, many hundreds of variations of circuits and thousands of variations of values of parts. For example, in a grid circuit you will find bias cells, series filters, speaker field dividers, regular voltage divider, screen grid bleeder divider or some other grid divider as from a noise suppressor or Q tube and in still other ways. None of these things will alter the value or capability of the VTVM.

For example, the control grid voltage of most of the electric eye tubes is the same as that of the AVC feeder lead. One measurement, of course, serves for both and both may be measured at the tuning eye grid. If it is desired to find the plate voltage for any grid voltage of the electric eye, simply attach test lead *N* to chassis and test lead *T* to the plate. Due consideration must be given each of these circuits with its effect on the measurement.

The voltages which will be most difficult to read will be the RF voltages as these measurements must put not only a small AC load on the circuit but a small DC load as well. Such voltages are small and connections for making a reading may detune the circuit under measurement so that its value will be nullified. Furthermore, there is likely to be by-passing at the instrument producing false readings.

In spite of all these difficulties, there is no instrument which can give as much information about the operation of the circuit while operating as the VTVM. It takes no more experience to learn its peculiarities than for any other voltmeter or any ammeter or ohmmeter.

Manufactured vacuum tube voltmeters are preferred in actual service work. However, you will find building directions given for the construction of vacuum tube voltmeters in many of the radio magazines. New uses for the unit are also often described. Thus it will pay you to keep up with the developments in this work.

It is only possible to give general instructions in this lesson on the use of the VTVM. However, you should realize that it is a very versatile instrument capable of giving you very valuable information. For this reason it is recommended that manufactured instruments be used (not home made types which may not have all the design "bugs" worked out of the circuit). Then the specific manufacturer's instructions should be studied and applied. If this is done you are sure to get the best results from the use of a VTVM.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 What must be the minimum sensitivity of the meter Rm in Fig. 4 to read the plate voltage to within 3% accuracy? (Refer to Fig. 5.)

No. 2 With what type and class of amplifier tube may a vacuum tube voltmeter be compared?

No. 3 What method is employed to make a VTVM read zero for no test voltage applied when it is associated with a plate circuit which must carry current?

No. 4 Under what conditions can the grid resistor of a DC vacuum tube voltmeter be removed?

No. 5 What are the three important advantages of using a cathode resistor in the VTVM as in Fig. 16?

No. 6 What function does the 6C6 tube serve in Fig. 23?

No. 7 Why is the rectifier in an AC vacuum tube voltmeter for high frequencies placed as close to the test lead end as possible?

No. 8 Will the VTVM in Fig. 25 read both positive and negative polarities without switching test leads?

No. 9 Would a VTVM be necessary in order to read the plate voltage of either of the 6F6 tubes in Fig. 28 at reasonable accuracy?

No. 10 In Fig. 29, where would you expect to read the maximum IF signal voltage with an AC vacuum tube voltmeter?

THE RIGHT TESTING METHODS FOR AM, FM AND TELEVISION RECEIVERS

LESSON TV-5

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

DON'T HESITATE TO DEVELOP YOUR OWN TESTING SYSTEM

Regardless of your training there is usually one best way for you to do a given job. This is because you are an individual with certain characteristics not usually duplicated in every way in your fellow man. Thus, you will do your best work if you are left to your own methods and if you are permitted to work at a pace best suited to yourself. This does not mean that improvements cannot be made in your present methods. It does mean however that once you learn a new method or system that you yourself can best put it to most efficient use. That is why after studying our instructions that you should adapt them to your own way of doing things.

There are many ways to correct defects in AM, FM and Television receivers. For example if the same defective television receiver is given to three qualified men to repair each of them will probably test and repair the defect by entirely different methods and procedures, yet in the end the receiver will be in first class condition. This takes into account the varying nature in different men and their natural aptitudes. So whether you are conscious of it or not, you will, as you get experience, gradually develop your own test and repair system. In doing this you should deliberately try to be efficient and systematic. In this way you will get in the habit of not wasting time and materials. Thus, you not only make money but you save money.

In this lesson, we show you how to develop your own test methods and urge you to adapt them into a system to fit your own nature and aptitudes. The information given can be applied to all types of receivers. It is just as applicable to a complex television receiver as it is to a simple AM receiver. So with these thoughts in mind study the lesson carefully and don't hesitate to develop your own testing system—applying all techniques as described to AM, FM and television receivers as you can best use them.

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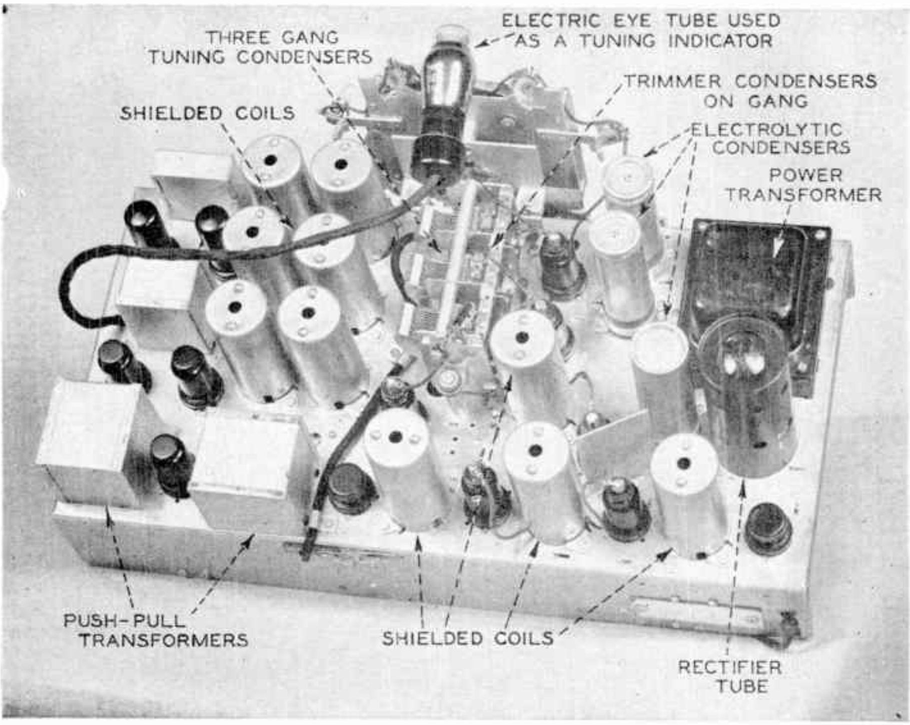


The above view shows a top-side chassis view of a large AC operated receiver. With so many parts in use, it is easy to see that the possibility for defects are numerous. This lesson explains how to develop a testing technique for this and other types of receivers.

The Right Testing Methods for AM, FM and Television Receivers

Lesson TV-5

It is the general practice to place all arbitrary methods of receiver defect correction, not subject to measurement or definite analysis, in the category of experience. Often this experience is of vital importance in the saving of wasted time and effort, and may be the decisive factor in the success or failure of a servicing business. Not possessed of this experience, the serviceman may spend $10 in his time and overhead costs in elaborate testing for a $3 repair without realizing it. If he must charge for this time, he cannot compete with the more efficient organization, whose costs are less by virtue of getting the work done in a shorter time. If he takes this long time and does not charge for it, he is doomed to failure. Moreover, he cannot pass on the cost of one repair to other repairs as this again decreases his competitive value. Of course, in every shop there are bound to be some losses which must be made up out of the profits from other jobs, but the manager who can minimize these the most can devote more profits to expansion of his business.

It is a good idea, therefore, for the serviceman to become familiar with all of the service and repair techniques which have risen from the experience of others. Many believe that experience cannot be taught, but must be learned first-hand or must arise through actual practice. This is true only of the personal technique in the same sense as the techniques of playing a musical instrument, driving an automobile, or ice skating. However, the principles of application of these techniques can and are being successfully taught, and in the same sense we are teaching you the rudiments of all of the successful servicing techniques.

Between 80 and 85% of the time spent on a repair job is usually required to *locate the defect or defects.* All replacements, adjustments, analysis and even transportation are included in the balance of the time.

No more emphasis than this fact should be necessary to point out the importance of a successful technique in locating receiver defects. While testing instruments are essential, a rapid method of determining *what to test* is equally essential from a business viewpoint. With a sufficient number of precise tests and with no time limit, any fault in any receiver may be located, but the owner of the receiver is not willing to pay for time in excess of the shortest time available and he should not be expected to do so. The matter of replacing a tube, a condenser, a resistor or even a transformer requires relatively little time, once the cause of the defect has been definitely determined.

It should be remembered that these tests by observation serve as an important step in determining where to start with a repair job once it is in the shop. Often your estimate for the cost of repairs in the home of the owner must be based largely on what you can observe in a preliminary way. So a technique on estimating the cost of repairs must be developed. It is an important preliminary shop practice.

You have four senses which can often aid you in locating a receiver defect. They are the sense of smell, the sense of sight, the sense of hearing and the sense of touch. With the aid of these four senses along with some good common sense many of the receiver defects can be found, or at least isolated to a particular stage, without the aid of test equipment. It is of particular importance to be able to give a quick estimate of the receiver repair cost to a customer and if a quick accurate method of diagnosing the trouble can be made, you can save considerable time as well as demonstrating your ability as a serviceman to the customer. These preliminary tests are usually made in the customer's home before removing the receiver to your shop.

Where a defective part in the receiver is completely destroyed by some abnormal condition of the part itself or due to some circuit defect, it is usually an easy matter by sight to locate such a defect—electrolytic condensers, gassy tubes, broken resistors, etc. A short within the receiver can often be detected by the smell emanating from the receiver and in most cases it will be accompanied with smoke, both of which should be valuable aids in locating the faulty part, making it an easy matter to estimate the repair cost. The sound from the speaker usually gives an excellent clue to the source of the defect. The customer can also aid by giving you all the details leading up to the receiver failure. It is wise to make sure that the customer hasn't tampered with the receiver and if he has be sure and find out what he did. Often much time can be saved by knowing what has been done to the receiver before you were called.

In many instances the customer may not care to have the service man do any testing on the receiver in his or her home and will not be concerned about the estimated cost. In cases of this kind make as few tests as are necessary to determine that the receiver failure is due to some defect within the receiver and not due to an influence external to the receiver. When this is done remove the receiver from the customer's house without any further test. Never, in any case, attempt to repair a receiver in the home if the customer seems reluctant to have you do so, even if the repair is a very simple one.

There are numerous tests that can be made in the home without the aid of elaborate test equipment which will give you enough information concerning the receiver for making a fair estimate of the repair. It isn't wise, unless it is absolutely necessary, to remain in the customer's home for long periods of time. Do your job, get the information you came for, and either take the receiver with you or *make sure what you have done has corrected the cause of the complaint.*

Preliminary Analysis

There is only *one definite procedure* which is best for most rapidly determining the source of a defect in a receiver, and all of the steps in this procedure will be given. Depending on your observations all of this procedure need not be followed as many steps may be omitted. To illustrate this important point, consider the very simple following case:

The first point to determine is whether or not the receiver will burn out a line fuse when the power is turned on. If the owner of the receiver tells you that this has never happened you may omit this step. Or, if the receiver is turned on, and operating when you arrive at the owner's home, you may omit this step. If the receiver is not turned on and will not draw power from the line when turned on, that is if tubes and pilot light bulb do not light and the owner says that no fuse is or was burned out, you can omit this step even if the receiver is totally inoperative.

Above is shown a Triplett signal generator which is most often used in connection with the adjustment of tuned circuits. Note the use of the directly calibrated dial. Thus the value of the generated test frequencies may be read directly without reference to a chart.

To be able to take in such situations quickly is an important part of servicing. While this observation analysis is not intended as a method of absolutely locating the defect, it will be found in many cases, the exact defect will be localized and no instruments for testing will be necessary. This, however, cannot always be done, and it should not be expected. Your analysis will be originally guided by the remarks of the owner of the receiver, who in the usual case, can only give you the *effects* of faulty operation. From these effects and those of your own observation it will be necessary for *you to find the cause.*

Procedure

Fuse Burns Out: This defect is most likely to be confined to the primary circuit of the power transformer. In order to burn out a 20 ampere line fuse from the secondary side of the power transformer on a 110 volt line, the transformer core must carry 2.2 KW of power, and no transformer manufactured for receiver operation can carry this amount of power. Knowing this, the search for

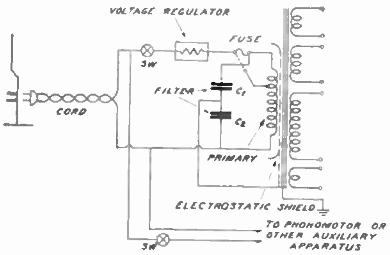


FIG. 1

the trouble may be confined to the primary circuit.

Now the primary circuit of a receiver as shown in Fig. 1 may include a filter, C1, C2, a voltage regulator of the tube, or open wire type, a fuse with two or more clip positions for rough voltage adjustment, and the transformer may have an electrostatic shield between its primary and secondary. It must, of course, have a switch in its circuit and there may be an additional connection for a phonograph motor, a lamp or other auxiliary apparatus often used with a receiver.

Even limiting the fault to this circuit, if you were to test individually every item here, considerable time would be consumed. You would detach and test the cord for a short, inspect the plug connection, and often replace the fuse in the house power line or try a lamp or another electrical appliance in the wall socket to be sure that the defect is not there.

You would then for example in Fig. 1 test the switch for a short to chassis or ground, test the voltage regulator for resistance value, the fuse, the condensers C1 and C2 for shorts, and the auxiliary circuit for possible defects. You must also test the shield for a short to the primary. A continuity test of the voltage regulator or the transformer primary would probably disclose nothing as to the defect as the resistance of the voltage regulator would be quite different when cold than when hot. The primary DC resistance would test from 10 ohms down to possibly .5 ohm and would not necessarily disclose the defect. Any splicing of the power cord must be examined for a short or an open and to make all of these tests, the chassis must be removed, as well as any covers or shielding associated with the power transformer. Condensers such as C1 and C2 must be disconnected at one terminal to be tested and in general such a lengthy procedure is undesirable where it can be avoided.

Here is a way to quickly get at the source of the defect. Look at the cord and plug, noting how the wires are connected to the plug terminals. With the line plug out of the power supply socket, operate the switch noting any unusual noise, or stiff or loose operation. Note if the voltage regulator is secure in its socket. Inspect it, if of the open wire type, looking for shorts to ground. No attention need be given the fuse because it has a much lower rating than the main line fuse and would, therefore, burn out before the other one. Where two fuses are in series the one of lowest rating will blow and the other will not.

The auxiliary circuit may be disconnected and quickly tested separately with an ohmmeter. Or, the ohmmeter may be placed across the switch SW of this auxiliary circuit and the switch turned off. If a short is indicated (ohmmeter shows a reading) this external circuit is probably at fault.

Now, if the fuse is intact in the receiver, it is very unlikely that the defect will be in the power transformer. If the receiver uses no fuse, carefully inspect the transformer, noting any packing material (wax, etc.) which may have melted and run out of the transformer. Note if there is any odor about the transformer due to burning of insulation. Note, also, any burned or charred appearance of the windings of the transformer or the results of overheating such as discolorations or loss of paint or lacquer on the power transformer. If any of the wiring has a charred appearance on its insulation, this should be taken into account. See that the line cord is properly insulated where it enters the chassis and that the rubber or composition grommet is in place.

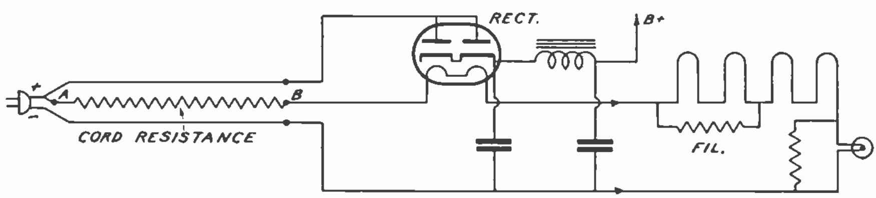
All of these facts may be taken in, in a very short time, and you should now be able to tell the owner of the receiver, from your findings what the price of repairs will be. If the transformer looks to be in perfect condition from all points of view, external surface, windings, leads, and packing material, the repair will be a minor one and perhaps may be done on the spot. If not, the receiver must be removed to your shop.

For small AC-DC receivers an additional item must be noted, and one which by the way is the most usual external defect to be found. This item is the line resistor in the power cord or in the receiver chassis proper. Connections to this resistance wire cannot be soldered because of its high operating temperature and, furthermore, it is more brittle and subject to breaking when bent. For this type of receiver, this is the first thing to check. Check its connection at A (Fig. 2) at the plug and its connection B at the receiver by inspection. If an ohmmeter is used, connect it beween the wire ends, not the terminals or lugs.

In many of the AC-DC type receivers, one side of the power line is directly connected to the receiver chassis. One side of any power line is grounded, leaving the other side of the power line 110 volts above ground. Now if a receiver of the type just mentioned is plugged into the wall power socket with the chassis connected to the ungrounded side of the power line, the receiver chassis is made 110 volts above ground. With the receiver thus connected, if the chassis of the receiver is allowed to come in contact with any grounded metal objects, the house fuse will, no doubt, blow or open. Usually these AC-DC receivers are the small table model type and are often moved from room to room. Thus, they may be so placed as to cause the chassis to be grounded to a radiator or to another grounded metal object and if the plug is in the wrong position, the house fuse will blow or become open.

Figure 2A illustrates the connection of such a condition. The manufacturers of these receivers have warnings posted on the receiver, warning against connecting the chassis to ground, but as most people owning these receivers do not realize what constitutes a ground, receivers of this type are often the cause of blown out fuses or a current overload is caused to damage the receiver.

When you encounter a receiver of this type and the complaint is a



A.C.-D.C. INPUT POWER CIRCUIT

FIG. 2

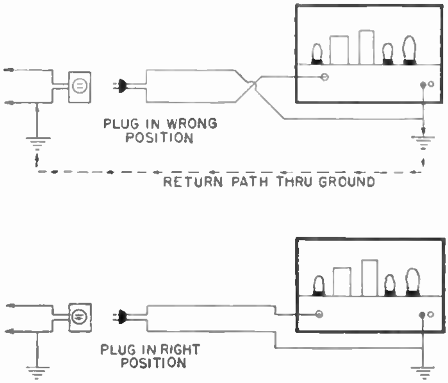


FIG. 2A

burned out fuse, it is well to make a quick check of the connections of the receiver. If the fuse *blow out* is due to the receiver chassis becoming grounded, unless it is directly grounded through a connecting wire, there will usually be evidence of sparking somewhere on the receiver chassis as indicated by a black mark on the metal part which contacted the ground connection. By making a quick visual survey of the receiver and power connections, you will, no doubt, be able to ascertain if the defect is due to the receiver being grounded when the plug is in the power outlet wrong.

Receiver Does Not Turn On

The first check to make in a case of this type, when you are testing the receiver in the customer's home, is to check the line voltage at the wall power outlet. Many times the defect may not be due to a receiver fault, but due to the lack of voltage at the power outlet itself. The line voltage can easily be checked with a light bulb by placing it, with the aid of a power cord and socket, across the plug terminals. Many times the wall outlets are connected to a separate power circuit from the house lighting circuit and although the house lights are working the power outlets may still be open. Fuses are often blown on the outlet circuit due to heavy overloads carried by other electrical appliances other than the receiver. A faulty electric refrigerator will often cause the fuse to blow and much time can be wasted by assuming there is voltage at the power outlet when there is none.

If the power line fuse has not burned out, but the receiver will apparently not turn on, that is, the tubes and pilot will not light and apparently from lack of vibration or transformer hum, the transformer is not getting primary current, the defect is much more easily diagnosed because you at least can use the power line cord as a test. In this event as in Fig. 3, look immediately for an open switch, open line voltage regulator (see if it warms up when the receiver is turned on), burned out fuse, or faulty open circuit at the cord plug, splice twisted or marred place in the cord or loose connection at the transformer or rectifier tube terminal. This latter, of course, would apply to the AC-DC type of circuit, using no power transformer.

A defect in this instance can usually be rapidly located. If it is not obvious from an inspection, an ohmmeter test of the primary circuit will indicate whether or not the circuit is open. It will also test the filament circuit of the receiver without any plate current flowing. This is preferred to an individual test of each filament as for a series filament arrangement it is rare that more than one filament can be burned out at a time.

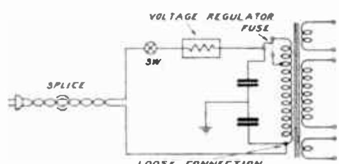


FIG. 3

Receiver Turns On But No Signals Are Heard

While this condition does not make the analysis any simpler, it at least eliminates certain parts of the power supply from further investigation. In the former cases it is not necessary to bother about the antenna the shielding on the coils and tubes or its connection, the dial settings, or anything about the signal circuit. This condition, however, more or less places the blame in the signal circuit. The cases where the signal circuit is not at fault should first be investigated.

If the receiver makes use of metal tubes they will heat up when turned on if their filament circuits are complete. Feel them shortly after turning on the receiver. If cold, they are defective. Do not wait very long as they will get hot enough to cause a serious hand burn in a short time.

If the receiver is of the AC-DC type, the line plug might have been placed in the socket improperly with a DC line. This should not be overlooked, as it will permit operating the filaments perfectly but will allow for no plate voltage. Figure 4 shows the effect of this connection.

For AC receivers a partial filament short is possible as in Fig. 5, which may permit the tubes to light *dimly* but the emission will be insufficient for operating the signal circuits. This will be identified by overheating of the transformer or a burning odor, due to burning insulation. A more usual defect which will cause the same results, also in Fig. 5, is a shorted

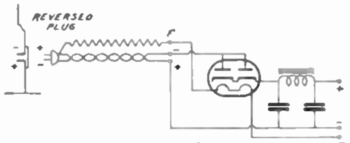


FIG. 4

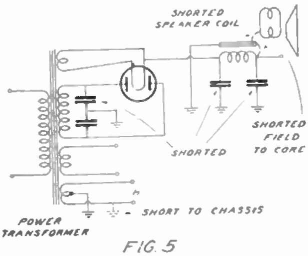


FIG. 5

filter condenser, preventing the signal carrying tubes from getting the proper plate voltage. This may often be identified by *a blue haze* around the rectifier plates, overheating of the rectifier and of the power transformer. A shorted speaker coil (see Fig. 5) may cause the same symptoms. This also may overheat the speaker field coil and magnet and may burn out the field coil, producing a burned odor about the speaker. Note also the possibility of a shorted high voltage input condenser as in Fig. 5.

It will make a considerable difference in the final repairs as well as the cost of the repairs if the defect is in the power supply circuit or in the signal circuits. There are several other things which may be done to ascertain this fact. If the foregoing conditions have been noted and parts seem to be in good condition, you must make a rapid inspection of the signal circuits to make your work conclusive. Here there are a great number of possibilities with regard to the defects in the signal circuits, and you are faced with the necessity of ascertaining definitely if some element in the signal circuits or in the power supply circuit is at fault. In this case you are not to be concerned where, in the signal circuit the defect lies, but simply if it exists in it or not.

First see that all shields are in place, all tubes are in place and operating and that the antenna and ground are attached. Touch the grid caps of all tubes having top caps, and detach and reconnect the grid cap connection as illustrated in the diagram of Fig. 6. If the speaker reproduces a click due to the electrical disturbance of the circuit, you may be sure the power supply is in good order or at least is operative. If plate voltage is applied, the speaker should reproduce a click if any tube is removed from its socket. There may be several exceptions to this, such as for example an oscillator or AVC tube, so it is advisable to pull out several tubes in succession not including the output amplifier or rectifier tube. If no click is heard for any of these, the defect is either in the power supply or output including the speaker. Now pull out the output tube or one of them, listening for a *thud sound,* indicating that the speaker field current has been reduced suddenly. If this does not occur, the power supply is usually at fault. The term *power supply* is used in a very general sense as this includes the speaker field in most cases. It also includes various voltage divider resistors and by-pass condensers which affect the output of the power supply directly.

This latter test is quite important as it eliminates the possibility that the receiver may be so far out of tuning alignment that a circuit disturbance may not carry it from some of the input stages to the speaker. There is one other condition against which

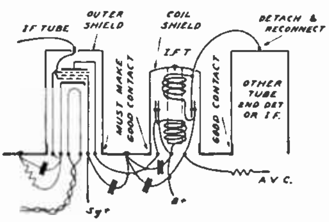


FIG. 6

you must guard. This is an overbias on the output tube or an output tube of the single stage type which has completely lost its emission. Then, too, the speaker could have an open voice coil or be otherwise defective. Inspect the voice coil and pull the speaker plug out of the socket momentarily if it is provided with a separate plug. If not, make sure that the diaphragm is free to move by tapping it and where convenient, apply the ohmmeter terminals across it, noting if a click is heard.

In many types of receivers where the S series of tubes are used, there will be no top caps on the tubes. These tubes have their grids connected to one of the pins on the tube base and in order to make the grid check, the grid pin of each tube will have to be identified. To make the check on the grid, just touch this grid pin for the test. Make sure, however, that you are touching the right pin and if a metal object is used for the test, be careful you don't short out other terminals on the tube base. You can cause a short which may damage some other part in the circuit. if the short is allowed to remain for any length of time. Fuses can easily be blown if a short across the power line is made. This is more apt to happen in the AC-DC type receivers where there is no power transformer used and the power line is terminated on the unused terminals of one of the tube sockets.

Pulling out the tubes of a receiver is not always advisable if the receiver is of the AC-DC type. Sometimes the tube filaments and the pilot light are wired in a series parallel arrangement and if one of the tubes is removed while the receiver is operating, it may cause another tube or the pilot light to be burned out. This is more true since World War No. II because of the tube

This photo shows a modern Triplett multimeter having a sensitivity of 20,000 ohms per volt. It includes several AC and DC ranges and several ohmmeter ranges. With such an instrument the serviceman can make almost any measurement required to be made on a receiver.

shortage during the war. Many of these AC-DC receivers were rewired for other tubes than called for by the original design and many times complicated series parallel filament connections were necessary to get the correct distribution of voltage on all of the tubes.

For almost any receiver except one entirely operated by batteries with no vibrator power supply, there will be hum if power is supplied to the receiver. Therefore, if the speaker is completely dead the defect is undoubtedly in the power supply or speaker. If your other observations leave you in doubt as to the power supply, you can easily remove any amplifier tube and quickly test for high voltage at the plate terminal with respect to chassis. Get readings at two or three different tube sockets to be sure that the particular circuit used for the test is not at fault, thus destroying your analysis.

From the preceding information it is obvious that the analysis is greatly complicated by various methods of receiver design. However, in only very rare cases will you have to go into all of the details mentioned. You will, no doubt, localize the trouble before you go through the entire series of tests described. Through association of known symptoms with known faults you will, of course, be more and more able to identify defects with increased experience, thus reducing the preliminary steps.

Constant Hum—No Signals

In this analysis no distinction will be made between the ordinary hum of the receiver and any abnormal hum that may be reproduced. Hum will signify that the power line and input to the power supply is in good shape and that the power supply is at least partially operative. It insures that the speaker is also operative although it may need adjustment, etc., according to the detailed test to be described later.

The same circuit tests as already described may be used in this case with the assurance that there is a possibility of getting an indication at the speaker. If this test shows no sound after pulling out all tubes from their sockets, except the power output and rectifier tube or tubes, one at a time, the following items may be suspected.

Open plate circuit or bias resistor.
Shorted tone control.
Open volume control.
Shorted tube element.
Shorted by-pass condenser.
Defect in wiring.
Overload in power supply.
Defective rectifier tube.

These items are so general and numerous that practically nothing has been gained by the test thus far. A little advantage may be gained if any disturbance signal is heard when touching the control grid cap of any stage. Or, if every tube beyond and including a certain stage when pulled out of its socket causes a click in the speaker, it may be known that the fault is in the tube or stage preceding the first one in the series which produces a click. The greater the number of tubes which will show such an indication, the more definitely will the defect be localized.

Even this is not a conclusive test of the stage at fault, because with high gain stages and particularly with a circuit disturbance test the signal may skip one or even two defective stages. Usually, however, these stages may be identified by the fact that such a disturbance does not originate in them.

Without making specific circuit tests, this is about as far as you can go with this type of analysis. Further tests must be made at the shop in accordance with the information in the other lessons for individual tests.

Hum in most cases is associated with the power supply and is generally due to a defective electrolytic filter condenser. When the hum is due to a defective filter, the signals can usually be heard in the background which indicates that there is voltage on the tubes.

The input filter condenser of the power supply is usually the most common filter condenser to break down due to the high voltage applied to it. Many times, hum in a receiver is due to the misplacement of the filament leads. This defect is easy to find because you can usually tell by inspection if the filament leads have been rerouted, or if they have been tampered with because the factory made wiring of a receiver is neat and well supported. When you encounter a receiver with an untidy wiring job on a factory made receiver and hum is the complaint, this may be a clue to the source of hum. Upon rerouting the receiver wiring, the hum may, in many cases, be entirely eliminated.

There are, of course, a number of conditions of reception beyond the entirely dead receiver or the one which only reproduces a hum which have other means of rapid analysis.

Motorboating

This is a type of trouble wherein the receiver reproduces a sound resembling the sound of a motor in a motorboat. If you are not already familiar with it, it will not be long before you are, in practical work. Many possible defects cause this peculiar sound and the defects causing them cannot usually be repaired unless the receiver is taken to the shop.

When it is possible, the first thing to do is to touch the control grid terminal of the detector or second detector with your finger. If the sound (motorboating) completely stops, it is a fairly definite indication that the defect is in the RF system. Poor neutralization of a circuit which requires neutralization or incorrect alignment of a sharply tuned circuit or an open plate or screen by-pass condenser will cause unstable oscillation (motorboating). It is not the purpose here to determine which of these is actually causing the defect, but simply to determine if it occurs in the RF or AF section of the receiver.

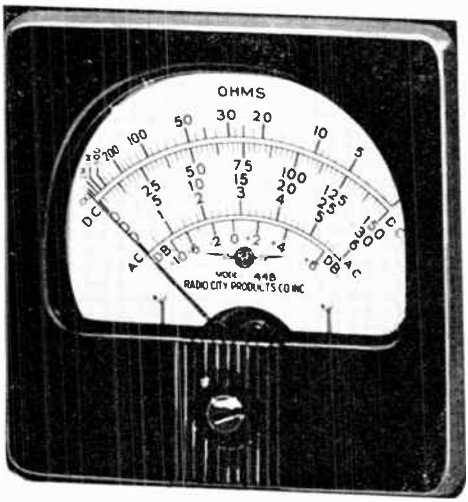
Now, if on touching the detector grid terminal (second detector in superheterodynes) the motorboating continues with little or no change in volume or tone, this is a satisfactory indication that the defect lies in the audio system. Having determined this from the simple test just described you can now proceed with the possible causes of motorboating in the audio system. Some of the more important of these are:

1. Low emission.
2. Low filament current.
3. Open grid circuit.
4. Excessive grid resistance value.

5. Excessive plate resistance value.
6. Open cathode bias condenser.
7. Leaky coupling condenser.
8. Gassy tube.
9. Insufficient plate voltage.

Note that only one of these faults (item 3) may be identified accurately by observation, and then only if the grid lead is obviously open. It may still be open at some connection that does not show this appearance and in this event may be located by a continuity test.

Now, if the motorboating changes pitch or intensity or if it changes in any way whatever with tuning, it is a positive indication that it originates in the RF system. In either case a signal may accompany the motorboating in a highly distorted state and particularly if the signal is accompanied with a *hiss* or *squeal* (heterodyne), you may be sure that the RF section is at fault. The term RF section is used very broadly here to include both preselector and IF sections in the case of a superheterodyne.



This is a view of the smaller type of multimeter. It measures both AC and DC and has several ohmmeter ranges. Such a meter might be incorporated in a large and complex tester or it may be used alone as a tester. It is made by the Radio City Products Co.

With the latest type of signal tracing equipment, the stage which is oscillating can easily be found. Where a signal tracer is not available other methods of distinguishing which stage is oscillating can be used. If you touch the control grid terminal of a tube that is oscillating the oscillation will stop.

In many cases, the stage (being stopped from oscillating) will carry the received signal through the receiver if tuned to a fairly strong signal and reception will be resumed at reduced volume. Touching any tube control grid will usually *reduce volume or cut off the signal entirely* unless it is a first RF or first detector tube, but usually oscillation will not stop until you touch the offending tube's control grid.

It will not take long to distinguish between motorboating and oscillation. While in some cases they will sound very much alike, tuning always changes the pitch of the oscillation beat. Of course, motorboating is often due to intermittent oscillation caused by an unstable circuit, but in this case, both sounds will be evident.

Microphonic Noise

The cause for this type of defect is much more rare today than for most defects, and is usually the easiest to find. It is identified by a *ringing* sound and is critical to vibration or to the touch. It may be stopped simply by holding the audio or second detector tube at fault with your hand while it is in operation. Replacement of the tube is usually sufficient, although in some cases, it may be necessary to change the position of the receiver in relation to the wall or other surroundings or to change the position or mounting of the receiver chassis or speaker. Sometimes a tuning condenser or other part may vibrate and cause microphonic sounds. In this case, it is only necessary to more securely mount the part or add weight to the vibrating part, so as to change the period of vibration. Sometimes weight is added to a small part in the form of solder. It may be used at any place on a part as long as it does not interfere with operation of the receiver.

In many receivers, the tuning condenser and sometimes the RF coils are mounted on rubber shock mounts. This is done to prevent the vibration from the speaker from affecting them. Usually when receivers employing these shock mounts are shipped, some means of clamping these shock mounted units rigid are used to prevent them from becoming damaged while in transit. It is necessary to remove the bolts which hold them rigid and unless this is done microphonic noises are likely to occur. These clamping bolts are often overlooked when the receiver is unpacked. Also when these shock mounts become hard or deteriorated they will no longer act as shock mounts and may cause a microphonic condition to exist.

Low Signal Strength

This difficulty is limited to relatively few distinct possible sources. First you check the antenna and inquire of the owner as to any changes made in the antenna purposely or accidentally. Compare the signal with the antenna connected to the receiver to that with it disconnected. If there is a noticeable and marked improvement when the antenna is connected, this indicates the *relative* effectiveness of the antenna without further antenna tests. If touching the antenna post or lead wire with your finger improves signal strength over that of the antenna you might readily assume that the antenna is for some reason rather ineffective, and needs further attention. If reducing the volume control from its maximum setting seems to increase the signal strength, it is clearly a case of overload. If the volume is satisfactory before overload is reached, this may be assumed as the normal operation of the receiver while if not, attention must be given to the circuit and parts.

Some very commonly found causes of low volume follow:

1. Low line voltage.
2. Old tubes.
3. Tuned circuits out of alignment.
4. Ineffective antenna.
5. Overload of tubes.
6. Other circuit defects.

It is interesting to note that you can easily and quickly diagnose for the first five of these defects and by this means arrive at the sixth in the foregoing list. In other words, if the receiver shows no symptoms of the first five causes some other circuit defect must be responsible. The sensitivity of an AC receiver is affected more by reduced filament voltage than any other reduced voltage and hence a reduction of 10 to 15% from rated value is likely to become serious. Line voltage reduction may be estimated by its effect on any electrical appliance, particularly a light. Otherwise for more accurate testing, the line voltage must be measured with an AC voltmeter. Old tubes are quickly identified by test or by simply inquiring of the owner as to how long they have been in use, judged by the hours of operation. If they have been in operation two to five years, you might almost assume without test that they are at least partly responsible for the defect. If the receiver does not have proper tuning alignment, it will tune broad and there is likely to be cross talk.

Now other circuit defects which may cause low volume would normally not display the characteristics by which the others are identified. They are, of course, numerous and require detail testing to find. Included in these possibilities are reduced resistance value of plate resistances, screen grid bleeder resistors, volume control resistors, increased values of screen grid series resistors, cathode RF resistors, moisture in coil forms, a shorted by-pass or tuning condenser or coil or one of a variety of other causes.

Faulty AVC or AFC circuits are often the cause of low volume. Usually where the low volume is not due to bad tubes the receiver will have to be taken to the shop and a more thorough investigation of all the circuits made.

Noise When Operating Controls

This is a fairly definite type of defect in point of its exact cause. You will know if the receiver reproduces considerable grating and static-like noise when the volume control is being moved that the volume control resistance element is defective. If considerable scratching or grating noise is heard while the tuning dial is being adjusted at certain points in the range or throughout the entire range, this may be attributed to dust or foreign material between the condenser plates or poor contact of the sliding type rotor brushes for connection to the chassis. Likewise, if the adjustment of the tone control or fidelity control is noisy the defect is almost certain to be in the switches or in the control resistance.

Where an estimate of the cost of a repair of a noisy control is involved, it is best to allow for a replacement cost of the control. If it can be repaired a lower service charge can be made. It is better in most instances to give a higher estimate than a lower estimate. The customer will feel more satisfied with your work if you can repair the receiver for less than your quick estimate, at first indicated.

Spontaneous Circuit Noise Other Than Hum

A distinction has been made between hum and other circuit noise because the sources of the two have generally no relation with one another. The antenna post or wire lead should be shorted to ground, to prove that the noise is not due to external man-made or atmospheric interference. The next thing to do is to notice if the noise has any relation to the received signal. Note if the noise only accompanies a signal or is heard only or heard loudest between stations on the dial or if the dial setting makes no difference whatever. Note the same things with reference to the volume control setting.

These are very important considerations because with these notations the fault is more definitely located. If the setting of the volume control or the station selector dial has no influence on the noise, it evidently lies in the audio system past the volume control. It may be a defective transformer connection, carbon resistor or leaky coupling condenser. If it is much more pronounced with a signal, it is in the RF system and may be due to a faulty cathode by-pass condenser, screen by-pass condenser, plate by-pass condenser, shorted trimmer condenser, defective plate supply or bleeder resistor, or a defective tube or other contact. If not noticed between stations on the dial, it is likely to be a trimmer or AVC filter condenser. If noticed only between stations it may indicate a gassy tube, a filament to cathode leak in the tube, or a faulty series plate or cathode resistor.

Spontaneous noise may be caused by outside interference. So don't be misled into making a false diagnosis. To distinguish outside interference from that which is generated within the receiver, it is necessary to isolate the receiver from any noise from the outside. This outside interference may get to the receiver through the antenna circuit or through the power line. Usually the nature of the noise is sufficient to tell which type it is but to make sure it isn't getting in through the antenna circuit, disconnect the antenna from the receiver and short the antenna lead of the receiver to ground. This will eliminate any interference that is getting to the receiver through the antenna circuit. Thus, if the noise is still heard, it is not due to the antenna circuit. The best way to check interference that may be entering the receiver through the power line is to operate a test receiver which you know has no internal noise from the same power outlet. If the interference is picked up on the test receiver, the noise is external. Later SAR lessons will cover the subject of interference, both external and internal in detail. When these complaints are encountered, methods of curing or, at least reducing them, will be given in these later lessons.

When it is found to be an internal noise within the receiver itself, usually, unless a noisy tube is found, the receiver will have to be given a more thorough check in the shop to locate the exact cause of such noise.

Hum With Reception

Having studied the condition of hum without reception, you may now see what different effects may account for it with reception. To the beginner in radio repair work it may be a major problem to determine what amount of hum would be considered normal for the design of any receiver. No AC operated receiver is completely free from hum although

This view shows a multiple tester as made by the Reiner Electronics Co., Inc. It will provide all of the usual multimeter tests and combines several other special tests for condensers, resistors, inductances, etc.

many of them are designed so that the hum is negligible. For example, if the receiver owner objects to a hum which is normal for the design of the receiver, the serviceman cannot usually make a satisfactory cure. As this would require extensive redesign of the circuit, the average serviceman could not undertake it profitably. To a great extent he must be his own judge of what to do about hum.

First eliminate all of the possible simple external causes of hum. See that the antenna and lead-in are not exceptionally close or wound around electrical cords or coupled to them. See that all shields are properly in place and making good contact with their supports. Make sure that the receiver is properly and adequately grounded to a satisfactory ground connection.

When you notice an excess of hum when a signal is tuned in *(called tunable hum)* you should know at once that this hum is modulating the signal somewhere in the RF system of the receiver. The AC voltage ripple from the plate supply in older circuits is ordinarily the major cause of hum, but with high-mu tetrodes and pentodes of modern design there is little or no possibility of this type of hum modulation unless the power supply is defective. Most generally this shows up in the audio system rather than in the RF part of the circuit.

In the case of tunable hum, you must investigate cathode circuits of RF and detector tubes and filament center-tap circuits. Filament to cathode leakage within the tube also may be responsible for hum.

For constant hum irrespective of the volume control setting, a defect in the output stages, speaker or power supply is indicated. A more definite localization than this may only be disclosed by test of parts. A hum which is proportional to the setting of the volume control has its origin naturally somewhere in the circuit prior to the volume control. This will usually indicate that the second detector or its plate or grid supply are at fault. Unless an RF signal is present to carry the hum, it cannot be transferred through the RF system of the receiver.

Sensitivity Varies over Band

This is clearly a case of improper tuning alignment. If noticed in a TRF receiver, it is simply a matter of improper adjustment of the trimmer condensers. For a superheterodyne, it must be the RF or oscillator adjustments.

Mechanical Noise Reproduction

If such noise is suspected of emanating from some part of the receiver other than the speaker, the speaker should be made inoperative by opening its voice coil or disconnecting one of its leads if of the magnetic type. Sources of noise are usually power transformers and the wet type of electrolytic condensers. The former will cause a 120 cycle hum when its laminations are loose while the latter will cause *sputtering* or *sizzling* sounds if defective. Included in this group, there is noise due to vibration of tube elements, shields, braces, wiring and cabinet parts; all of which must be identified by inspection and temporary holding or bracing so that they may not vibrate.

The speaker is a more frequent source of noise due to rubbing of the voice coil on the field magnet, making a noise like *sandpapering,* loose or broken cone *paper rattle,* loose spider, cracked or broken spider, *high pitched buzzing* somewhat like the sound of paper on a piano string that is being struck. This is usually most dominant only on certain frequencies. If the edge of the cone is loose the same general noise will be formed or if the cone has hardened with age this may occur. With very limited experience, such noise may readily be distinguished from distortion in the receiver which causes a somewhat similar noise.

Distortion of Signals

There are many types of distortion, most of which may be fairly definitely characterized. The following classifications will take care of the majority of defects of this nature.

(A) Loss of low frequencies and tinny sound of signals may be due to hardening of the speaker cone, excess bias on any AF tube or defective plate load on any AF tube. It is also frequently caused by insufficient speaker field current due to a shorted or open field coil. The magnetism of the speaker field may be judged relatively by the magnetic pull on a screw-driver or on any iron or steel brought near it. Even through the cone and spider the average magnetism from the pole piece of a dynamic speaker should be able to hold a ½ pound screw-driver or other metal piece from falling away from it. If it cannot hold a small screw-driver or small file, it is almost without question not obtaining the proper field current.

If any of the AF tubes have excess bias or a defective plate circuit, they will operate somewhat cooler than others in the same receiver. If the output or first audio tubes seem cool to the touch after 10 or 15 minutes of operation, you may be assured that their plate current is low, or cut off completely. In either case, high frequencies only will be reproduced as signals can usually be heard provided that there is not something else wrong as well.

A less serious loss of low frequencies may be due to incorrect setting of the station selector dial.

(B) Loss of high frequencies—*booming* may be the result of incorrect alignment of a multistage superheterodyne or the incorrect mounting of the speaker or even an incorrect type of cabinet for the receiver. This latter trouble is, of course, one of design and may not be solved by ordinary corrective measures as a defect.

Booming is often caused by placing the receiver cabinet too close to the wall, not allowing the air pressure due to the motion of the speaker to equalize when the high frequency tones are being fed to the speaker.

The effect is similar to moving a piston inside of a closed cylinder. It is easy to move the piston slow, but when you try to move it fast the air behind the cylinder cannot escape fast enough. Thus the piston cannot be moved at a high rate of speed. When the receiver is too near the wall, the same effect is produced. The low tones which move the speaker at a slower rate can be produced but the high tones which try to move the speaker at a high rate cannot; and, therefore, they are not produced, causing a booming sound due to the loss of the high frequencies.

(C) Change of energy content of high and low frequencies is a natural condition together with periodic fading of distant broadcast and short wave signals. So far in the practical field, this is a natural condition due to wave interference about which nothing can be done.

(D) Other forms of distortion not characterized by any special form as mentioned but noticeable in the reproduced speech or music must be found by detail tests of parts and circuits. Such defects may be found in the grid or plate supply of almost any stage. In addition the detector operation is critical to rather small changes in values of components of its circuit and to various signal levels. For example, it may overload easily or it may distort on low volume due to a change in value of a bias, grid or plate resistor. These things must be traced out individually by making measurements.

Signal Interference

All types of signal interference have their origin in the RF system of receivers. The type known as *double spot* tuning is a matter of incorrect alignment or inadequate design. If by making the correct adjustments in accordance with the standard tuning procedure, you find the defect still present, you may know that the design of the receiver is inadequate to take care of this defect. It is identified by the fact that a *single station* may be received at two points on the receiver dial.

If you encounter interference with a desired station by another on an adjacent carrier frequency, the difficulty is, of course, broad tuning and may be corrected insofar as the design of the receiver will permit by proper adjustment of the RF and IF circuits. This is not possible in certain locations or if the receiver has inadequate selective ability. It may require more tuned stages for one locality than another, as effective selectivity is inversely related to signal strength and is less in certain locations than in others for exactly the same receiver.

The interference of a desired signal with some other signal which is being transmitted on some unrelated frequency is called *cross modulation*. Here again, there is the possibility of the design of the receiver being inadequate for its correction. If the receiver has one RF stage preceding the first detector and uses a super control tube, this possibility is remote, while if not, it is probable. If the first detector is preceded by a two stage band pass filter rather weakly coupled, it is probably that correct adjustment or repair of any fault in this RF system will be effective in eliminating cross modulation. If the receiver is located near a powerful local station. less than a mile or so from a 1 to 5 KW station and within 5 to 10 miles of a 50 KW station, the correction of this difficulty may be impossible.

Code interference may be a result of any or all of the foregoing mentioned factors and has the same manner of correction. A code signal for this purpose may be considered in every sense like a modulated broadcast signal.

Intermittent Reception

Intermittently operating receivers, where they will operate absolutely normal for a period, then either cut off completely or distorts terribly, are often encountered. Many times this intermittent operation is due to a defective tube, but the offender is usually rather difficult to identify even with the aid of a tube tester. It is not always certain that you have located the exact defect even when you have located a defective part. Thus, when the complaint is intermittent reception, it is best to remove the receiver to your shop where you can observe its action and when it cuts off, make tests upon it. A later lesson covers the test procedure for the intermittent receiver. The important thing to learn here is that it is best to remove these receivers to your shop where a much better check can be made and usually much time can be saved by doing so.

Certain Receiver Characteristics

You must know some facts about receiver performance in general so that your judgment will be improved when analyzing for defects. A receiver is naturally more sensitive at high RF frequencies than on low RF frequencies. Do not attempt to change this condition by tuning alignment. Reception in the broadcast band is naturally somewhat poorer in the day time than at night, and for short wave reception, reception is not dependable or consistent either day or night. It is generally believed that frequencies above 28 to 30 MC are received better in the day than at night while those below this figure act in the reverse manner. This is true as an average over a long period of time but must not be used as an index for reception under any conditions. Winter reception is somewhat better than summer reception not only because of much greater signal strength but also because of much lower atmospheric interference.

Many older type receivers are unstable in the RF circuits, requiring a long antenna to prevent self-oscillation at high frequencies.

It will be apparent from this discussion that the main interest has been with basic circuits, individual circuits have not been considered. This includes such circuits as AVC, AFC, muter or volume expansion circuits, etc. There are certain auxiliary indicator circuits, such as the electric eye, the reactance dimmer, the tuning meter, the shadowgraph or the neon tuning indicator which must be included in this list.

The existence of defects in any of these circuits will make itself evident in faulty operation of the receiver which in turn may originate in a general circuit of the receiver or in a special circuit such as those previously mentioned.

Failure of an AVC circuit may take many forms, some of them being identical with actual faults in the signal circuit. For example, if the AVC circuit is open the same general result will be evident as for an open grid circuit as this is in reality what has happened. However, shorting to ground of the AVC feed line at one of the grid returns due to a shorted AVC filter condenser will cause failure of AVC action which is at once identified in the response of the receiver.

Likewise, in the failure of an AFC circuit, there may be failure of the circuit to establish accurate resonance, stopping of the oscillator, excessive drift of the resonant point with extreme loss of sensitivity of the receiver or complete cutting off of the audio output in certain cases.

These circuits must be individually analyzed and the effects of a short or open or a change in value of every individual part must be considered. Consider an individual case of AVC as in Fig. 7. The object is to determine what effect on the receiver various conditions of the AVC circuit would have on receiver reproduction. If resistor R1 increases in value or reduces in value considerably, there is not likely to be any difference in the operation of the receiver. However, if any of the AVC controlled tubes develop gas, there will be motorboating. If R1 is open there will be loss of low frequencies, greatly reduced signal strength and motorboating. If it is shorted, there may not be any change in the operation of the receiver or there may be a little hum, or in some rare cases feedback causing oscillation either constant or intermittent. The same information applies to AVC filter resistors R2 and R3 as they have the equivalent function in other stages.

If R4 in Fig. 7 is open, there will be no AFC control and the receiver will go into violent motorboating with probable oscillation. What signals could come through the RF circuits would have no RF check on their intensity and the receiver would act as though there were no AVC control over it.

However, if R4 were shorted, the AVC feed line would have AF impressed upon it, which would cause serious distortion with low signal strength and loss of low frequencies. If R5 is open there will be no reception while if shorted, there may be no difference noticed in operation unless you hear one or more very shrill high frequency audible tones. Under these conditions the volume control is more likely to be defective.

The result of an open in the volume control (R6) will be no signals and blocking of the RF system. This may cause motorboating by impact through the B+ line, and hence to the plate circuits of the first AF and output stages and may cause them to reproduce the sound. If, on the other hand, R6 is shorted, there will be no signals, although the RF system will be at its highest sensitivity.

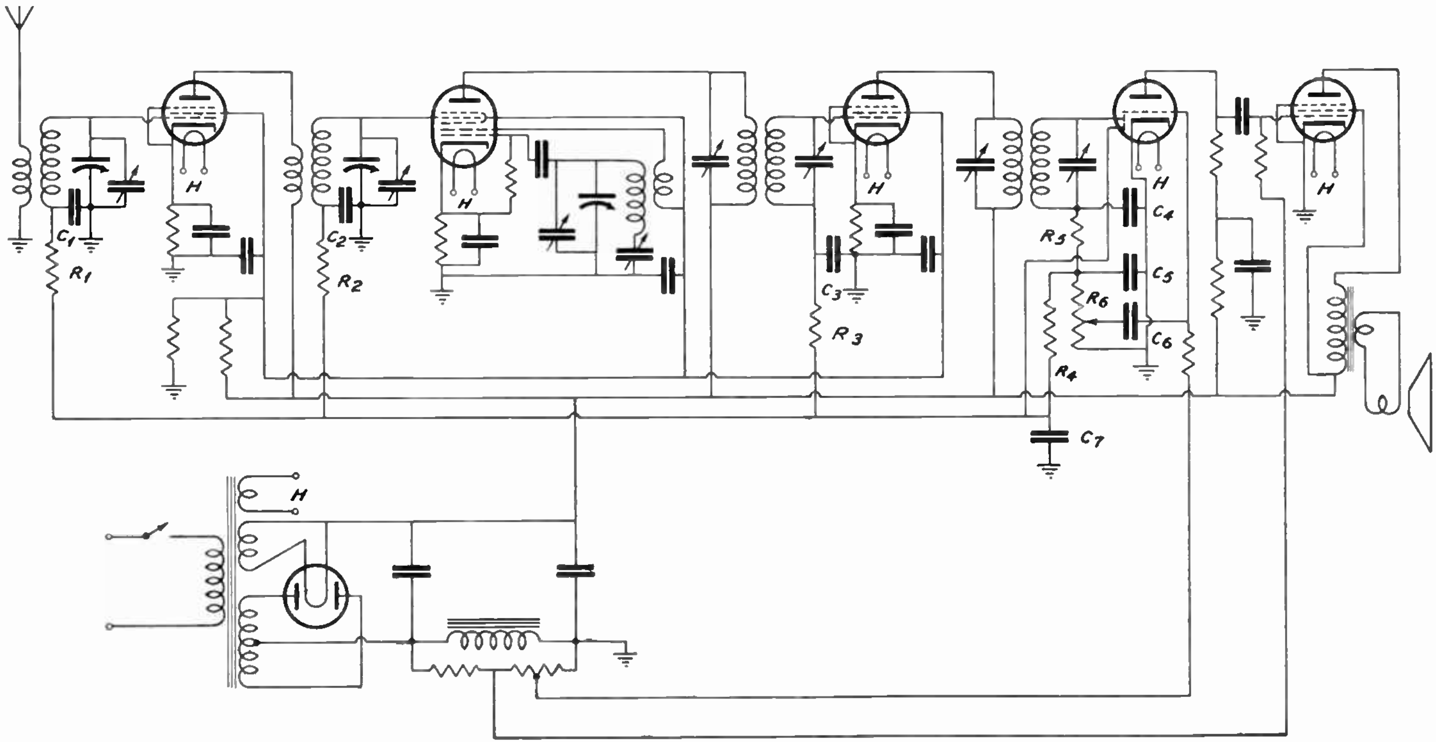


FIG. 7

Consider now what effect the condensers will have on the operation of the circuit if defective, shorted or open or have excessive leakage. These condensers have a fairly low voltage rating and rarely is more than 60 or 70 volts placed across them. They are not required to charge at a rate of more than about .1 milliampere (average) and it is very rare that these condensers (C1, C2, C3) will break down due to operating conditions. However, they might become defective for other reasons, such as moisture penetration, expansion, electrolytic action, etc.

If C1 is shorted, the first tuned circuit will be slightly out of tuning alignment due to a change of the total capacity of the circuit. This will broaden the tuning of the receiver and increase the sensitivity of the receiver at resonance as the AVC voltage developed at R1 will be shorted out. Cross talk, cross modulation, and double spot tuning (for the superheterodyne circuit) may result. Substantially the same will be true for C2, but for C3 the tuning characteristics will not be altered while the sensitivity at resonance will be noticeably higher, acting as though the AVC circuit were only partially active or totally inactive.

When these condensers (C1 and C2) are open, the only change in the circuit operation will be lack of selectivity with possible motorboating. An open of C3 is likely to produce some feedback, resulting in possible oscillation or if not this, the AVC feed line may not be adequately filtered causing some audio distortion, characterized by lack of low frequencies in the reproduction of sound.

If C4 or C5 are shorted, there will be no output while if either or both are open, a shrill output tone may result. Condenser C6 is the audio coupling condenser to the first audio amplifier. When it is open there will be no output and when shorted there will be a distorted output due to the negative DC of the second detector-diode section impressed on the grid, giving it excessive variable bias. The distortion will again be identified by a loss of low frequencies. In this way with a diagram before you, it will be possible to *estimate* the results of any type of defect in any circuit.

As mentioned elsewhere in your SAR course, the power supply of a receiver is one of the most common sources of receiver defects. There are many different types of power supplies, most of which are versions of the fundamental transformer rectifier type. In automobile receivers, the power supply is associated with the vibrator and in general is somewhat more complex than the power supply of an ordinary home type receiver. A later lesson will cover automobile power supplies very thoroughly, so no further discussion concerning them will be given here.

There are, however, special power supply circuits which are used in receivers where a power transformer is not used. These circuits are known as *voltage doublers.* A voltage doubler is so constructed that two condensers are charged, one on each half of the alternating cycle, and so arranged that the voltage impressed on the condensers adds across the output, thus making it possible to get a voltage as high as twice the peak AC voltage impressed upon the circuit.

Figure 8 shows a circuit of a conventional voltage doubler. Two rectifier tubes of the half wave type are needed. There are, however, a number of tubes which have two separate rectifiers in one tube envelope for use as a voltage doubler. Such tubes as the

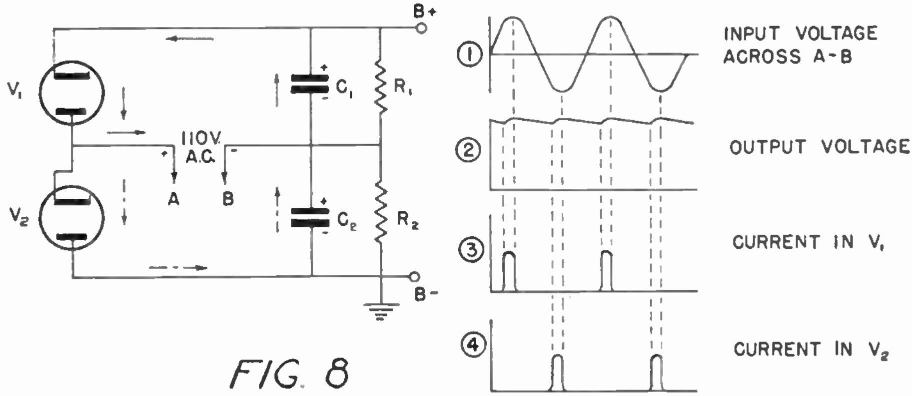


FIG. 8

50Z6G, 50Z7G, 117Z6T, 12Z5, 25X6GT, 25Y5, 35Z6G, 25Z6, 25Z5 are of this type.

Separate tube envelopes are used in this explanation to simplify the circuit arrangement—thus making the circuit easier to understand. From the diagram of Fig. 8 the operation of this circuit can be easily understood. Assuming the direction of the alternating cycle is such that point A on the diagram is positive, at the same time point B will have to be negative. As the plate of tube V_1 is made more positive than the cathode, electrons will flow and as the condenser C_1 is in series with the plate and cathode circuit, electrons will be drawn from the top condenser plate and deposited on the bottom plate, charging condenser C_1. Since C_1 is charged by the AC voltage, it will reach a voltage equal to the *peak* AC voltage. Bear in mind the fact that an AC voltage as measured by a meter is only 70.7% of the peak value. In other words, with an AC voltage of 110 volts as measured by an AC meter, the voltage actually reaches a value of:

$$\frac{110}{.707} = 155.54 \text{ volts.}$$

This is the voltage to which C_1 will be charged when an AC voltage of 110 volts is impressed across it. The current flow through R_1 can be neglected due to its high resistance value. Now as the cycle is reversed and point A is made negative and point B positive, V_1 becomes non-conducting due to the negative voltage on its plate; but V_2 is made conducting due to the negative voltage on the cathode causing electrons to be removed from the positive plate of condenser C_2 and deposited upon the negative plate through the tube. R_2 is in this case as R_1 was in the previous case—disregarded, as its high resistance causes but little current to flow. C_2 will be charged to a value equal to the peak voltage on this half of the cycle as did C_1 on the previous half cycle. *As C_1 and C_2 are in series across the output,* their voltages will be additive and a voltage of twice the peak AC line voltage will appear across the output from B+ to B— provided that the current load and the values of R_1 and R_2 are such that the current drawn from the circuit is within the allowable current drain of the circuit.

R_1 and R_2 are used to improve the voltage stability of the circuit and to discharge the condensers when the circuit is turned off. Thus, their resistance value is very high and, therefore, they have little effect upon the charging and discharging of the condensers. As the current load value is increased, the discharge rate through the resistance load will be high thus reducing the average voltage available across resistors R_1 and R_2. The larger the condensers are, however, the more energy can be stored in one cycle allowing for better regulation. If large condensers are used, the instantaneous charging current will be high, and may exceed the peak rated current of the rectifier and it may be damaged. To avoid this when large condensers are used, limiting resistors of about 1000 ohms should be placed in the cathode lead of V_1 between the cathode of the tube and the positive plate of the condenser and between the plate of V_2 and the negative plate of C_2. This will prevent a high surge current when the condenser first begins to charge, limiting the current to a value that will not damage the tubes. The charging and recharging of the condensers on each alternate cycle produces the voltage doubling. The condensers as mentioned should be of a large capacity. Usually the electrolytic type of from 10 to 50 mfd. is used. The voltage regulation is poor but where a constant load is placed upon the circuit, as is the case in a receiver, the circuit is satisfactory.

The curves at the right of the diagram of Fig. 8 represent the voltage and current distribution within the circuit. The first or top curve is the impressed alternating voltage as appears across A and B. The second curve is the output voltage across R_1 and R_2. The bottom curves illustrate the current flow through the two tubes. It is seen that the current flows through V_1 on the positive half of the sine wave and current flows through V_2 on the negative half. The larger the condenser used, the higher the peak current will be unless limiting resistors are used as mentioned previously. Many of the AC transformerless type receivers use these voltage doubling circuits for supplying the DC voltages to the receiver. As the output is not pure DC, a filter must be used in conjunction with these circuits for smoothing out the ripple.

Another voltage doubling circuit is shown in Fig. 9. This type of doubler is known as a cascade voltage doubler. The operation of this circuit is somewhat different from the previously described doubler, but the possible obtainable voltage across the output is the same.

The operation of the circuit in Fig. 9 is considerably different from that of Fig. 8. Assuming that V_1 is left out of the circuit and that the cycle is such that point A is negative at this instant before condenser C_1 has time to fully charge, the full voltage of the

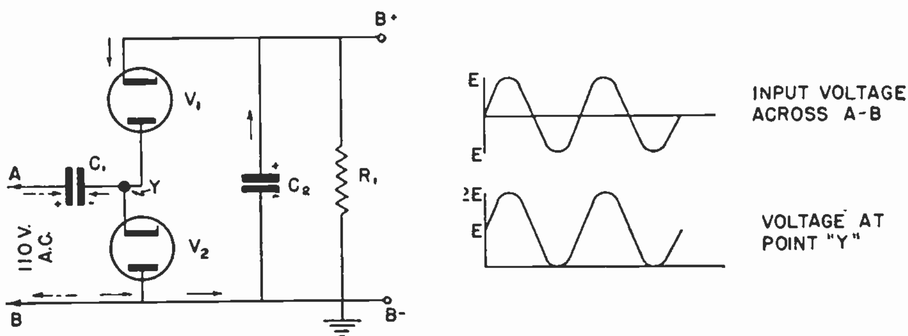


FIG. 9

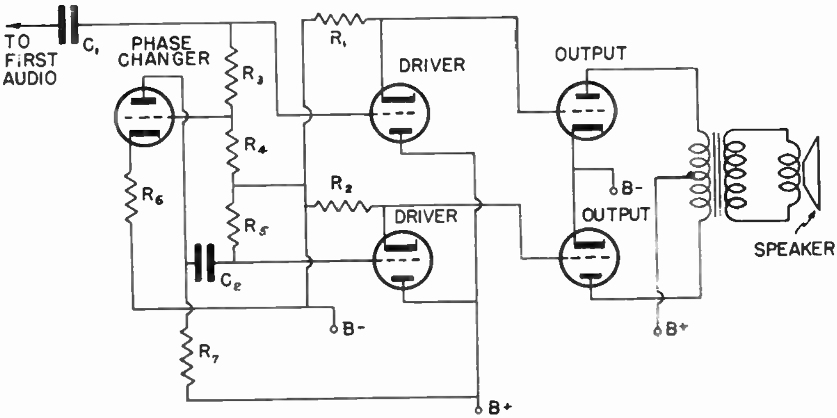


FIG 10

power line is placed across tube V_2. This causes a current to flow through the tube charging condenser C_1. After a few cycles have been completed C_1 obtains a charge equal to the peak AC voltage. As the voltage across condenser C_1 is in series with the line voltage and equal to the peak AC voltage when charged, when the cycle is such that point A is positive and point B is negative, the voltage at the cathode of V_2 will be equal to the sum of the applied voltage plus the voltage of the condenser because they are in series. As the AC cycle reverses and builds up in the opposite direction the voltage of the condenser just balances the applied voltage reducing the voltage at the cathode of V_2 to zero. Now as current can flow through a tube in one direction only and condenser C_1 is charged equal to the peak applied voltage, the voltage at the cathode will vary between zero and twice the applied voltage as is indicated by the bottom curve to the right of the diagram in Figure 9. The voltage on the cathode of V_2, because of this charged condenser, then varies between zero and twice the peak AC voltage. Now consider what happens when tube V_1 is connected in the circuit and made conductive. As the voltage upon the cathode of V_2 is twice the peak AC voltage, the voltage across V_1 through C_2 will be twice the AC peak since the plate of V_1 is connected to the cathode of V_2. Thus condenser C_2 receives a charge of twice the peak AC voltage and as the load is connected across C_2 this same voltage appears across the load. The same type tube as mentioned for the circuit of Fig. 8 can also be used in this type of doubler.

The voltage regulation of this circuit is similar to that of Fig. 8 but as long as the load is in the neighborhood of from 10 to 15 milliamperes, the circuit will perform satisfactorily.

The type of circuits described here are used in many of the small table model receivers of the low priced range. There may be a slight variation from the two circuits mentioned here but by following through the circuit, tracing out the electron paths, you will, no doubt, be able to understand their operation. Often a complex circuit diagram can be simplified by redrawing the circuit.

There are a few tricky audio amplifier circuits used in present day receivers. In one the cathodes of the ariving tubes are connected direct to the plates of the preceding tubes. This type of circuit is called a direct coupled amplifier. Figure 10 shows a circuit diagram of such a circuit.

The grids of the first driver tubes are driven by the first audio tube. The grid of the second driver is fed through a phase changing tube which produces an *out of phase voltage* (180 degrees) of the same amplitude as the first tube, giving the correct phase relation and amplitude for driving the second driver tube. The voltage for driving the grids of the output tubes is produced in the cathode circuit across resistors R_1 and R_2. The final amplifier or output stage is of the conventional type.

Following is a complete index of receiver defects classified by the symptoms and traced to their most probable sources. While more than one symptom may be present, they may be treated one at a time until the entire receiver is in good working condition. Most of the causes outside of the receiver and those due to inexpensive and faulty design of receivers have been omitted. Those given are principally defects which occur in otherwise properly operating receivers.

Necessary Tools For Developing An Efficient Testing Technique

As brought out in this lesson, it isn't always necessary to have an elaborate set of test equipment to locate receiver defects. The main and most important tools are those that will aid in locating the defective part or parts in the least possible time.

A thorough understanding of the circuit under test is by far the most important and efficient tool for doing a repair job. If you can visualize in your mind the complete operation of the receiver under test with a few

SYSTEMATIC TROUBLE LOCATION INDEX

GENERAL SYMPTOM	SPECIFIC SYMPTOM	POSSIBLE SOURCES OF DEFECT
		Receiver Inoperative
Fuse blows.	Receiver fuse blows.	Shorted power transformer—shorted input filter—transformer primary grounded—secondary winding overloaded (shorted, etc.)—shorted fuse lug to ground—fuse clip shorted to cable cover (auto radio).
	Line fuse blows.	Faulty receptacle plug—faulty line splice shorted switch—voltage regulator shorted to ground—shorted input filter—shorted transformer primary.
Receiver does not turn on.	No indication.	Open switch—open ballast tube—open transformer primary—open fuse block—broken cord or connection to plug.
No tubes light.	Smoke from chassis.	Shorted filament winding—partially shorted primary—shorted high voltage winding—shorted rectifier tube—shorted filter choke or speaker field shorted to ground—shorted voltage divider—shorted output tube.
Some or all tubes light.	Completely silent.	Open or shorted voice or speaker coil—rectifier shorted—high voltage winding open—output transformer open or shorted—output tube shorted or grounded.
	Hum only.	Shorted grid or plate circuit—open signal circuit at coupling condenser—open volume control—open plate circuit—open power supply lead.

		CIRCUIT NOISES WITH OR WITHOUT SIGNAL
Oscillation.	Only on high frequencies.	Improper neutralization—incorrect tuning alignment—improper stage coupling—incorrect plate or screen voltage—open screen by-pass—open plate by-pass—feedback through common grid return—through common plate supply, unfiltered—shields not grounded—condenser rotors open—wiring out of place—undesired stage coupling—open detector by-pass—improper bias—insufficient antenna—no ground.
Motorboating.	Only on low frequencies.	Improper alignment—also many of the same conditions for high frequencies.
	Over entire dial constant.	Open audio grid—leaky coupling condenser—gas in audio tubes—low filament voltages and current—low emission—increase in plate circuit resistance—grid resistance too high.
	Varies with dial setting or volume control setting.	Open grid or plate circuit filter condenser—low bias—open cathode by-pass—detector shield not in place—grid to cathode leakage in tube (audio)—open volume control. Condition of unstable oscillation—check all conditions under oscillation.
Microphonic noise.	Ringing sound.	Loose element structure in detector—excessive vibration of chassis—improper mounting or location of speaker or other parts.
Mechanical noise.	Controls.	Defective volume control—defective tone control—defective power switch—defective band selector switch—defective AFC control switch—defective station selector dial or mechanism.
	Other.	Dirty contacts—cabinet vibration—shield rattle—tube vibration—transformer laminations loose—wet electrolytic condenser sizzle.
Electrical noises.	Clicks irregular.	Punctured filter condenser—defective mica dielectric in condenser—dust or metallic particles in variable condenser plates—defective carbon resistor in cathode, grid or plate lead—outside interference.
	Scratching noise.	Faulty metalized or carbon resistor in plate, screen, cathode, or diode circuit—poor switch contact—corroded terminal—defective transformer winding.
	Frying noise or sputtering.	Note under scratching noise—electrolytic filter or by-pass condenser—defective field or filter choke coil—defective tube—defective tube spray shield—poor contact of shields or wiring.
		INTERMITTENT RECEPTION
Instantaneous circuit action.	Cuts out.	Temporary short of any filter, by-pass or coupling condenser—short to ground of any grid, plate, diode, screen, coil or condenser wiring—transformer short, audio, power, output coupling—see temporary cases under Inoperative.
	Volume reduces.	Special cases under Circuit Noises.
		FAULTY RECEPTION
Hum.	Constant.	Incorrect bias, plate, screen, or filament voltage—shorted hum coil in speaker—hum control out of adjustment—excessive grid resistance—wiring dislocated—heater to ground short—open plate or grid filter—open filter condenser—open bias by-pass condenser.

(Continued on next page)

	Tunable.	Open bias by-pass in RF or IF—shorted cathode resistors or condenser—cathode to heater short within tube—improper tuning alignment—induction from grid return—see also conditions under oscillation.
Fading.	Complete fade out.	Old tubes—discharged batteries—vibrator failure.
	Fades out and in.	Defective tube heater circuit—insufficient antenna, poor location of antenna—distant reception.
Reduced signal strength (low sensitivity).	Only part of band.	Improper tuning alignment—oscillator out of tuning adjustment—padder, trimmers—condenser plate warped—stator plates shifted—rotor shaft bent—bearings worn.
	Entire band.	Old tubes—moisture in coils—out of tuning alignment—(see only part of band), excessive bias—defective vibrator—low voltage batteries—low voltage filament supply—loss of rectifier emission—dust on tubes, coils and condensers.
Broad tuning.	High frequencies.	Incorrect trimmer adjustment—moisture in coils or dielectric weakness in coil forms—poor receiver design.
	Low frequencies.	Incorrect padding adjustment.
	Entire band.	Incorrect tuning alignment of entire band—antenna too long.
Station interference.	Adjacent channel.	See broad tuning—poor receiver design.
	Howl.	Natural condition of station carrier assignments—bad location of receiver.
	Double spot tuning.	Incorrect IF adjustment—incorrect RF adjustment—incorrect oscillator alignment.
	Cross modulation including code reception heterodyne (squeal).	Band pass filter out of alignment—too long antenna—use of sharp cut off RF tube instead of super control type—too near powerful local station—improper adjustment of wave trap.
Distortion.	Loss of low frequencies.	Improper tuning of the dial—speaker cone stiffened—speaker field shorted—excessive audio bias—open signal by-pass condenser at output plate circuit—open audio cathode by-pass—inadequate filter capacity.
	Loss of high frequencies.	IF adjustment too selective—shorted tone control resistor—presence of regeneration (see oscillation).
	Booming.	Loose cabinet back—closed cabinet—receiver too close to wall—stiffened resonant cone structure.
	Mushy.	Low detector bias—detector overload—low audio bias—very low plate voltage—regeneration (see oscillation).
	Broken signal.	Excessive 2nd detector bias—excessive audio bias—overloaded detector circuit—excessive delay bias for AVC.
	Hiss near resonance.	Tuning adjustment too selective—regeneration (see oscillation).
	Change in audio quality.	Distant reception—natural condition due to wave interference.
		INCIDENTAL CASES
	Dial out of calibration.	Wrong scale adjustment—loose scale, allowing slip.
	Tuning indicator inactive.	Shorted out—AVC inoperative—defective tuning instrument—mechanical defect.

Auxiliary circuits.	AVC inactive.	Shorted AVC filter condenser—shorted AVC filter resistor to ground—AVC diode emission low—improper tuning alignment of AVC amplifier—open grid return in separate AVC tube.
	AFC inactive.	Incorrect adjustment of discriminator—gassy AFC tube—change in value of AFC filter resistor—grounded discriminator cathode—shorted AFC circuit to ground.
	No control of volume.	Volume control shorted (cathode type)—knob loose on shaft—slider terminal broken—volume control open.
	Receiver does not turn off.	Power cord in reverse position—transformer short to chassis.
	Dead on short wave band.	Faulty switch contacts—defective oscillator tube.
	No response of fidelity control.	Switch contacts defective—mechanical adjustment incorrect—mechanical faults in mechanism—improper alignment.
	Electrical shock to touch chassis or controls.	Power transformer primary shorted to chassis—for AC-DC receivers—power system shorted to chassis—plug reversed.

symptoms which are gathered, and by means of some well chosen tests, the possible defects which can cause such faulty operation will be evident. Then by following through with more exacting tests the defect can soon be located. It is not only essential that the serviceman understand the circuit under test, but he must also understand the equipment best suited for a given test.

Many inadequately trained radio servicemen have elaborate test equipment but due to the lack of knowledge concerning this equipment, it just sits on the shelf collecting dust. This, of course, is a waste of money, and far from the essence of efficiency. With all the new developments in radio, it becomes more important than ever to understand the best type equipment to use for one particular job. It isn't the object of this lesson to pick out any particular type or brand of equipment which will do the best job for you because there are numerous models and makes which will perform equally well if operated properly. What is meant to be emphasized here is for the student to make a thorough study of the available equipment and from his own needs determine which instruments are the most needed in his shop. (This refers to other equipment besides the general universal types which are necessary in every radio shop such as voltmeters, ohmmeters, milliammeters, etc.)

Your SAR lessons to follow go into detail concerning the use and operation of the most common types of test equipment. It will be necessary for the student to study these lessons thoroughly if he is to know which type of equipment is best suited for his particular need. It is always advisable to study over the principle of a certain piece of test equipment before purchasing it, making sure you understand how this test equipment can aid you in your service business. Fancy and elaborate looking test equipment may impress your customer but a far better impression which will last is your service work and the price the customer pays for this work. If you buy a large number of the expensive test instruments in order to pay for them, you will have to charge more for your work or put out more service work. If the equipment cannot save you time or improve your work, it isn't economical to buy such equipment.

As an example, consider a practical case and note how one type of equipment is advantageous over another. It is desirable to locate the stage in which there is a defect causing the receiver to be inoperative. With the aid of the tests outlined in this lesson, the defect is isolated to the RF or IF stages. With an ohmmeter only, the defect would have to be traced out by testing one part of it at a time and as there are a large number of components within the RF and IF section of the receiver, considerable time can be lost in locating the defect. If it can further be isolated to one stage of the RF or IF section of the receiver, there aren't so many parts to check. Therefore if an instrument can be obtained that will aid in localizing the fault to only one stage, considerable time will be saved. Equipment that, in general, can do this are the signal tracing and signal injecting types which you will learn more about later on in your SAR course.

A service technique which is the most efficient is one where little time is wasted in locating the defect. After a defective part is once located it takes but little time to replace and correct it. For this reason emphasis is placed on methods of locating the faulty part or parts within the receiver. It is true that a certain percentage of radio repair jobs are obvious to even a partly trained serviceman, but it is the remainder that requires a highly skilled serviceman.

Every person regardless of his training follows his own technique—the one he feels is the most efficient. It is not our purpose to set down a definite technique that cannot be altered. The procedure to follow is, however, more definite but the method of applying this procedure may vary and you will, no doubt, develop a good sound method after you have completely mastered your SAR course. The technique you choose to follow should be one that will allow the maximum work in the least time with the best quality of workmanship.

As you gain more and more experience your ability will improve and you will wish to change your technique to suit the conditions under which you are working.

The methods of testing and repairing receivers given in your SAR course are complete and up-to-date, and as you progress the best test methods and techniques will be clearly and definitely given so that you will have the advantage of knowing what techniques to follow in the majority of cases. You will have a sound enough background to choose a technique of your own and where there is a question of which is the better procedure to follow you will know how to proceed.

A close study of this lesson will help you develop your own particular diagnostic technique. Learn to make a quick and accurate analysis of a receiver or amplifier. Your ability to do this will determine how effectively you can compete for radio service work. The quicker you diagnose the trouble, the more you will impress your customer, and generally speaking, the more money you will make if your diagnosis proves to be correct.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 Would you suspect the power transformer primary circuit of having a defect if the tubes in the receiver were all normally heating, or if they were all cold?

No. 2 In Figure 2 if you measure a satisfactory plate voltage at B+ is there any reason for testing the line cord and cord resistance if the receiver is not working?

No. 3 If a motorboating is heard and it changes pitch with the RF tuning, would its origin more likely be in the RF or AF parts of the receiver?

No. 4 What preliminary test is completely satisfactory as an antenna check?

No. 5 If there were low volume accompanied with cross-talk, what would be your first logical suspicion as to its cause?

No. 6 If you find a noise to be always proportional to the signal strength, where is its origin most likely to be found?

No. 7 Does the fact that a loud hum is tunable or constant indicate where it may be originating?

No. 8 Can signal interference always be eliminated in all types of receivers?

No. 9 Is there any purpose in distinguishing one type of signal interference from another?

No. 10 From the list of causes of oscillation given in this lesson, would you say that they are all due to some circuit defect in the receiver?

HOW TO APPLY THE SIGNAL GENERATOR

LESSON TV-6

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

SIGNAL GENERATOR AND OUTPUT INDICATOR CONNECTIONS FOR AM, FM AND TELEVISION RECEIVERS

This lesson deals with the AM modulated signal generator, frequency modulated signal generators, calibration of signal generators, beat frequency oscillators and output indicators.

There is a basic procedure to follow when adjusting the tuned circuits of any type of receiver be it the oral or the visual type. The object of using such generators and output indicators is to enable the technician to adjust the tuned circuits so that they will operate at their maximum efficiency. In general a signal generator feeds a suitable signal to the receiver under adjustment and an output indicator records the performance of the tuned circuit as the technician makes adjustments. Usually the signal generator output leads are connected to the input of one or more tuned stages and the output indicator is usually connected somewhere in a detector or AF stage depending on the type of AF circuit and type of tuning adjustment to be made. The details of such connections and adjustments are all given in this lesson. In this connection you might be interested to know that in a television receiver the picture tube itself is often used as an output indicator for certain adjustments. This will all be taken up in considerable detail in a later lesson of your SAR course. Also there are certain FM tuning adjustments requiring special treatment and this will be taken up in a later lesson devoted to FM receivers. A section of this lesson describes visual tuning methods as made with the oscilloscope. It is included so the lesson will be complete on general tuning work—another later lesson will treat the complete oscilloscope and will show how it is used in radio and television receivers. This lesson also includes information on the Beat Frequency Oscillator—an instrument used to check the AF section of a receiver—the AF amplifier being common to all AM, FM and television receivers. So you will see this is an important lesson and one that you will want to refer to often in connection with your tuning work on AM, FM and television receivers.

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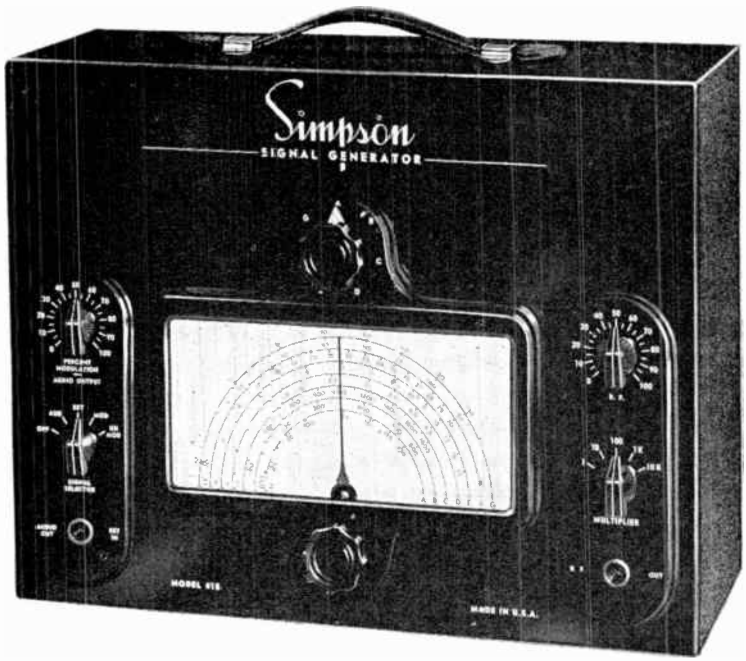
CHICAGO, ILLINOIS
K 9552M



Above is shown a typical signal generator as made by Simpson. It is of the all wave type and has seven tuning ranges. The upper left knob controls the modulation and audio output. The lower left knob selects the ranges and tuning is done by the knob at the lower center. The RF is controlled by the right upper knob and the one below it is the attenuator control. Tip jacks are provided for the RF and AF output.

HOW TO APPLY THE SIGNAL GENERATOR

Lesson TV-6

The application of the signal generator in connection with the adjustment and repair of radio and television receivers is a subject worthy of the attention of every radio man. Its application and field of use is ever widening. The signal generator (or test oscillator) was ushered into general use by the radio serviceman at the time the superheterodyne type receiver came into prevalent use. The signal from a broadcast station was formerly widely used for all purposes of tuning alignment, neutralization and adjustment when there was no intermediate frequency amplifier to adjust. On present day receivers the signal from a broadcast station is not nearly as satisfactory as that from a signal generator. Basically the signal generator is simply a high frequency oscillator but the uses for an RF modulated signal are so widespread that almost every signal generator employs some form of modulation.

The High Frequency Oscillator

The high frequency oscillator of the signal generator must be stable in operation and accurately calibrated. The accuracy of alignment of a receiver depends upon the operation of

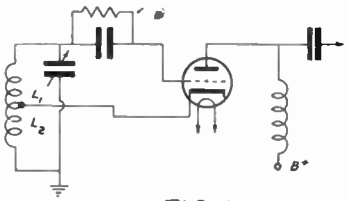


FIG. 1

this oscillator. Any deviation in frequency or in the output voltage of the generator may cause a serious error in the receiver tuning.

As the oscillator is the heart of the generator, it must be of a stable type to give best results. There are several types of oscillators used in signal generators. One of the simplest types of oscillators is shown in Fig. 1. It is a Hartley series fed oscillator. Feed back for sustaining oscillation is accomplished in two ways: One through the interelectrode capacity between plate and grid of the tube and the other through the magnetic coupling between the two coils L_1 and L_2. This magnetic coupling is obtained because the plate current of the tube must pass through L_2. Thus any change in the plate current will be induced into the grid circuit. When the amplitude and the phase of this induced voltage is correct, the tube will oscillate at the frequency determined by the combination inductance of L_1 and L_2 and Condenser C. That is—

$$F = \frac{1}{2\pi \sqrt{(L_1 + L_2)\, C}}$$

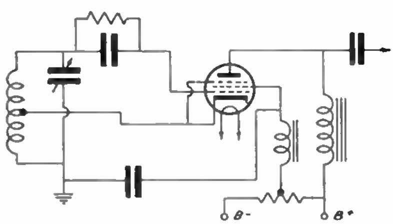


FIG. 2

This type of oscillator is unstable due to the two feed back paths. Because of this, it is seldom used in the more modern type signal generators.

Another common type of oscillator is shown in Fig. 2. The operation of this oscillator is similar to that of a Hartley oscillator but a pentode tube instead of a triode is used. By using a pentode, the stability of the oscillator is considerably improved due to the shielding effect of the suppressor and screen grids. This type of circuit is usually called an electron coupled oscillator.

Another type of oscillator is shown in Fig. 3. This is a Colpitts oscillator. Feed back from the plate to the grid is obtained through condenser C_1 which is a special double rotor, single stator tuning condenser. The frequency of oscillation is determined by condensers C_1 and C_2 and coil L_1.

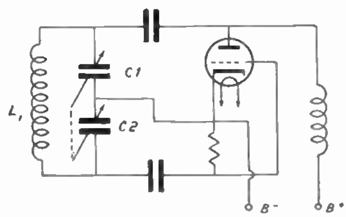


FIG. 3

The crystal oscillator is sometimes used in the more elaborate type signal generators to obtain an accurate check at the crystal frequency and of its harmonics. Usually, the crystal is ground to give a 100 KC or 1000 KC signal and the oscillator circuit is designed to give strong harmonics of the fundamental frequency. That is, frequencies of 100 KC, 200 KC, 300 KC, etc. can be checked with the 100 KC crystal and frequencies of 1000 KC, 2000 KC, 3000 KC, etc. with the 1000 KC crystal. These crystal oscillators are usually designed so that frequencies as high as the 50th harmonic of the 100 KC oscillator can be used and frequencies as high as the 100th harmonic of the 1000 KC crystal oscillator can be used.

These oscillators must be modulated at an audio rate if an output meter is used when adjusting the tuned circuits of a receiver. Most of the signal generators use some type of audio oscillator and modulate the signal with the audio frequency generated by this oscillator. A typical audio oscillator is shown in Fig. 4. The transformer is nothing more than a small audio transformer connected in such a way as to cause feed back between the grid of the tube and its plate causing the tube to oscillate at an audio rate. Some generators use what is called an RC audio oscillator. By using an audio oscillator of this type, the audio transformer can be eliminated, making a less expensive oscillator. In this type of AF oscillator condenser and resistor values are chosen to cause oscillation at the desired AF rate.

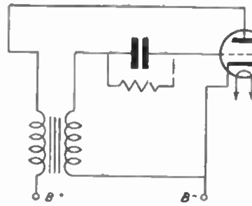


FIG. 4

In most of the smaller, less expensive oscillators, the modulation is added directly to the oscillator tube. This is not in all cases desirable because the modulation, should be entirely of an amplitude form. Thus this may cause frequency variations as well as amplitude variations. However, with correctly designed oscillators, these frequency variations are practically eliminated.

Figure 5 shows a circuit where the oscillator is modulated. This is the Simpson Model 415. Here the oscillator is an electron coupled type and the modulation is added at the suppressor grid. By using a stable oscil-

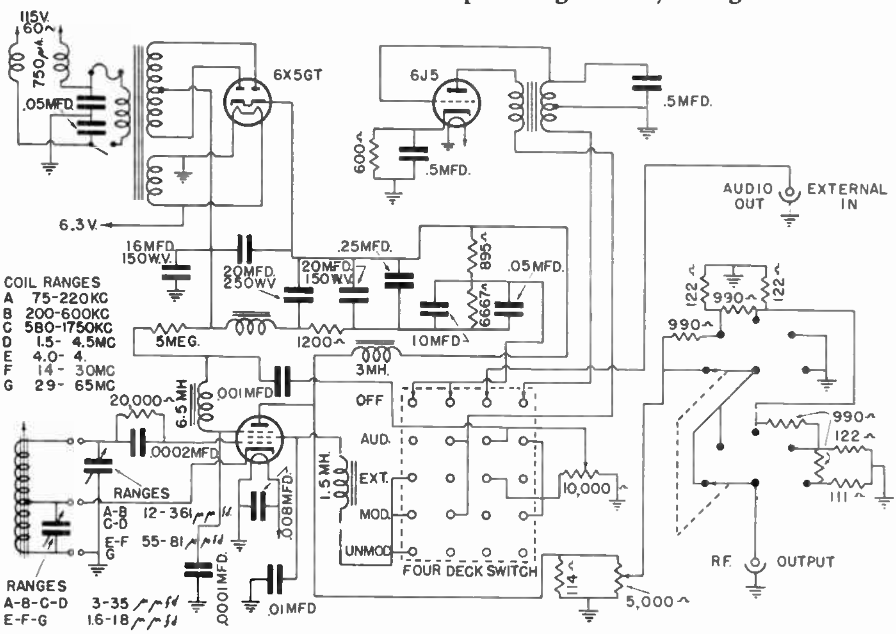


FIG. 5

This photo shows a typical multimeter. It has the usual AC-DC scales and also ohmmeter ranges. Such a meter can be used as an output meter in connection with a signal generator. For this purpose it may employ either the AC or DC scales as explained in the lesson. Courtesy of Simpson.

lator of this type and introducing the modulation at the suppressor grid it tends to eliminate frequency drift and also frequency modulation.

Some of the more elaborate generators use a stage of radio frequency amplification after the RF oscillator. By doing this the effect of the load on the oscillator is entirely eliminated from affecting the frequency. When a separate RF amplifier is used the modulation is added at the amplifier stage.

Signal generators should be stable. The earlier model generators used a battery voltage supply to secure good stability and hum free operation. These battery operated generators were inconvenient due to the necessity of having to replace the batteries at short intervals. With newer designed power supplies, better voltage stability is obtained. This is accomplished by the use of a specially designed glow tube voltage regulator. By using a tube of this type in conjunction with a resistor as shown in Fig. 6, the voltage is regulated over quite a wide range. The operating voltage of these regulator tubes depends upon the design of the tube. How the regulation is accomplished is rather simple. The characteristics of these glow tubes are such that the higher the voltage applied to them, the larger the current flow. At normal voltage a very small current is drawn by the

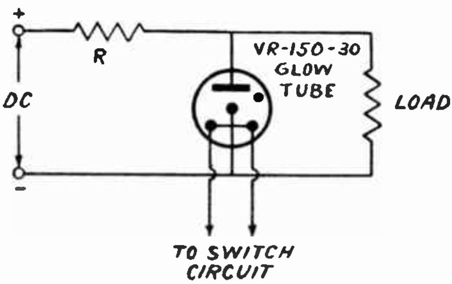


FIG. 6

glow tube from the circuit of Fig. 6. As the voltage increases above the rated voltage of the tube, a heavy current flows causing a voltage drop across the resistor R, bringing the voltage across the load back to normal. When the applied voltage reduces, the tube draws less current and the voltage drop across R is reduced, keeping the voltage across the load constant. The applied voltage must be allocated at a slightly higher value than that of the regulator tube in order for the circuit to regulate the voltages above and below that of the

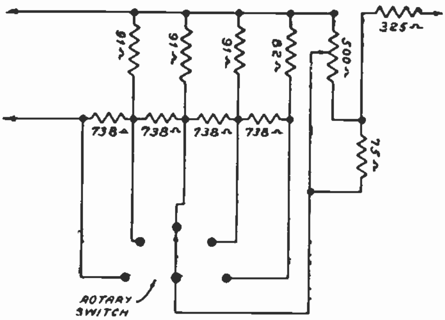


FIG. 7

regulator tube. These regulator tubes are designed to operate on a certain steady voltage. There are three common types—the VR-75-30, VR-105-30 and VR-150-30. The first number is the value of the voltage it is intended to regulate and the second number is the maximum current drain of the tube.

The RF output of a signal generator is usually controlled by a continuously variable attenuator and a step attenuator. The step attenuator is so designed as to give output voltages in multiples of 10—that is, the first step would be X1, the next step X10 and so on up to X10,000—the X in this case indicating multiplication by 10, 100, 1000, etc.

In order to accomplish these different steps on the *attenuator*, a special ladder network is used. Figure 7 shows a typical resistor network of this type. It is used in the Triplett 1632 signal generator. The reason such a resistor network is necessary is that the output must vary in certain different steps and also because the load on the output is not constant. Thus an *output attenuator* is essential.

Referring to Fig. 5 again it shows a circuit diagram of the Simpson Generator Model 415. This generator is a very simple yet efficient unit, using just three tubes. The high frequency oscillator is of the electron coupled type, similar to the circuit of Fig. 2 using a 6AK6 tube.

The band switching circuit has been eliminated from the diagram to make it easier to read. There are eight bands covered by this generator from 75 kilocycles to 65 megacycles.

The oscillator is connected through a special attenuator network to the output giving the usual steps of 1, 10, 100, 1K and 10K (K meaning to multiply by 1000) with a continuously variable potentiometer for varying the output in between these steps. The dial is directly calibrated, requiring no charts for reading frequency.

The audio oscillator tube is the 6J5. The audio signal from this generator can be used externally or it can be made to modulate the oscillator by simply changing the selector switch. To modulate the RF oscillator the audio signal of the internal oscillator or an external AF signal can be used. The modulation is added to the oscillator through the suppressor grid. The power supply is designed for good regulation and effective filtering.

Note there is an RF filter used in the primary of the power transformer to filter out unwanted signals, and to keep the signal from the generator from feeding back through the power line.

Figure 8 shows a circuit of a complete signal generator manufactured by the Triplett Electrical Instrument Co. This circuit may seem complicated at first due to the intricate switching arrangement for changing bands. The oscillator is a 6J5 triode tube operated as a tuned grid, plate feed back oscillator on bands A to G inclusive and as a Colpitts oscillator on bands H to J inclusive. The oscil-

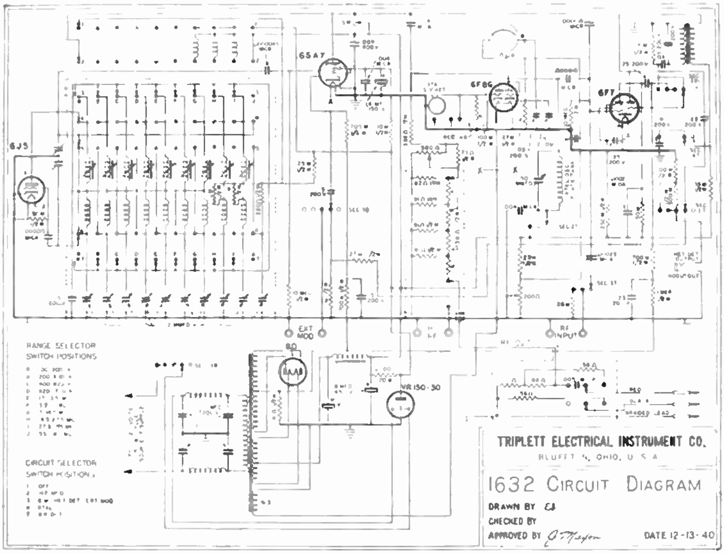


FIG. 8

lator tube drives a 6SA7 buffer (RF amplifier) tube. The triode section of the 6F7 tube is the audio oscillator and the modulation is introduced at the third grid of the 6SA7 tube. The output of the audio oscillator, when the selector switch is turned to *AF out*, is available at the phone jack and can be used to test the audio section of a receiver.

The power supply uses a VR-150-30 voltage regulator tube for stabilizing the supply voltage. One section of the 6F8G is the crystal (Xtal) oscillator used to check the calibration of the RF oscillator. The other section of the tube is used as a diode in a special meter circuit, for measuring the RF output in terms of output units, these output units are proportional to but not equal to absolute microvolts. However, this is not objectionable as relative readings are indicated on the meter.

The attenuator, as you can see from Fig. 8 is a ladder network corresponding to Fig. 7. The last shunt resistor of this network properly terminates the 5 foot coaxial transmission line which is supplied with the generator.

The pentode section of the 6F7 is used as a grid leak detector with the radio frequency voltage from the Buffer Modulator, external RF jack and crystal oscillator output permanently connected to the control grid. When the selector switch is set for heterodyne detection, the triode section of the 6F7 is used as an amplifier for the heterodyne detector. This permits an external RF signal or the crystal oscillator harmonics to produce a beat note with the signal generator RF oscillator, thereby permitting calibration of either the signal generator or the external RF signal. This beat note signal is heard with a headset connected to the phone jack.

The coaxial cable supplied with the generator has the last shunt resistor of the attenuator at the far end. It is enclosed in a shielded box with a switch to select the proper resistor network as indicated in Fig. 8. The coils and condensers in the primary circuit of the power transformer are

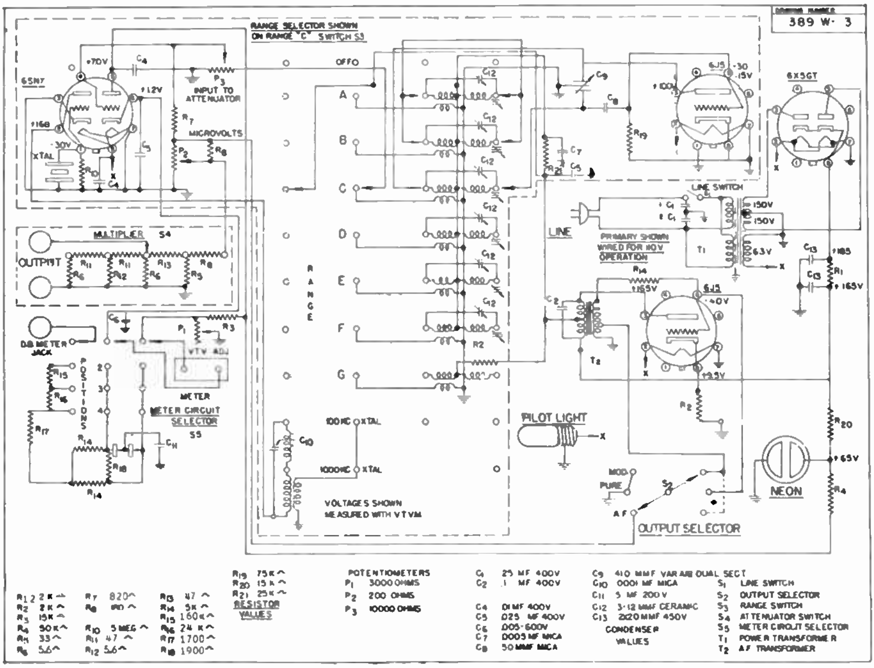


FIG. 9

used to eliminate any unwanted signal from the power line.

Figure 9 shows a circuit diagram of the Hickok signal generator model 19XD. This generator has many of the same features as described for the other generators in this lesson. It has, in conjunction with the generator a vacuum tube voltmeter which can be used as an output meter when adjusting the tuned circuits of a receiver.

The three signal generators presented here are typical examples of commercial models. Specific operating instructions on a given model of a signal generator should be obtained from the manufacturer.

Calibration of Signal Generators

With the facilities available at present to every serviceman, his signal generator may be the most precise piece of test equipment in his shop. As easy as it is to calibrate signal generators today, no technician need bother about costly equipment or need access to a laboratory for this work. By constantly checking his work, he can for short intervals of time duplicate frequency precision which originally may have cost thousands of dollars to set up and maintain.

The oscillator of a signal generator of course will not hold to any exact frequency for a long time under various conditions of temperature, moisture, line voltage, loads and many other factors but it will hold to the required values very accurately for short periods of time. Calibration is so simple that many servicemen check and adjust their signal generators at regular intervals.

As mentioned in the foregoing description of commercial made signal

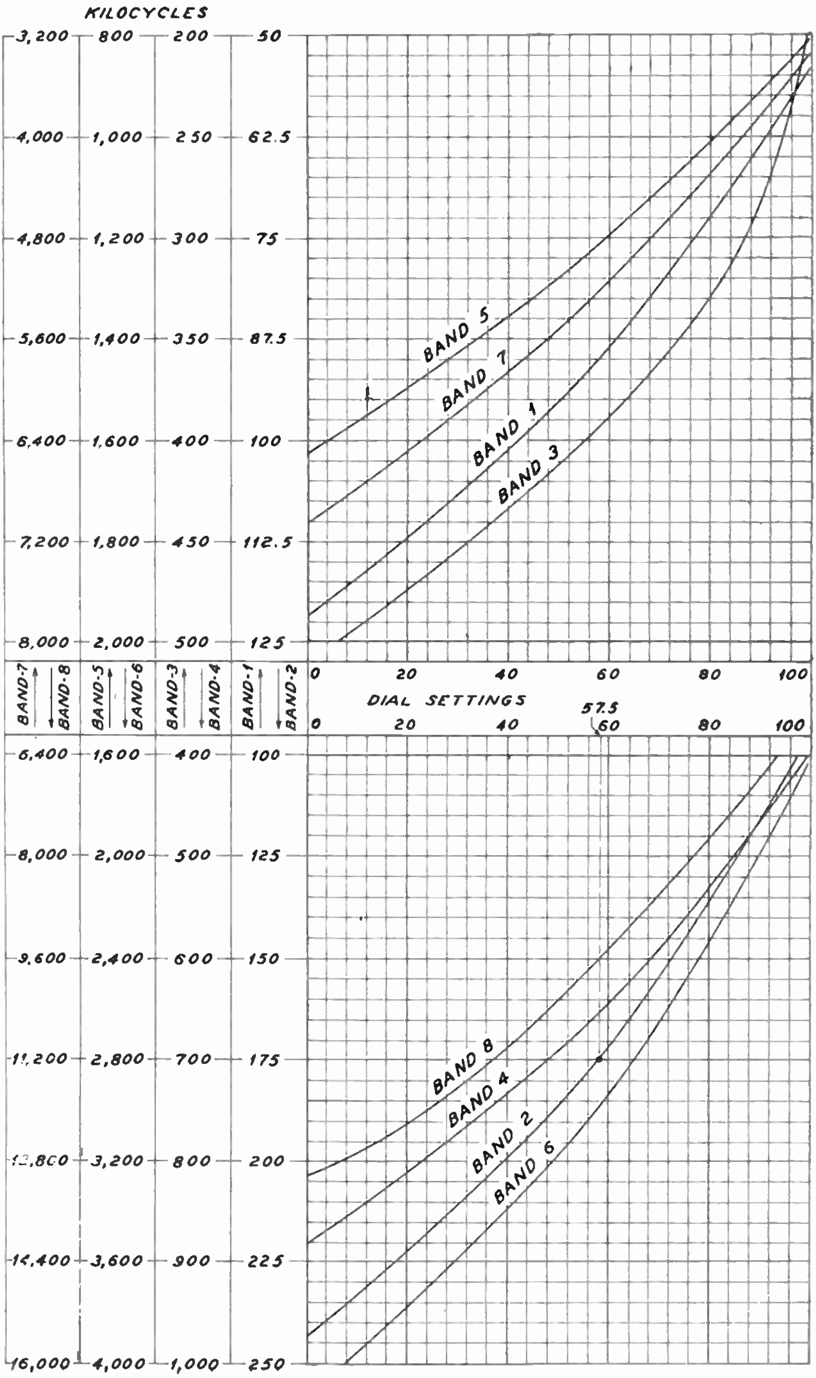

KILOCYCLES
3,200 800 200 50
4,000 1,000 250 62.5
4,800 1,200 300 75
5,600 1,400 350 87.5
6,400 1,600 400 100
7,200 1,800 450 112.5
8,000 2,000 500 125
BAND 5
BAND 7
BAND 1
BAND 3
BAND-7 BAND-8 BAND-5 BAND-6 BAND-3 BAND-4 BAND-1 BAND-2
0 20 40 60 80 100
DIAL SETTINGS
57.5
0 20 40 60 80 100
6,400 1,600 400 100
8,000 2,000 500 125
9,600 2,400 600 150
11,200 2,800 700 175
12,800 3,200 800 200
14,400 3,600 900 225
16,000 4,000 1,000 250
BAND 8
BAND 4
BAND 2
BAND 6

FIG. 10

generators, some of the better more expensive type generators have an accurately ground crystal in a specially designed oscillator circuit for checking the calibration of the generator. With signal generators having this convenient checking feature the calibration process is simple and no outside source of RF power is needed for the check. Reference should be made to manufacturers instructions for recalibrating a given signal generator.

There are many signal generators in use at present that do not have a calibrating oscillator. It is these older model oscillators that will require a special method of checking their calibration. The following explanation will be useful for calibrating signal generators of older designs. The presentation of this method of calibration is very instructive and even though you may not have a signal generator that needs calibrating, go over this explanation carefully. Much information concerning harmonics, etc. is given.

Suppose you have an IF amplifier of a receiver to align and you find its peak value as given by its manufacturer is 175 KC. For this work it is first necessary to set or tune the signal generator to exactly 175 KC.

Some of the manufacturers of signal generators supply the purchaser with calibration charts which are graphs showing the relation of the dial setting to the actual frequency. Figure 10 shows a typical graph of this kind, for a signal generator having 8 bands. Note 175 KC is found at the point marked 175 in the 2nd band. Tracing across to the curve marked band-2 and up to the dial scale note that the dial must be set at 57.5 while the band switch is set at band-2, for 175 KC operation. This setting is not likely to be accurate because of the many variable factors *but the dial should be set here first.*

Now the character of nearly all vacuum tube oscillators is such that the wave generated will have a number of harmonics which are simply higher frequencies or exact even multiples of this original 175 KC. Thus if the generator is correctly set, the following frequencies will be the 2nd to 10th harmonics respectively:

Fundamental		175 KC =	175 KC
2nd	Harmonic	2 x 175 KC =	350 KC
3rd	"	3 x 175 KC =	525 KC
4th	"	4 x 175 KC =	700 KC
5th	"	5 x 175 KC =	875 KC
6th	"	6 x 175 KC =	1050 KC
7th	"	7 x 175 KC =	1225 KC
8th	"	8 x 175 KC =	1400 KC
9th	"	9 x 175 KC =	1575 KC
10th	"	10 x 175 KC =	1750 KC

Now the higher the order (number) of harmonic the less will be its energy but servicemen may work regularly with harmonics as high as the 20th or 25th—harmonics as high as 400 have been detected.

It will be noticed from the foregoing that the 4th through the 9th harmonic of 175 KC are all well within the broadcast band. Furthermore, these harmonics can be tuned in on a receiver just as signals from broadcast stations. *It is the fact that these harmonics can be compared to other frequencies of known value that allows such accurate calibration of the signal generator.*

You cannot depend on the receiver

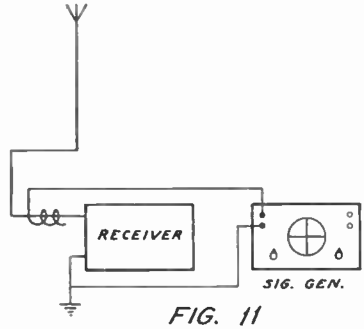


FIG. 11

dial any more than on the signal generator dial for great frequency precision so you should couple the signal generator to the antenna of a receiver tuned to a broadcast signal and adjust both circuits for *zero beat*. Figure 11 shows a typical coupling for this work. Station WLW may be tuned in almost anywhere in North America (at night) and its 700 KC carrier is an excellent means of comparing with the 4th harmonic of the signal generator set to 175 KC. Tune in the station and adjust the signal generator for zero beat. The adjustment will be attended by the familiar whistle or squeal each side of the right setting. You will find that the tuning of the receiver does not change this beat frequency but of course will tune out any heterodyne by reducing its intensity.

All broadcast stations are compelled by law to keep their carrier frequencies within a few cycles of their carrier frequency assignment. Most of them stay within 5 to 10 cycles of the correct value. Thus if the 4th harmonic is tuned to exactly 700 KC the fundamental frequency will be 175 KC exactly. If the carrier of WLW is high (up to the limit) which is very improbable or at 700,-050 cycles instead of 700,000 cycles, the 4th harmonic of the signal generator tuned to zero beat with it at 700,050 cycles and the fundamental will then be ¼ of this or 175,012.5 cycles or just 12.5 cycles off. This is a precision much greater than will ever be needed for receiver alignment. In fact, you may notice that the signal generator may shift several hundred cycles in a few minutes causing an audible beat which is not serious.

To check on this you should tune in the 5th harmonic (another station at 875 KC) with the receiver not changing the signal generator setting. Check it again by tuning in the other stations at 1050 KC, 1225 KC, 1400 KC and 1575 KC. If you find broadcast signals at those values divisible by 10 as 1050 KC and 1400 KC it will be a further check on the work.

The setting found by this method is preferred to that found from the charts if they differ. The chart or graph, is, however, very helpful as a start. If the signal generator is considerably off value you can make a new chart of exact values as will be explained.

For any intermediate frequency in present use, you will find harmonics in the broadcast band except those used for short wave converters or ultra-high frequency receivers.

On an accompanying page are listed a number of intermediate frequencies together with their harmonics which lie in the broadcast band for quick reference.

Obviously with this information it is possible to identify any fundamental frequency simply by checking for pick-up of its harmonics. In this work, however, there are a number of pitfalls which you must regard with the greatest care so that no errors will be made.

In the first place by observing these harmonics it will be noticed that relatively few of them are divisible by 10—in other words, few of them will fall exactly on broadcast frequencies so that accurate checks may be made. For a great many of them, such as 448, 456, 458, 459, etc. neither of the two harmonics which they produce lying in the broadcast band are evenly divisible by 10. However, you can usually find a signal sufficiently near one of them to produce a satisfactory audible beat note.

For example, for 456 KC there are

harmonics of 912 KC and 1368 KC in the broadcast band. Try to get a heterodyne at 910 KC and *reduce* the capacity of the tuning condenser until a high pitched note is formed. The correct pitch of the beat should be about equal to that of the 3rd C above middle C on any musical instrument. This is just a little over 2000 cycles and the beat note may be tuned to this pitch. Again at 1368 KC tune the receiver to 1370 KC and attempt to get a heterodyne with the signal generator. If the first was done correctly, the second will fall exactly right. If there is no station on 910 KC with sufficient intensity to form a heterodyne there may be one at 1370 KC.

At 1370 KC the signal generator tuning condenser must be *increased* from zero beat until the 2000 cycle note is heard.

Be sure to tune between 910 and 1370 carefully, making sure that no other sounds from the signal generator are heard. While the modulation may be just audible, there should be no heterodyne in this case.

It cannot be emphasized too much

IF HARMONICS WHICH LIE IN THE BROADCAST BAND

IF	2	3	4	5	6	7	8	9	10	11	12	13
45											540	585
105				525	630	735	840	945	1050	1155	1260	1365
110				550	660	770	880	990	1100	1210	1320	1430
115				575	690	805	920	1035	1150	1265	1380	1495
125				625	750	875	1000	1125	1250	1375	1500	
130				650	780	910	1040	1170	1300	1430		
132				660	792	924	1056	1188	1320	1452		
140			560	700	840	980	1120	1260	1400			
170			680	850	1020	1190	1360					
172.5			690	862	1035	1207	1380					
*175			700	875	1050	1225	1400					
177.5			710	887	1066	1242	1420					
178			712	890	1068	1246	1424					
180			720	900	1080	1260	1440					
181.5			725	907	1089	1270	1451					
182.5			730	912	1094	1278	1460					
235		705	940	1175	1410							
250		750	1000	1250	1500							
252.5		757	1050	1262								
260		780	1040	1300								
262.5		787	1050	1312								
264		792	1056	1320								
265		795	1060	1325								
345	690	1035	1380									
370	740	1110	1480									
445	890	1335										
448	896	1344										
450	900	1350										
*456	912	1368										
458	916	1374										
459	918	1377										
460	920	1380										
462.5	925	1387										
463	926	1389										
*465	930	1395										
467.5	935	1403										
472.5	945	1417										
480	960	1440										
485	970	1455										
490	980	1470										
517.5	1035											

* The three which are identified with an asterisk are by far the most widely used values.

This view shows another version of the all wave signal generator. It is the Simpson model 310 employing six bands on fundamental frequencies from 75 KC to 30 megacycles. The RF-AF output is controlled by the upper left switch and the band switch is just below it. The attenuator multiplier function is controlled by the upper right switch and the one below it controls the output in terms of microvolts.

that two points at least are highly desirable in this connection as the heterodyne at any one place on the dial does *not* disclose the *number* of the harmonic.

For example, suppose you were working with a signal generator for which you had no calibration graph or curve and you tuned the receiver used for calibration to a station at 1370 KC and then tuned the signal generator at random until you received a 2000 cycle heterodyne on the *high capacity* side of resonance or zero beat. Remember that a heterodyne will be formed either if the signal generator is 2 KC below the station (1368 KC) or at 2 KC above the station (1372 KC). To insure that the signal generator harmonic is at 1368 KC tune to the side of zero beat which lies on the high capacity side. Inspection of the position of the tuning condenser will determine this fact.

Now suppose you have located this 1368 KC harmonic by adjusting the receiver and signal generator, and then tune the receiver slowly to lower frequencies, hearing another heterodyne or modulated signal at 1026 KC or near this value. The difference between these two is 342 KC whose 4th harmonic is 1368 KC. Therefore, the fundamental is not 456 but 342. Likewise, if you find a signal at 1084 KC approximately there will be a difference of 1368 — 1084 or 284 KC which is approximately the fundamental frequency. Now 1368 divided by 284 is very nearly 5 which means that 1368 is the 5th harmonic. The accurate fundamental is, of course, 273.6 KC but the discussion is simplified with round numbers.

Thus the numerical difference between any two adjacent harmonics is equal to the fundamental frequency. Be sure that you have found the two adjacent harmonics, so that there is no possibility of missing an intermediate point. For example, suppose you tune in a harmonic at 1300 KC and leaving the signal generator set, tune the receiver rapidly down to 1040, where another harmonic will be heard. Thus on first notice you would conclude that the fundamental was 1300 — 1040 or 260 KC. You may have skipped a harmonic at 1170 in the work, which would mean that the fundamental was 1300 — 1170 or 130 KC instead of 260 KC. Inasmuch as you can use the 2nd harmonic of a signal generator practically as well as the fundamental for alignment purposes where low intensity is required, this oversight would not be serious.

Whereas 1300 KC is the 5th harmonic of 260 KC it is also the 10th harmonic or 130 KC, and you cannot tell the number of harmonic by its sound or intensity. Following are estimates for average intensity values for the various harmonics for some types of oscillators. These figures should not be used as exact values since they are included to give you a rough idea of the relative harmonic energy to expect.

FUNDAMENTAL	100%		
2nd harmonic	15.	to	20. %
3rd ”	4.	to	5. %
4th ”	3.	to	8. %
5th ”	1.	to	1.5 %
6th ”	.5	to	2. %
7th ”	.1	to	.15%
8th ”	.25	to	.5 %
9th ”	.02	to	.05%
10th ”	.05	to	.1 %

Note that the even numbered harmonics are usually stronger than the odd numbered harmonics in the usual type of oscillator. Harmonics having only 1/1000 of 1% of the fundamental are readily picked up by the average sensitive receiver provided the fundamental voltage is at least several volts.

Another important consideration is in connection with picking up *image harmonics* in the case of a superheterodyne receiver. To illustrate this point, consider a definite case with a superheterodyne having an IF of 175 KC.

Suppose you get a response from the signal generator at 1060 KC on the receiver dial. Divide this number (1060) by 2, 3, 4, 5, 6, etc. as follows:

1060/2	= 530	Fundamental
1060/3	= 353+	“
1060/4	= 265*	“
1060/5	= 212	“
1060/6	= 176+	“
1060/7	= 151+	“
1060/8	= 132+*	“
1060/9	= 117+	“
1060/10	= 106*	“

Thus comparing these fundamentals with the IF table there is a possibility of the fundamental being any of these marked with an asterisk. You may be tuning in the—

4th harmonic of 265 KC

6th harmonic of 175 KC (175 or 177.5 approx).

8th harmonic of 132 KC (130 KC exact).

10th harmonic of 106 KC (105 KC approx).

The signal generator may not be accurate enough to distinguish between 175 and 176 KC or between 105 and 106 KC. As 1060 is a fairly high value tune down the scale listening for another adjacent lower harmonic. Suppose you receive another heterodyne at 975 KC on the receiver dial. Subtracting this from 1060: 1060 − 975 = 85 KC which you can readily see is no IF from the table of standard IF frequencies.

It may not be possible to trace the reason for all such cases but for this one, the following situation has taken place. When the superheterodyne dial was set to 1060 the oscillator being 175 KC higher was operating at 1060+175 or 1235 KC. Now when the dial was tuned to 975 the oscillator was producing 975+175 or 1150 KC. This frequency is exactly 175 KC less than the 5th harmonic of 265 KC or 1325 KC, thus forming a beat of 175 KC which was picked up by the IF amplifier of the receiver. Unless the coupling to the antenna is very loose and unless the pretuner of the receiver has a good image rejector circuit this may happen.

However, tuning further down you will pick up the 3rd harmonic of 265 KC at 795 on the dial, etc. To make sure of the fundamental in this case it is a good plan to check at all of these harmonics which lie in the broadcast band which in this case are 795 KC, 1060 KC and 1325 KC. The image reception may occur of course with any harmonic of any IF value.

In some cases you may pick up a *multiple heterodyne* which is due to the modulation of the signal generator. In this case, cut off the modulation if possible, and if it cannot be cut off, select another point for your calibration.

If you want to make a calibration curve for a signal generator for which there is none available, here is a good method of doing it. Tune the signal generator dial to its center position using one of the IF bands of the band switch and tune in the signal with the receiver, noting its frequency on the receiver dial. If it is possible to also receive a station this should be done, while if not, at least you have a rough value. Assume it is tuned in at 1280 KC. Now tune the receiver to a lower dial setting to determine which harmonic is being received and the fundamental frequency of the signal generator. Although you can get the fundamental by making only this one adjustment there are many possible fundamental frequencies, one of which the signal generator could be producing. This is done by dividing 1280 by 2, 3, 4, 5, etc., as follows:

D1 H		F
1280/2	=	640 KC
1280/3	=	427 KC
1280/4	=	320 KC
1280/5	=	256 KC
1280/6	=	213 KC
1280/7	=	183 KC
1280/8	=	160 KC
1280/9	=	142 KC
1280/10	=	128 KC

D1		F		D2
1280	−	640	=	640 KC
1280	−	427	=	853 KC
1280	−	320	=	960 KC
1280	−	256	=	1024 KC
1280	−	213	=	1067 KC
1280	−	183	=	1097 KC
1280	−	160	=	1120 KC
1280	−	142	=	1138 KC
1280	−	128	=	1152 KC

The legend for the column is—
D1 original dial setting.
D2 second dial setting.

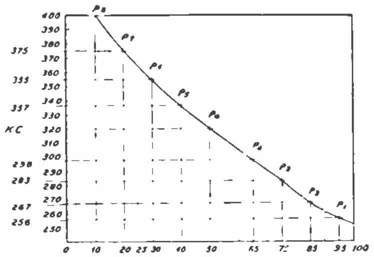


FIG. 12

H number of harmonic.

F frequency of the harmonic.

Thus as you tune down the receiver dial you will get a signal at one of the settings as given in column D2. Suppose a signal is again picked up at a setting (D2) of 960 KC. Immediately you will know that you have picked up the 4th harmonic of 320 KC. Now prepare a chart with cross-section paper as in Fig. 12, placing the number 320 at about the center of the left side and dial markings along the base. An 0-100 dial is indicated here but regardless of the markings this is the point at which the dial is set. Connect these points with a vertical and horizontal line as shown in Fig. 12 and you have one point Po as shown. The next thing to do is to mark off other points as shown on the vertical scale of any convenient units consisting of about 15 sections as done here in 10 KC steps. This will extend the range from 250 to 400 KC.

Next tune the signal generator toward the low frequency end of its dial (increasing capacity) slowly until the next signal is heard in the receiver. The receiver dial remains at 1280 and the next signal must be the 5th harmonic of 256 KC. When the dial is set. connect with a horizontal line, the point on the KC scale with the vertical line from the point on the signal generator dial, which it is assumed is 95, thus locating another point P1 on the graph. Now with the receiver dial set at 768 at first and with the signal generator producing 256 KC, tune the signal generator about 10 points down on the dial (increasing frequency) and then tune the signal in by tuning above 768 KC on the receiver. Note that 768 is the 3rd harmonic of 256 KC. At 85 on the signal generator dial you will pick up a signal at 800 KC or the 3rd harmonic of 267 KC. This will give you point P2 on the graph. Next set the signal generator dial to 75 and tune in another signal. If it is at 848 KC on the receiver dial and you are sure you have not skipped any signals, this divided by 3 gives approximately 283 KC for the next point P3 on the graph. Continue with this process at points 65, 40, 30. 20 and 10 on the signal generator dial, identifying the third harmonics of 298 KC, 337 KC, 355 KC, 375 KC and 400 KC.

The graph may be extended to the end of each band and the process may be repeated for each band until the calibration is complete.

If the signal generator is limited in number of bands the harmonics may be used for alignment. While this is not a generally favored practice it is often necessary when high frequency bands are not available. For example, if you have alignment work to do on the RF section of a receiver in the 6 to 14 MC band, having only available a signal generator adjustable to IF and broadcast band frequencies this may be done.

To get the greatest possible signal intensity, the *lowest* harmonic should be used, therefore, harmonics of frequencies lying in the broadcast band should be used in this case. The highest fundamental frequency in this broadcast band for which 6 MC is a

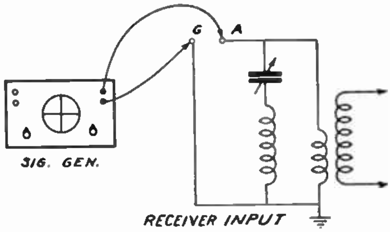


FIG. 13

harmonic is 1500 KC. Its 4th harmonic is obviously 6 MC. Therefore, with the signal generator tuned to 1.5 MC (1500 KC) the 6-14 MC band can be aligned at 6 MC. For 14 MC use the 10th harmonic of 1400 KC or the 9th harmonic of 1556 KC if the signal generator will tune as high as this.

The harmonics may be identified as described for the IF frequencies. Obviously when you are dealing with frequencies of the order of 30 to 40 MC, you must use higher order harmonics from the 20th to the 27th for alignment. The receiver may not be sufficiently sensitive at these frequencies to pick up the very low energy of these upper harmonics and this is why a signal generator having a full band range is very desirable.

Coupling of Signal Generators To Circuits

The coupling of the signal generator to various radio circuits is a very important factor in tuning alignment work. The results obtained are quite materially affected by methods of coupling. There are certain basic rules which must be observed.

Antenna Coupling: An antenna circuit may be a DC conductive circuit or a condenser may be in series with the antenna coil so that it will not conduct DC. However, normally there will be no DC voltage at the antenna post. Any terminal such as high, medium or low output of the signal generator may be connected to the antenna post as in Fig. 13. The adjustment which you intend to make will determine what amount of signal you will need at the antenna. For neutralization, a high output is required while for tuning alignment, especially when operating below the AVC threshold level a very low output is required. For rough or preliminary alignment work where the circuits are likely to be somewhat out of adjustment, a medium output is required. This may be the maximum setting of the low output if there is no medium output terminal on the signal generator.

The ground terminal is always connected to the chassis of the receiver under test. For a desired output the balance between the attenuator setting of the signal generator and the volume control of the receiver under test will be determined by the work to be done on the receiver.

The effective attenuator resistance in many signal generators is as low as 10 ohms. Obviously when this low resistance is shunted across the antenna coil, the coil will affect greatly the secondary to which it is connected. Due to this effect the coupling and hence the resonant point of the secondary may be seriously altered. In this case, it is best to use a resistance in series with the signal

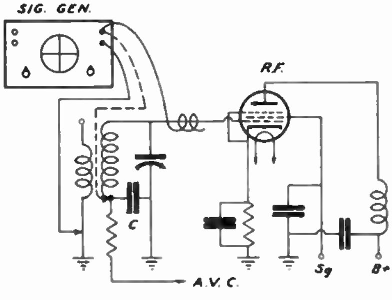


FIG. 14

generator lead. A 400 ohm carbon resistor is quite commonly used for all average purposes. This will be found of special value in alignment of bands above the broadcast.

For various tests and adjustments which must be made it is more often necessary to feed the signal into a particular circuit rather than at the antenna. Since the circuit must operate as normally as possible with the signal generator coupled to it, the coupling should be as small as possible, so that the low output resistance or other characteristics of the signal generator will have the minimum possible effect on the circuit under test. Moreover, the DC continuity of all circuits must remain intact where the circuit operation depends on them. For the benefit of operation of the receiver and for protection of its parts, no DC supply may be shorted while testing.

There are two ways of coupling a signal generator to the grid circuit of an RF amplifier as in Fig. 14. This connection may be necessary to skip any defect in a preceding RF stage, a band pass filter or antenna input or may simply be a means of individual alignment. A few turns of wire from the signal generator output (designates the high, medium or low ungrounded lead which conveys the signal) are wound around the control grid lead of the tube without removing the insulation from either. This, of course, cannot be done if the control grid lead is a metal shielded lead. The alternative as suggested by the dotted line in Fig. 14 may be used in such an event. This latter connection will induce an RF voltage across condenser C which is in series with the tuned circuit and usually there will be sufficient signal to be picked up. Note carefully that this connection will automatically *prevent AVC action* in the stage as the low attenuator resistance of the signal generator will shunt the grid return directly to ground. A large coupling capacity of .1 mfd may be placed in series with this dotted line lead to avoid this trouble. If the cathode of the tube does not have a self-bias resistor and depends on the threshold bias supplied by the AVC circuit as its minimum bias, this will be shorted out with the conductive connection and therefore must be avoided.

Now if the grid circuit is not being adjusted and is unimportant in this connection, it may be disconnected by removing the control grid lead and attaching the signal generator signal lead direct to the control grid. Care must be taken that the grid circuit is not left open as this will make the

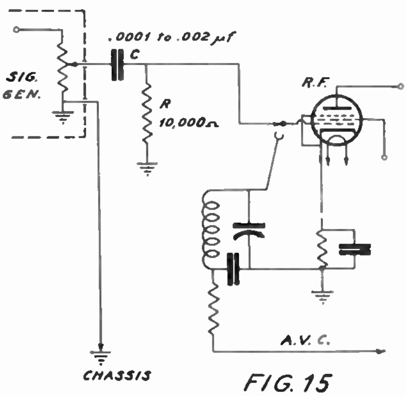


FIG. 15

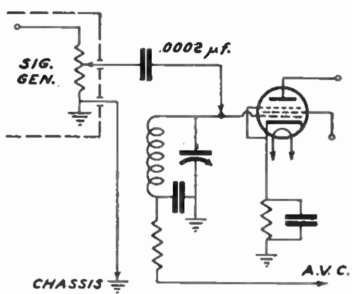


FIG. 16

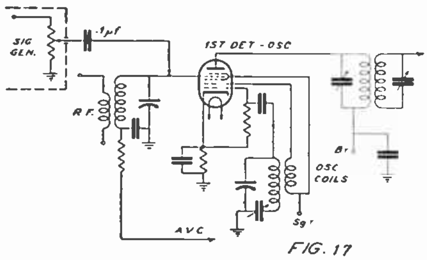


FIG. 17

tube useless as an amplifier or converter.

Two alternative connections for coupling to the input of an RF stage are shown in Figs. 15 and 16. In Fig. 15 an auxiliary circuit (dummy antenna) is used. Resistor R (10,000 ohms) closes the grid circuit while capacity C couples the signal into the grid of the tube. The tuned grid circuit for this stage is entirely out of operation. In Fig. 16 the coupling is made directly to the grid through a 200 mmfd. condenser. This is possible because the grid circuit is tuned to the same frequency as the signal generator and hence very little capacity is needed for a large signal.

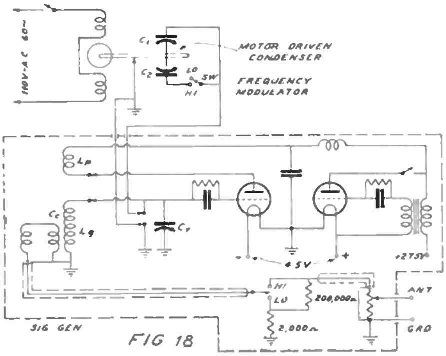
First Detector and IF Couplings: Next comes the problem of coupling into the input of the IF amplifier. It is always desirable to influence the tuned circuit to be adjusted as little as possible because otherwise the adjustment may not be effective when the signal generator is removed from the circuit.

As in Fig. 17, the IF amplifier invariably starts with the plate circuit of the first detector. Now on first thought, it might seem that the best way to form the coupling to this IF plate tuned circuit would be to remove the tube and attach the signal generator lead direct to the plate terminal of the tube socket. It is obvious that a high voltage is applied to this terminal and hence a series capacity would be needed for the coupling. The coupling capacity and low resistance of the signal generator attenuator would shunt the tuned circuit and thus alter its tuning characteristics. This coupling system is therefore undesirable. Coupling into the signal control grid is greatly to be preferred.

Without removing the control grid lead from the tube the signal generator lead may be attached directly to the control grid terminal through a .1 mfd. condenser (see Fig. 17). While this is a large condenser value, the energy must be relatively great to prevent its being completely shorted by the RF coil which has a very low reactance at IF. Enough signal current is forced through this RF coil to cause an appreciable voltage drop from grid to cathode. There is a further advantage in this method in that the RF circuit remains intact with AVC action, etc., so that the circuit is adjusted under practically normal operating conditions.

Coupling into any IF circuit may be done by attaching the signal generator lead through a .002 to .0002 mfd. condenser to the grid or plate terminal of any stage, the smaller the coupling capacity the better will be the results of adjustment. The oscillator part of the first detector may be made inoperative by shorting the oscillator tuning condenser if this is necessary in IF alignment to prevent confusion of frequencies.

Audio Coupling: In audio frequency amplifiers testing or adjustment, the audio signal of a signal generator is coupled into the second detector diodes, volume control or first AF control grid. The same precautions must be observed here to avoid changing bias values and shorting plate supply voltages.



The Frequency Modulated Signal Generator

With the introduction of visual methods (cathode ray oscilloscope) of circuit analysis and adjustment, a method was needed to shift the frequency of the signal generator rapidly through a definite range of frequencies so that the corresponding characteristics of the amplifier could be noted in rapid succession simultaneously for any part of the range of frequencies.

When an IF amplifier for example, is peaked at 465 KC, this does not indicate what its relative response at 462 or 469 KC will be. Or, with wide band, flat top tuning characteristics (high fidelity) it will be difficult, if not impossible, to find a single peak or resonant point without this visual means of inspection.

The details of the cathode ray oscilloscope which provides the visual means of observation of amplifier characteristics will not be given here, as this will be taken up later—but the signal generator used with it and auxiliary sweep circuits will be discussed here.

The first method of automatically shifting the frequency of a signal generator was accomplished mechanically. This consisted of varying the capacity of the tuned circuit of the signal generator by shunting it with a *small motor driven condenser*. Its complete connections to the signal generator circuit are shown in Fig. 18. The motor driven condenser has two stators and a single rotor. The rotor is turned in and out of mesh with the stators from 20 to 30 times per second. With the rotor half way in mesh the signal generator condenser C1 in Fig. 18 is adjusted to the desired IF peak frequency (465 KC for example) with, of course, the correct band used for the right coils. The coils for only one band are shown here. Besides the adjustable feature of the motor driven condenser of the frequency modulator the two stators may be connected with the switch SW in the HI position, providing two frequency modulation ranges. The capacity of each of the condensers is only about 8% of the maximum capacity of the signal generator tuning condenser so that at any band for maximum capacity (minimum frequency) the frequency is about 4% with one condenser (C1) and about 8% with two of them (C1 and C2). At higher signal generator dial settings for any band, when the main tuning condenser is smaller in comparison to the frequency modulator generator, the frequency shift is greater, attaining a maximum at the high frequency end of the dial of 32% for both condenser (C1 and C2) and 16% for C1 alone.

If 465 KC on the signal generator is at about the middle of the dial, the frequency modulation will be about 10% total which means that the generated signal will rise in frequency 5% and fall 5% total as it swings from one extreme to the other 20 or 30 times per second. Thus 5% of 465 = 23.25 KC., 465 + 23.25 = 488.25 KC and 465 — 23.25

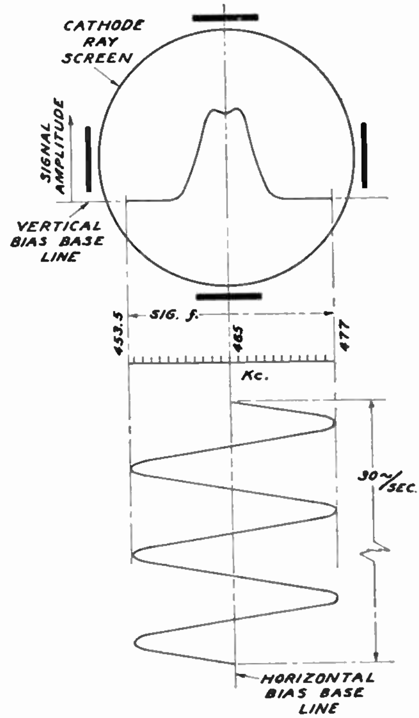


FIG. 19

= 441.75 KC. Thus the frequency is made to cover the band from 441.75 KC to 488.25 KC 30 times per second with both condensers C1 and C2 in use, and about half this band, approximately 453 to 478 KC, with condenser C1 being used.

Now in order to complete the system for visual alignment with the oscilloscope, these various frequencies must be separated horizontally (further explained in lessons on the oscilloscope) so that the amplifying power of the amplifier may be observed at any part of this band relative to any other part. If you were to use an ordinary output meter to indicate the condition of tuning you would know nothing as to the ability of the amplifier at frequencies other than at the IF peak. Moreover, if it were not possible to spread out the band horizontally, the cathode ray indicator would simply be a vertical line and would be actually inferior to the output meter measurement.

While the signal generator frequency is being varied, the voltage on the cathode ray tube horizontal plates must be varied in such a way that each frequency of the signal generator has a different horizontal location on the cathode ray screen.

This is shown in Fig. 19. The signal amplitude is in all cases applied to the vertical plates of the oscilloscope and the final curve is simply a graph of the amplitude frequency characteristics of the amplifiers repeated 30 times per second in each direction—that is, forward and in reverse.

The horizontal sweep voltage is generated by a simple two pole induction generator with its rotor fixed to the end of the motor shaft of the frequency modulator. It generates an approximate sine wave voltage in exact synchronism with the capacity changes as the condenser and generator rotors are on the same shaft. Its circuit with complete connections for testing an IF amplifier are shown in Fig. 20.

The frequency modulator varies the usual frequency of the signal generator while it is supplying the IF amplifier, and simultaneously supplies a horizontal sweep voltage to the oscilloscope horizontal plates. The IF amplifier output is coupled to the vertical plates of the oscilloscope. The band pass characteristics of the amplifier are thus visually indicated on the screen of the cathode ray tube.

This equipment (Figs. 18 and 20) has been superceded by the electronic frequency and sweep control doing away with all moving parts and combining the frequency modulator inte-

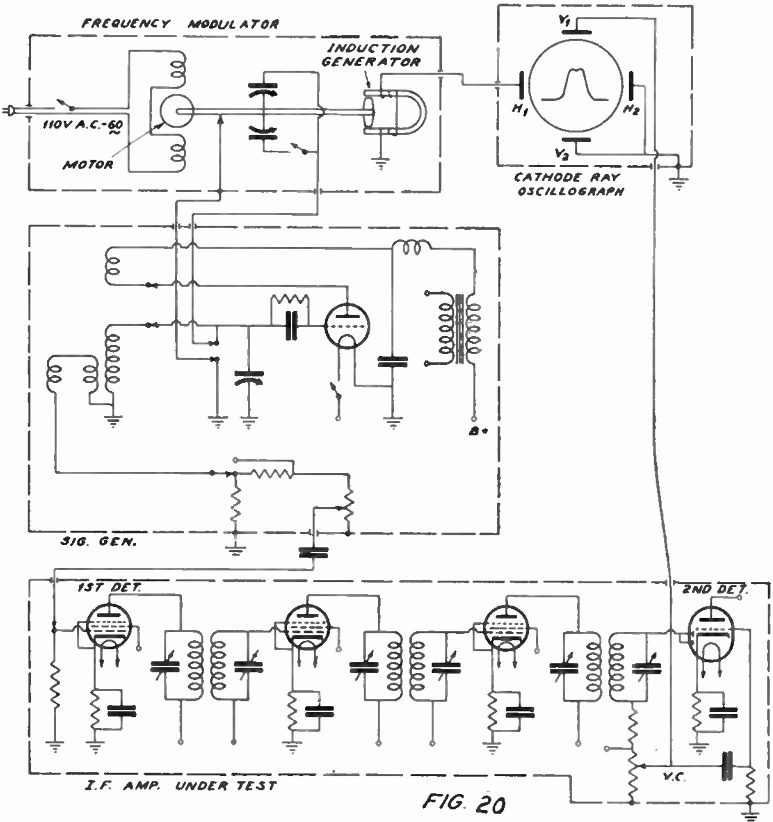


FIG. 20

grally with the signal generator. The circuit of this very versatile signal generator is given in Fig. 21.

First consider the RF oscillator section at the right of the diagram. This is a conventional 6A7 oscillator circuit, showing only one set of coils. Six bands are available as indicated by the 6 switch points for the control and anode grids. It is a series fed grid-plate coil oscillator and its output is available directly from the plate to a ladder type attenuator through C10.

Another high frequency is fed into the signal (TC) grid of the 6A7 which is generated by the pentode section of the 6F7 tube. This is a constant 800 KC signal brought into the control grid of the 6A7 tube by means of coupling coil C and condenser C25, which are fixed-tuned to 800 KC. The beat frequency formed by two high frequencies is used for the output. The output is the difference between this fixed frequency and the variable frequency up to 7MC and above this value the *sum frequency* is used. The coils of the variable frequency oscillator of the 6A7 are designed so that a total band of from 90 KC to 32 MC is available. For higher frequencies upper harmonics of these must be used.

Now looking at the 6F7 circuit in Fig. 21 note there are three possible connections of the triode plate, two of which are alike. On contact 1 of SW1 the plate is connected through (R7) directly to the Sg lead which

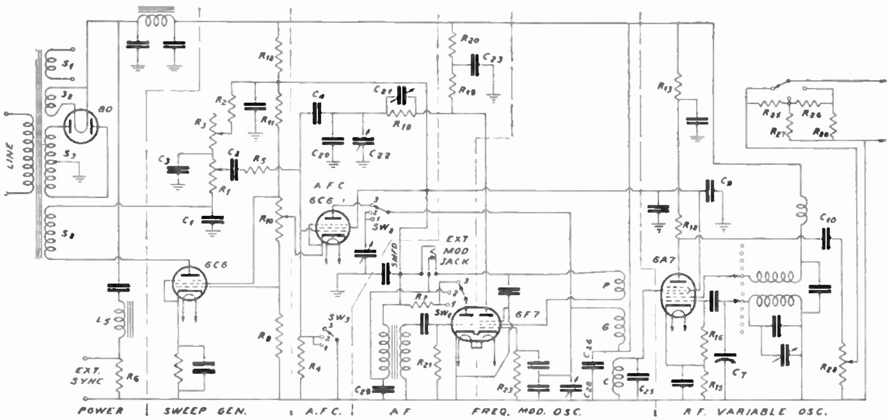


FIG. 21

is at a constant potential being by-passed by a .5 mfd. condenser. The same connection is made for terminal 3, both of which do not permit audio modulation of the 800 KC frequency. At contact 2 of SW1, however, the triode plate is connected to the audio transformer and the fixed 800 KC oscillator anode supply is in shunt with this, producing modulation of the 800 KC signal. This appears in the beat wave just as modulation appears in the IF of a superheterodyne when receiving a signal. Provisions are made for plugging in any type of external modulation such as a phonograph pick-up, microphone, etc. at the jack. It is obvious that this connects the external modulating voltage in series with the fixed oscillator anode coil. The anode coil is mentioned instead of the plate coil because in this case the screen grid of the 6F7 pentode section is used as the oscillator anode.

The plate of this pentode section is used with a resistance load (R19) to excite the control grid of a frequency control tube (AFC) similar to conventional AFC systems. C21 and C22 make possible the control of the phase shift of this signal component for a fixed action of the AFC tube. Through contact 3 of SW2 the AFC plate is supplied through the fixed oscillator grid coil G, tuned by C28 and C26 and the former being adjustable.

The plate circuit of the AFC tube thus is made to shunt the grid coil and in effect act as an inductance by virtue of the control over the phase of its AC plate voltage.

The bias on the AFC grid determines the amount of this effect after the other factors have been set and this bias in turn may be adjusted by R10. The AFC control grid is shorted to ground at positions 1 and 2 of SW3 while at position 3 of this

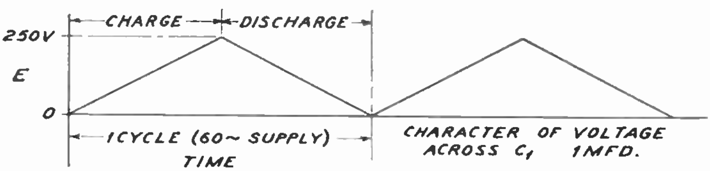


FIG. 22

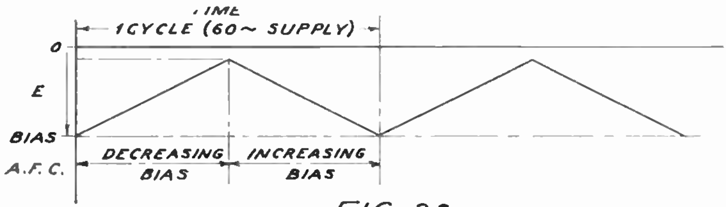


FIG. 23

switch, the grid is left connected to its 1 meg. load R4, which simply completes its normal grid circuit.

The sweep generator 6C6 tube in conjunction with its DC through R12 and 60 cycle supply S4. and resistance network R1, R2 and R3 produces a voltage of *pyramid wave form* at the slider on R1. The secondary S4 of the power transformer being in series with the DC supply to the 6C6 tube sweep generator modulates it practically 80%, making the plate voltage vary between a low voltage (80 or 90 volts) to almost twice its DC value in which operation range the 6C6 carries a *substantially constant current* and hence the voltage across C1 (1 mfd.) has a pyramid form as in Fig. 22. Naturally if the *charging and discharging current* of a condenser *is constant,* its voltage will rise and fall at a *constant rate* with time as in Fig. 22. Induced through C2 and R5 to the grid of the 6C6 AFC tube this voltage will make the bias follow this wave shape as in Fig. 23.

The bias on this AFC tube determines the effect it will have on the frequency of the 800 KC oscillator and changes the frequency in accordance with this characteristic. That is, there will be equal changes of frequency for each equal instant of time. Graphically this can be represented as in Fig. 24.

By adjusting R1 of Fig. 21, this change may be varied from plus or minus 20 KC as in Fig. 24 to plus or minus .5 KC. This frequency shift, of course, shifts the ultimate frequency after the beat is formed by the *same amount for every band* because the 800 KC oscillator remains at 800 KC except for this frequency modulation.

Now the cathode ray oscilloscope picks up impulses every *half cycle* from the terminals marked EXT. SYNC. in Fig. 21 (left) and actuates the horizontal deflector mechanism within the oscilloscope. The signal generator output is fed into the RF or IF sections of the amplifier under analysis or adjustment and the beam is returned to the left end of the oscilloscope base line every half cycle so that in one sweep from left to right, the frequency fed to the amplifier under test rises from minimum to maximum through resonance and the next sweep from left to right, the frequency falls from maximum to

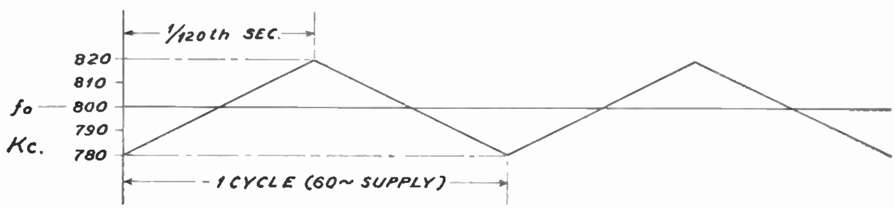


FIG. 24

minimum through resonance. The fidelity curve made in this way is actually two separate curves—one in the forward direction and one in the reverse direction. Seeing the two views of the curve in this way, it is much easier to adjust the amplifier for symmetry of the curves. Other lessons later on will explain all about oscilloscope work in much greater detail.

The Beat Frequency Audio Oscillator

So far simple fixed frequency audio oscillators have been discussed as used in conjunction with signal generators for modulation. Modern requirements for audio signals are much more extensive than this. For accurate work with audio amplifiers a signal of constant output voltage adjustable to any frequency in the audio range is highly desirable.

A signal of this kind is most easily obtained by beating or heterodyning two high frequencies, one of which may be varied so that their difference may fall between 30 cycles and 10,000 to 20,000 cycles.

These two high frequencies may be almost anywhere in the high frequency band except for the practical considerations involved. The higher they are the more unstable will be the beat in frequency, because each individual oscillator forming it is unstable. On the other hand, if the frequencies are too low, the range of the variable frequencies will be confined to the ratio of maximum to minimum capacity value.

Generally speaking, the fixed oscillator for a beat frequency oscillator (BFO) is fixed at between 70 KC to 100 KC while the variable frequency oscillator varies from near this value above or below it about 20 KC.

Assume that the fixed oscillator is tuned to 90 KC and that the variable one is arranged to tune from 90 KC up to 110 KC. Obviously, when properly coupled and rectified there will be a beat frequency ranging from zero to 20 KC.

A practical circuit of a BFO is shown in Fig. 25. It includes a fixed oscillator at left using a 76 tube in an inductive feedback circuit using separate plate and grid feedback coils. The variable oscillator to the right is the same except for the variable condenser for tuning from 90 KC to 110 KC. Each has a coupling coil, the two of which LC1 and LC2 are in series. The two frequencies are detected or mixed at the grid leak condenser type detector (heterodyne formed) and are amplified to some extent so that a good output signal will result.

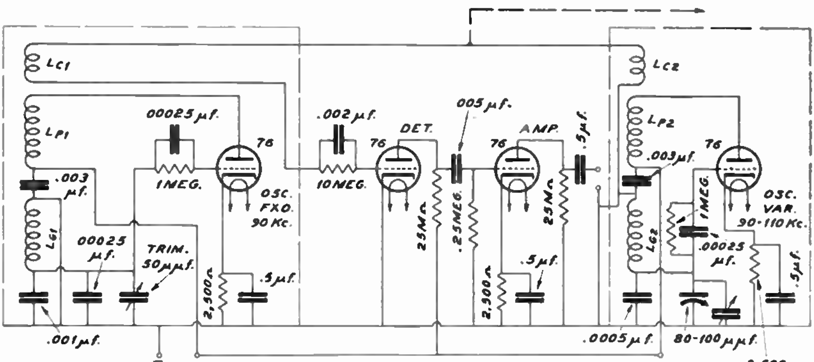


FIG. 25

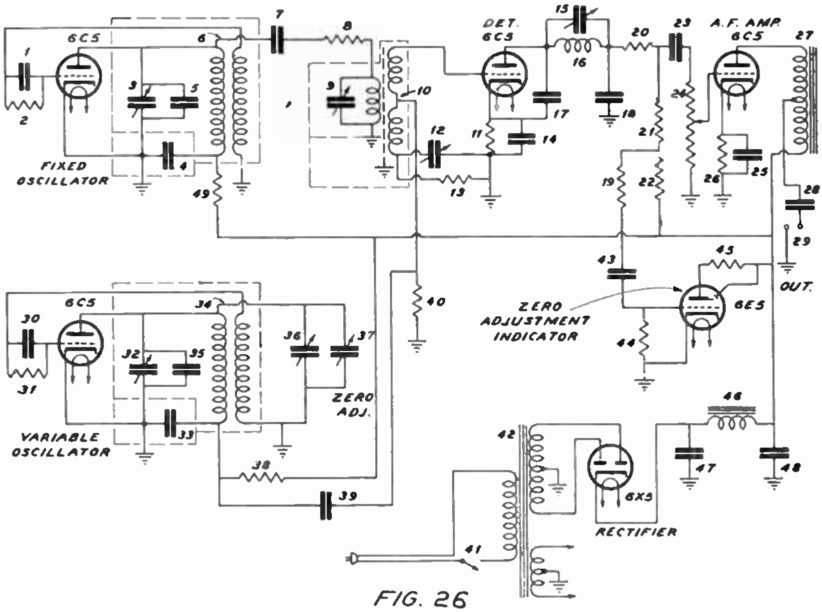


FIG. 26

The oscillators are separately shielded and the coupling of the coils to the oscillators is quite loose so that one oscillator will affect the other a minimum when they are nearly at the same frequency. One oscillator will tend to draw the other into synchronism if they are nearly at the same frequency and the nearer they are the greater the tendency will be with a given amount of coupling. If the coupling is increased the tendency of the two oscillators to fall into synchronism (zero beat) will be increased, so minimum coupling should always be employed.

For the production of as low as 30 cycles of AF the coupling must be quite small to each oscillator and this, of course, means that the output signal is quite low. Accordingly the grid leak condenser type detector is most practical for its detection. This detector output being insufficient for use, an additional amplifier is required.

Both high frequency oscillators may be calibrated by the harmonic method discussed in detail in the foregoing. Connections are made to the audio input or at any part of the audio signal circuit for testing the AF amplifier of a receiver, public address amplifier or transmitter audio amplifier.

Another type of BFO is shown in Fig. 26. Both oscillators are alike with the exception of a trimmer adjustment on one for zero beat setting. A very small RF component of the variable frequency oscillator is fed through condenser 39 into the untuned grid circuit of a plate type detector 6C5 together with energy induced into it from the fixed oscillator. Condenser 7 couples the fixed oscillator plate circuit to an auxiliary tuned circuit which in turn is coupled to the grid circuit of the detector. In this way there is a minimum effect of one oscillator on the frequency of the other.

The audio output of the detector is

capacity coupled to an audio amplifier from the output of which is available a good audio signal. Audio transformer action permits use of the signal at low impedance. The condenser output insures that no DC will be shorted for any connection desired in an audio amplifier.

This instrument is provided with an electric eye 6E5 tube which records the relative voltage of the beat. This is a very valuable item for a BFO as when checking an amplifier for its frequency amplitude characteristics the input voltage must be either constant throughout the entire range or at least known at all frequencies at which the beat is being made.

It must be understood that because of the action of the coupling and detector circuits, the detector output will vary somewhat with the beat frequency produced. The tube, filter and coupling capacities all have their effect on the intensity of the beat note. Therefore, an intensity indicator such as the 6E5 is very valuable. Note also that the instrument has its own power supply.

The Crystal Calibrator

It is very convenient to have at hand a standard signal by which signal generators, BFO's and receivers can be accurately set for frequency.

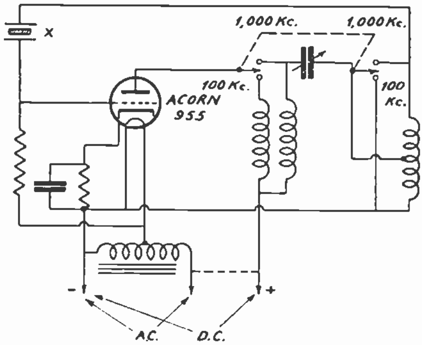


FIG. 27

The use of signals from broadcast stations are, of course, quite accurate but not available everywhere at convenient frequency values. The crystal calibrator is independent of outside reference signals as it is a standard.

A circuit of the crystal calibrator is given in Fig. 27. The crystal X is ground in such a way that its thickness vibration will be 1000 KC while its length vibration will be 100 KC. By the proper application of plate loads for the acorn tube used in this unit either frequency is available within .05%. The harmonics of the 100 KC signal may be used up to the 200th or to 20,000 KC while the harmonics of the 1000 KC can be conveniently used up to the 50th or 50,000 KC, all within plus or minus .05% accuracy. There are two plate coils and a tapped or grid coil going to the grid through the crystal. The trimmer is adjusted at the factory for the correct ratio of the two frequencies. Its adjustment can only affect the crystal frequency about .1%.

No provision is made for external coupling as there will generally be enough if the calibrator is within several feet of the device being calibrated. If additional coupling is needed. the end of a wire may be placed horizontally and lengthwise on top of the calibrator and connected to the antenna of a receiver.

It may be AC or DC supplied although if batteries or a DC line is used, it will be noticed that an AC 110 volt line must still be used for the autotransformer filament supply. When DC is used the link indicated by the dotted line is removed thus opening the circuit. For AC the RF signal will, of course be 100% modulated at the line frequency while for DC operation the signal will be unmodulated except for perhaps a little

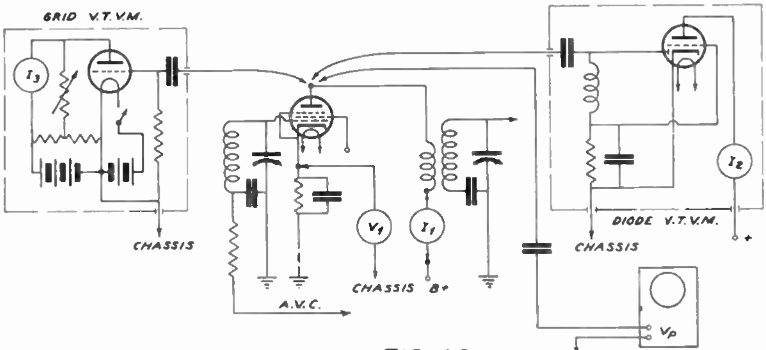


FIG. 28

induction from the filament. Output indicator connections must be connected according to whether the signal is modulated or not.

Output Indicators

The ear is too often used to indicate the relative output of a receiver or amplifier under test. The ear is unsuitable for such indication for two reasons. One, because its amplitude sensitivity is logarthmic and two, because its frequency sensitivity is very irregular. For accurate work the amplitude sensitivity of the output instrument must be linear and the frequency sensitivity should be as nearly uniform as possible in the audio spectrum. Any sort of accurate voltage or current output indicator will therefore be superior to the ear in this work.

For test purposes the signal output is not necessarily the speaker output or the AF output of the speaker. It may be the output of any stage or unit in the receiver depending on what specific parts or section are under test. For example, in testing one RF amplifier stage the output may be the plate circuit of that amplifier or any following stage or signal circuit if the following circuit is known to be in proper condition and its characteristics are known insofar as they may affect the test. You should simply use as much of the receiver as may be necessary or convenient. A good example of this is in the IF amplifier circuit. If it is more convenient you may use the second detector output or any AF input or output circuit or output indicator connections may be made to the speaker input. You must know, however, that the AF section of the receiver is in good condition and has characteristics which will give a faithful indication of conditions at the IF output. On the other hand, if it becomes necessary to align one IF stage at a time the input is the grid circuit of that stage and the output must be at the plate

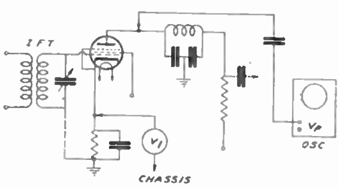


FIG 29

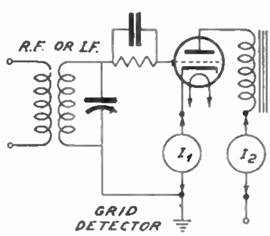


FIG. 30

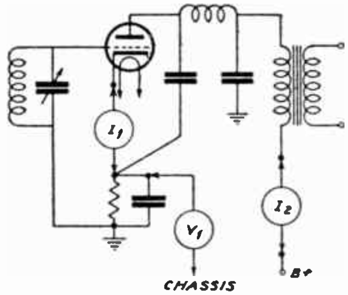


PLATE DETECTOR

FIG. 31

circuit of that stage. Where there is a choice of a number of output connections, the one which is most convenient in view of the apparatus at hand should be used.

Starting with the output of an RF amplifier for individual stage testing, as shown in Fig. 28, there are several methods of output indication. If the tube is properly AVC controlled and the AVC action is to be included in the given tests of the stage, a DC voltmeter 0-5 volts may be connected as V1, or a DC 0-15 ma. meter may be connected at I_1. If the tube is not AVC controlled, a vacuum tube voltmeter such as a diode or grid type may be used for an indication of the RF output of the stage. The sensitivity of the VTVM may in each case be made appropriate to the gain desired or expected of the stage.

The same information holds for triode and tetrode amplifiers and for

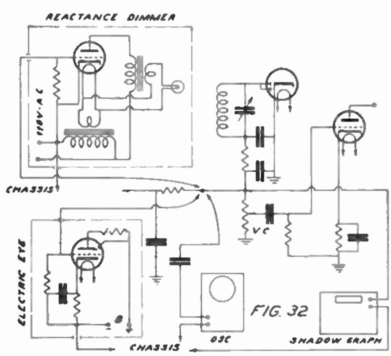


FIG. 32

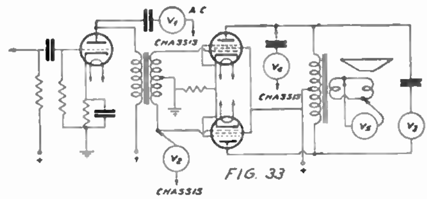


FIG. 33

IF and first detector stages. The same connection may be used for second detectors although the VTVM circuits are unnecessary here as the detector performs these functions.

For AVC controlled tubes the voltage at V1 will *reduce* with increased signal as also will the plate current at I_1. If there is no AVC control, or if the operation is performed below the AVC threshold level, there will be no change in reading of V1 or I_1. The VTVM method must be used here. An oscilloscope vertical plate connection may be made to the plate for visual recurrent indication.

For the plate type detector using the tetrode or pentode the cathode DC voltmeter as in Fig. 29 may be used or the oscilloscope. As the signal increases the cathode voltage drop V1 is increased. For the plate and grid triode detector the series DC ma. meter may be used either in the plate or cathode circuits as shown in Figs. 30 and 31. For the grid type detector the meter reading will decrease with increased signal while just the reverse will be true with the plate type. In addition a cathode voltmeter V1 in Fig. 31 may be used in the plate type which will increase reading with an increase in signal.

Figure 32 shows the proper output indicator connection for a diode type second detector for use with a reactance dimmer, a shadowgraph, an electric eye or an oscilloscope. One of the first three units may be part of the actual circuit in which case an additional indicating unit would not be needed.

Various output indicator connections for an audio amplifier using an AC meter only are shown in Fig. 33. The meter used should always have a condenser in series with it of low AF reactance (.5 mfd.) and should have high sensitivity except for the voice coil connection V5 in which sensitivity is unimportant. At all connections in Fig. 33 the AC meter reading will increase with an increase of signal strength.

The meter ranges should be chosen according to the voltage amplitude of the signal at the point measured. The following would be the approximate AC meter ranges for Fig. 33. V1—0-15 volts, V2—0-10 volts, V3—0-100-150 volts, V4—0-50-100 volts, and V5—0-10-15 volts.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

Questions

No. 1 Name the four types of high frequency oscillators mentioned in this lesson.

No. 2 What is the 5th harmonic of a 465 KC signal?

No. 3 Why does it become necessary to recheck the calibration of a signal generator?

No. 4 Why is it necessary to use a special attenuator on a signal generator?

No. 5 Why must the signal generator be weakly coupled to the local oscillator?

No. 6 Does the signal generator of Fig. 14 allow the AVC to act on this stage as usual or prevent it from acting?

No. 7 What two methods of frequency modulating an oscillator are mentioned in this lesson?

No. 8 Why must the coupling between the two oscillators of a beat frequency oscillator be as small as possible?

No. 9 Why is the human ear a poor judge of output volume levels?

No. 10 What must be used in series with an AC meter when it is used as an output meter?

RADIO FREQUENCY TUNING ADJUSTMENTS

LESSON TV-7

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

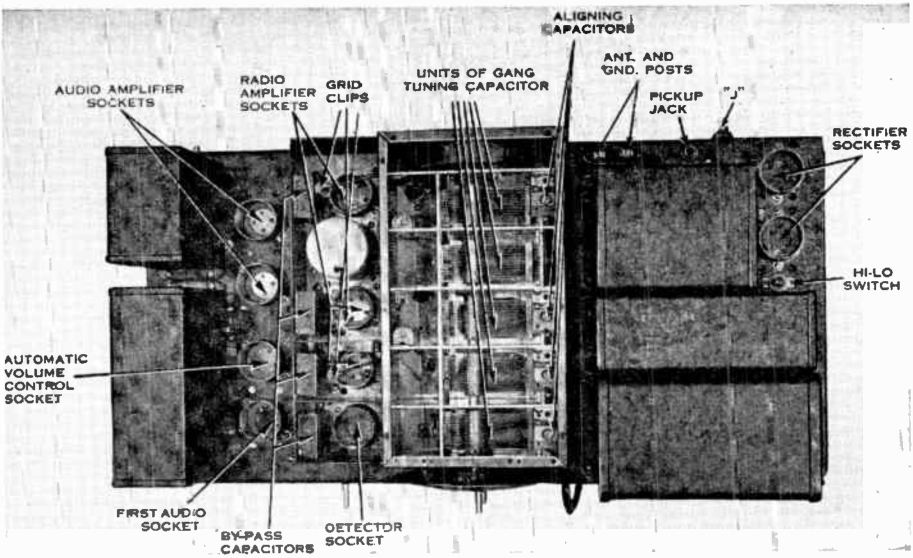
MODERN APPLICATIONS OF SOME OLD TUNING METHODS

This lesson deals with tuning adjustments in RF stages of many types of receivers. Basically, it gives you tuning adjustment directions for two older type receivers. However, many adaptations of these older tuning methods are coming back into use again, particularly in front end tuning units for television receivers. Several years ago (before the superheterodyne type receiver came into wide use) the two most popular types of receivers were the Neutrodyne and the Tuned Radio Frequency (TRF). These gradually became less popular as the advantages of the superheterodyne became better known. Even so the superheterodyne retained the feature of at least one tuned RF stage and many receivers of recent years have made use of a triode tube wherein neutralization of the stage was required. Also the modern FM receiver makes use of at least one tuned RF stage. So a factor common to all types of receivers is that one or more RF or tuned stages must at various times be adjusted in order to assure maximum performance. This is a type of job you will be called upon to do time and time again. So you should give this lesson your careful attention as it deals with a very practical tuning problem which you need to thoroughly understand. Be sure to keep in mind that where we describe an RF tuning adjustment (meaning a tuned stage using either a triode or a modern high gain tube) that the instructions apply to not only TRF and neutrodyne receivers but also to the modern AM superheterodyne, the FM receiver and also front end tuning units of television receivers. The only basic difference in the adjustment of any of these circuits is the frequency involved. The usual method of adjustment regardless of the type of receiver is to connect the signal generator to the input of the stage or stages to be adjusted, connect a suitable output meter to a detector or audio stage and then adjust the trimmer or trimmers for maximum reading on the output meter. This assumes, of course, that you will set your signal generator to the correct frequency according to the type of receiver involved. More detailed information relating to frequencies will be given in other lessons to follow.

SPRAYBERRY ACADEMY OF RADIO

CHICAGO, ILLINOIS

K 9552M



The above photo shows the layout of a TRF receiver which was in wide use at one time. Note the use of a five gang tuning condenser and the accompanying trimmer condensers which in this case are labelled aligning capacitors.

RADIO FREQUENCY TUNING ADJUSTMENTS

Lesson TV-7

The average owner of a radio receiver knows how to properly twist two or three knobs mounted conveniently on the front panel of the receiver so that he can receive a program to which he desires to listen or observe. Push button tuning is equally easy for him.

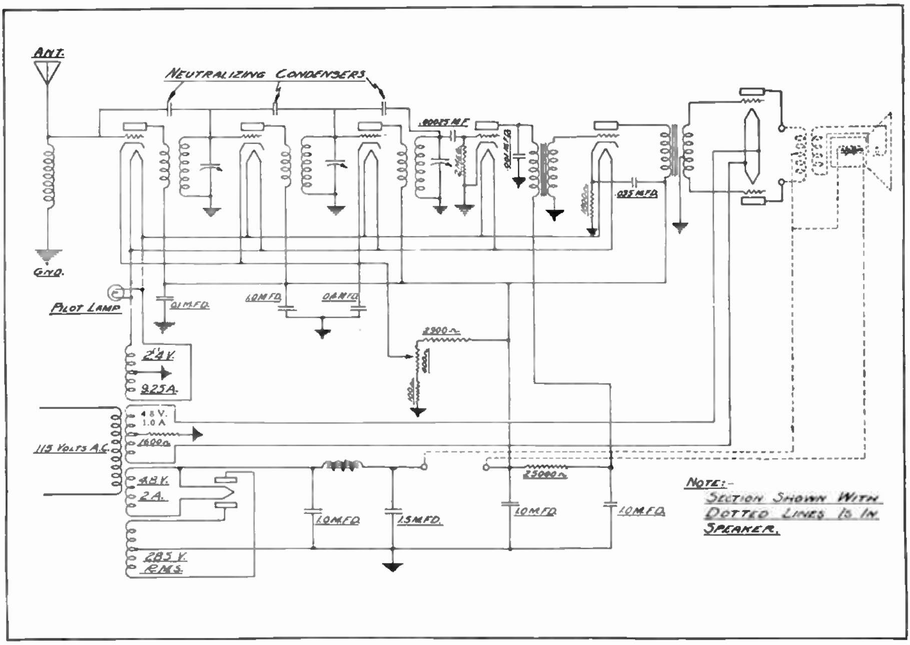
He turns on the power switch. Then he turns another knob (tuning control) carefully, until music, speech or a picture comes in clearly from the station he desires. This second adjustment of selecting the station must be made carefully, especially for FM or television receivers, or the sound will be distorted—even the average receiver owner knows that this adjustment is critical in most receivers, and as a result, he will turn the tuning control ever so carefully until the sounds are natural and clear. In some receivers, this adjustment is made more accurately by watching the action of the *Electric Eye* tube or by watching the deflection of a special *tuning meter* while turning the tuning control or by watching the picture of a television receiver.

From your studies you know that the owner of the receiver must make this adjustment carefully so he will tune *right on top of the carrier*. Where a tuning meter or other indicator is not a part of the receiver, you may have to demonstrate that this procedure of *tuning* is to be made most carefully to get the clearest response from the receiver. It is surprising how the public will complain of distortion which requires no servicing, but only a few words of explanation regarding the proper setting of the tuning control. Yet it is true that many owners of receivers—and servicemen too—do not realize that tuning must be done carefully. It will be up to you to keep this always in mind and also to give the proper tuning explanation to your customers.

Individual TRF (Tune Radio Frequency) and Neutrodyne receivers differ in the number of tuned circuits employed. Some of the old receivers have as many as five separate tuned circuits affected by a single tuning knob, and it is necessary that the right adjustment be obtained in each of the circuits. If any one of the individual adjustments has slipped (or is off), then the signal will be distorted, weak or probably more than one station will be heard, or no signal will result, depending on how much the receiver is out of resonance.

Where a complaint is received regarding any of these faults, you will find that it is necessary to adjust the *individual controls* of each tuned circuit to get signals with minimum distortion and minimum interference. All of this, of course, assumes there is nothing else wrong with the receiver.

The *individual controls* of each tuned circuit are, in the majority of receivers, nothing more than small adjustable condensers electrically connected in parallel with the main tuning condensers. Their actual physical arrangement, mechanical mounting and actual connections, however, differ widely. The most common name for this type of condenser is *trimmer condenser*.



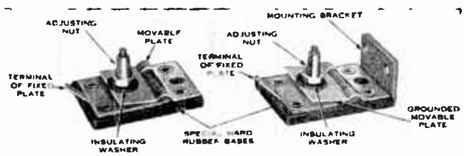
This diagram shows a typical early type TRF receiver employing neutralizing condensers which also places this receiver in the neutrodyne class. This lesson describes how adjustments should be made for both the trimmer and neutralizing condensers. The trimmer condensers for adjustment of the tuned circuits are connected across the main tuning condensers although the trimmers are not shown in this diagram as is the case in many diagrams.

An adjustable condenser of this type is usually in the form of two or more spring type metal plates, each plate separated from the other by means of mica sheets (slightly larger than the metal plates). The capacity of these small adjustable condensers is varied by pressure. A threaded screw usually extrudes through both the metal plates and the insulation. A *hex* nut may be fitted to the screw and it may be turned up or down on this screw. In other cases, no nut is provided. The screw simply has a regular screwdriver head and is adjustable in this way.

At any rate, turning the screw or nut to the right causes the small plates to spring together (compresses them) and the capacity is increased—the circuit tunes to a lower frequency. Turning the nut or screw to the left, causes the plates to spring apart and the capacity is decreased—causing the circuit to tune to a higher frequency.

Usually these small condensers are mounted on the frame of the main tuning condenser to which they are connected. Another common practice is to mechanically fasten one terminal of the trimmer condenser to the stator of the main tuning condenser—this eliminates one wire connection. Still another method of mounting is to mechanically fasten by riveting the trimmer condenser between the rotor and stator terminals of the main tuning condenser. This eliminates two wire connections. In other receivers, the trimmer condensers may not be mounted on the condenser frame at all—some manufacturers have mounted them on the receiver chassis or on coil forms, etc.

Whatever the method of mounting or connection to the tuned circuits, the function of these small adjustable condensers is *to provide an individual adjustment for each tuned circuit.*



The above view shows typical trimmer condensers as will be found on the average TRF receiver. Note the adjusting nut which permits moving one plate of the condenser in a hinged fashion.

Making adjustments on the small condensers is known by any one of several names which include: *synchronizing, aligning, tracking, balancing, compensating, tuning, trimming, adjusting,* and *padding.* One radio manufacturer may use one name only, while another may use several names when referring to this procedure in his instructions. You will now know that all of these names refer to the same general procedure of making tuning adjustments.

The small adjustable condensers may be called *synchronizing condensers, aligning condensers, tracking condensers,* or *compensators, trimming condensers* or *trimmers, adjusting condensers* and *padding condensers* or *padder.* The word trimmer is most often used, and we shall use it to refer to a parallel connected adjustable condenser. A trimmer condenser then refers to *any type* of small adjustable condenser commonly connected in parallel with tuned circuits. A *series connected* adjustable condenser such as one connected in *series with an oscillator tuned circuit* is most often called a padder or padding condenser.

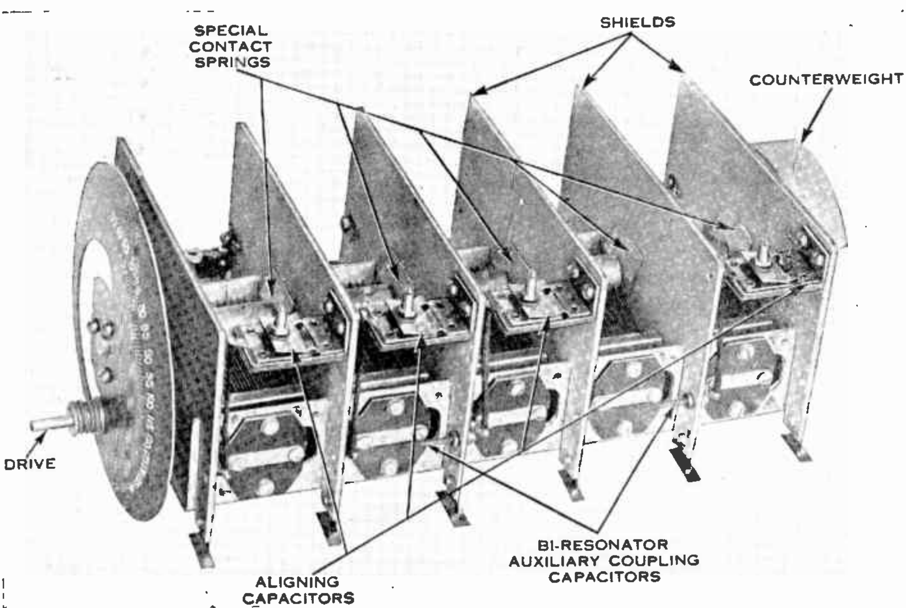
If it were possible to manufacture coils and condensers which would be exactly alike and if their inductance and capacity would not change by placing them near each other or near other devices, then there would be no need for trimmers. However, these will always be needed, because minor variations cannot be avoided in manufacture, neither can they be avoided because of changes which result in changes of capacity when new tubes are substituted or if some of the connecting wires have been disturbed in handling, etc.

Tools Needed for Adjustment of Tuned Circuits

Since receiver manufacturers in the past have not standardized on the manufacture of trimmer condensers, different types of adjusting tools are necessary for different types of receivers. Whatever their form, tuning tools should be made of some kind of insulating material such as bakelite or ameroid. If metal tools are used, body capacity effects will be introduced and it will be very hard to get a correct and critical adjustment.

Tuning adjustment tools are available from practically all local radio jobbers and from the radio mail order firms. They are usually in the form of a fountain pen style, having a clip so that they may be held in a vest or coat pocket. Since several types of tools are required for different types of receivers, such tools may be purchased in various screw driver forms as well as in a variety of wrench forms. Your local radio parts jobber will be glad to show you the different types of tuning tools that are available.

There are a great many tuned radio frequency receivers still in use and circuits requiring neutralization, while not as prevalent as in former years, still continue to make their appearance. For this reason, a careful study of RF and IF neutralizing adjustments is important. (In this connection TRF tuning adjustments are



Here is shown a typical tuning condenser gang assembly as used on many TRF receivers. The trimmer condensers are mounted near each main tuning condenser which it controls. Thus, short leads are possible which has a tendency to reduce oscillation. Note that each section of the gang is shielded from the others which was considered a necessity in the days when TRF receivers were more popular than today.

exactly like those for the RF or preselector stages of a superheterodyne receiver. A later lesson will treat superheterodyne tuning adjustments. However, in studying the TRF tuning instructions of this lesson it is well to keep in mind that the same adjustments apply equally as well to preselector stages of the superheterodyne type receiver).

Neutralizing condensers are exactly like trimmer condensers in appearance and in adjustment. They are not, as a rule. mounted on the condenser gang, but rather they are mounted on the chassis or on or near a coil form. So they need not cause any confusion (instructions will be given later on for making neutralizing adjustments).

There is another method of adjustment in addition to trimmer condensers used in the receivers of better design, which should be considered. It will be noted in many receivers that the *end plates* of each of the rotor plate sections of a gang condenser will be cut *radially into fan shaped segments*. There will usually be five or ten of these segments. These are adjustable and directions will be given later on for making these adjustments.

Now the alignment of tuned radio frequency receivers simply consists of *adjusting the individual capacities of the tuned circuits* in such a way that all of them will be resonant to the same frequency at the same time. While the coils and tuning condensers are manufactured as nearly alike as possible, there are a number of reasons why adjustments should be provided. The condenser plates may warp slightly. The bearings of the condenser shaft are subject to wear which will usually result in some change in capacity as time goes on. The condenser shaft may bend or expand, due to a temperature change or a plate may become bent in handling the receiver chassis. That is the reason why adjustments are provided for compensating for these small capacity changes.

Figure 1 shows a typical TRF receiver with neutralizing adjustments—a type of circuit in common use in past years. This TRF receiver uses a 5-gang tuning condenser with the rotors mounted in one piece (operated by one common shaft) and with five separate stator units. These main tuning condensers are identified as Cg in the diagram. Four of them are shunted by trimmers, identified as Ct in the circuit. The first main condenser of the group (to the left) is used with a variable inductance giving a special advantage for various antennas which will be used. Thus no trimmer is required for this stage. Each of the trimmers (Ct) changes the total capacity of the gang units and thus affects their tuning at *every* dial setting.

By referring to Fig. 2, you will see the exact nature of this capacity

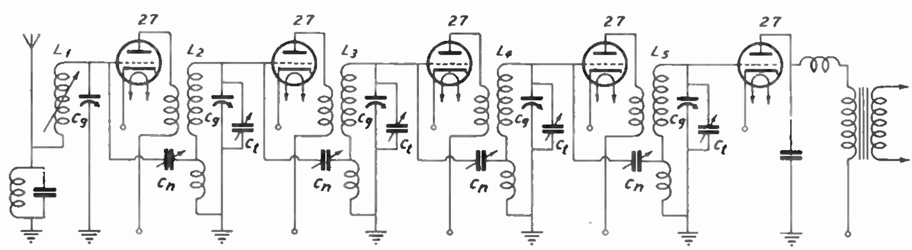


FIG. 1

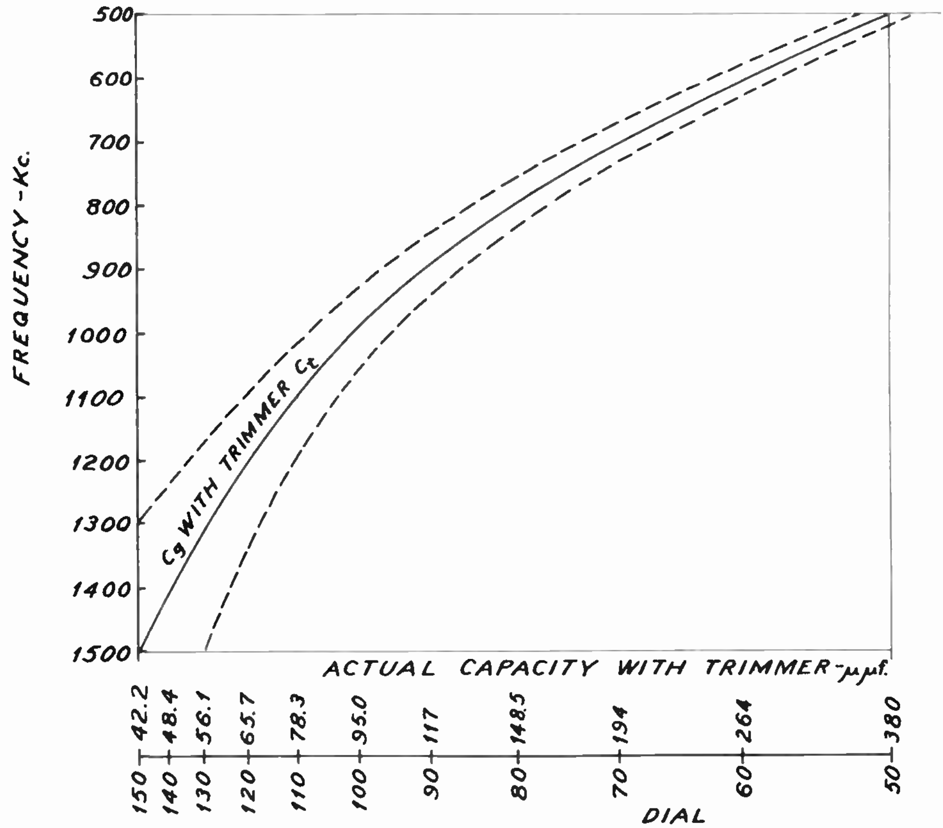


FIG. 2

variation. This graph shows the relation between the dial marking and the actual resonant frequency of the tuned circuits. This principle seems to be little known among radio servicemen. The actual dial markings and actual total capacity values are indicated. The solid line curve shows the correct capacity adjustment for one tuning condenser. That is, at 150 on the dial, the circuit tunes exactly to 1500 KC. At every other place on the dial, the KC markings correspond exactly with the actual carrier frequencies.

When the dial pointer is set to 150 to receive a 1500 KC signal, the total capacity is 42.2 mmfd. in this case and is made up of the minimum capacity of the tuning condenser and the *average value* of the trimmer. If the trimmer capacity is increased by about 14 mmfd. so that the total is 56.1 mmfd., you will see from this graph that when the dial is set to 130, the circuit will tune to 1500 KC. The lower dotted line shows this. However, without altering this trimmer setting, if you turn the dial pointer to 60, the circuit will tune to about 620 KC. In other words, at this end of the dial the setting of the dial is only altered 20 KC while at the high frequency end of the dial, it is altered 1500—1300 KC or 200 KC—*ten times as much.*

While the trimmer condenser changes *every dial setting*, it *has successively less effect on low frequencies.* It should be evident from this that the trimmer should be set *only at the high frequencies* where a small change in capacity makes a large change in dial setting, so that a critical and accurate adjustment may be made.

If you reduce the trimmer capacity by approximately 14 mmfd., an adjustment corresponding to the upper dotted line curve in Fig. 2 will be obtained in which a 130 dial setting will bring in a station at 1120 KC, and a 60 dial setting will bring in a station at 580 KC. With this understanding, the actual alignment process may now be studied. In making the tuning adjustment a signal source is essential. One simple method to provide a test signal for a TRF type receiver consists in tuning it to a powerful broadcast signal between 1100 and 1400 KC and simply adjusting the trimmer condensers for maximum volume or signal strength. First adjust (by turning the trimmer screw or nut to either the right or left) the trimmer connected in the detector grid circuit and continue to adjust the others toward the antenna stage (see Fig. 1). If the trimmers are so very far out of adjustment (alignment) that no signal can be picked up, tune the receiver to a station near 500 or 600 KC. Adjust all trimmers at this setting for maximum signal (as heard by the ear) and then tune to around 1100 to 1400 KC for the final critical adjustments. Do not go back to 600 KC and readjust, as the settings will then be incorrect at the high frequencies. It is best to set the volume control to the *lowest possible position* at which the signal is audible. In this way alignment is usually more accurate.

You will now see why it is objec-

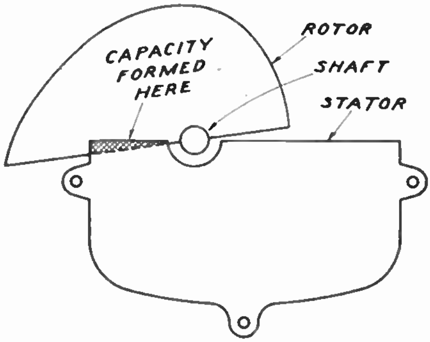


FIG. 3

tionable to align any receiver at 1450 or 1500 KC or higher if the dial is marked any higher. In Fig. 3 the end view of a tuning condenser is shown. When this is turned past its minimum capacity setting or to the end of the dial motion, *the long ends* of the rotor plates may usually mesh with the short ends of the stator plates, *causing the capacity to again rise.* This condition would appear graphically as shown in Fig. 4. In each of the three curves, a rise in capacity (or lowering in resonant frequency is shown at the left ends). Thus, if the adjustment is according to curve 2, when the dial index is set at 1280 KC (point P), a 1500 KC station may be received. Suppose you rotate the dial *off scale* at point Q and notice that the 1500 KC station comes in perfectly, which would be the case according to curve 2. It is desired to bring this down to the 150 mark on the dial by use of

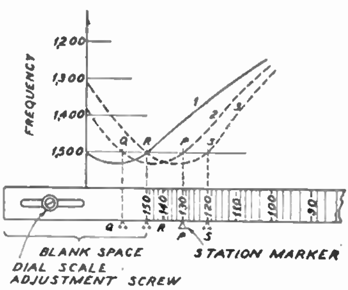


FIG. 4

the trimmers so you would set the dial at exactly 150 or point R, by turning it to the station marker at R, and then adjust the trimmers until you obtained maximum signal, 1500 KC, at this point. You may accidentally get an adjustment such as shown by curve 3. If this was true, you could hear no signals between points R and S, as the capacity here is all lower than the proper minimum and the receiver would be tuned entirely above 1500 KC. At point S (118 on the dial), you would again receive the 1500 KC station, because the capacity is now the same as it was at the 150 setting and all other broadcast band signals would tune in below the 118 mark on the dial.

The correct adjustment is shown by curve 1 in Fig. 4. By choosing an original alignment signal between 1100 and 1400 KC, you will usually avoid this trouble.

Now if the minimum settings of the trimmers at minimum capacity of the tuning condensers do not permit tuning to 1500 KC. make use of the means usually provided for shifting the dial scale backward as shown in Fig. 5. Here the main condensers are tuned to minimum capacity for 1500 KC. but the dial reads 130 whereas it, of course, should read 150. With the tuning condensers set correctly, the dial scale is shifted to the right by loosening the adjustment screw at each end of the scale and moving it along the slots at either end provided for the purpose until the 150 mark is exactly opposite the dial index instead of 130. The circle section type of dial scale may be rotated to the proper position in an equivalent manner. Other types of dials will have an equivalent adjustment.

Use of Signal Generator

Comparatively few radio service shops are located in such a way that signals from broadcasting stations will be available when wanted. An RF signal modulated with the usual entertainment is not entirely satisfactory for tuning alignment purposes, because of the apparent change in volume, due to changes in modulation depth at the transmitter. *A signal generator is, therefore, recommended for all proper alignment work.* With it a constant signal at any desired intensity for this purpose at a constant modulation is available.

Ordinarily the *low output lead* of the signal generator is attached to the antenna post or lead of the receiver

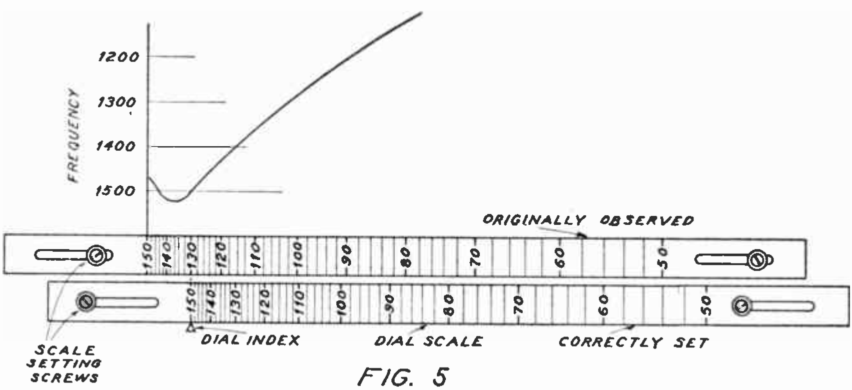


FIG. 5

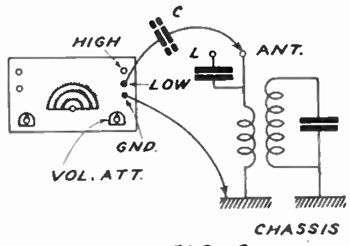


FIG. 6

while the ground lead is attached to the ground post or chassis.

The usual practice is illustrated in Fig. 6. There are several points about its connection which must be carefully noted. In some types of signal generators, the connection of a low resistance coil to the output will short the internal circuit in such a way as to make the signal generator stop oscillating. If this is the case, use a series condenser (about .0001 mfd.—the value here is not critical) as shown at C, Fig. 6. If, however, the receiver has a connection for a long antenna with a condenser already in series with the antenna coil, this may be used without the condenser C in series with the signal generator lead.

If the signal generator is of the modulated type, an audible signal will be produced by the speaker and the receiver can be aligned fairly well by adjusting each trimmer as described in the foregoing. The output meter is more accurate as the ear cannot be depended upon within a range of approximately plus or minus 12%. While this is very often all that may be necessary, it is none the less susceptible to inaccuracies.

Several means of connecting output meters to any receiver were explained in the preceeding lesson. However, it is briefly repeated again here, so that a method may be chosen from the test equipment which you may already have at hand.

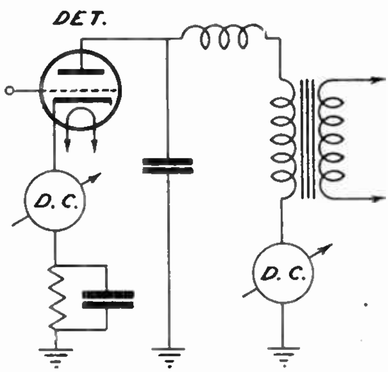


FIG. 7

For a power detector (high negative bias) a DC milliammeter 0-10 milliamperes reading may be placed in series with the B+ or cathode circuit of the tube. See Fig. 7. When the receiver is properly aligned, *it will read a maximum value.* This actual maximum value will vary with different receivers, volume control settings and the output adjustment of the signal generator. The actual value is, therefore, of no importance as long as a *maximum* reading is obtained.

The analyzer means of inserting either of these meters in the circuit will not be practical because the RF signal will be forced to feed through the cable. In this way, the signal intensity will be reduced considerably and the alignment will be affected by the capacity effects of the cable. It is best to make such connections to the chassis wiring without removing the detector tube from its socket.

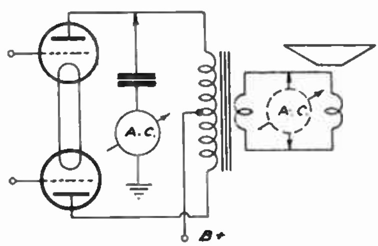


FIG. 8

For a grid leak condenser type of detector, the same information applies equally well, except that here you must adjust *for minimum reading* on the meter instead of maximum. A modulated signal may be used for this output connection at the detector, but modulation is not necessary as an unmodulated RF signal is perfectly satisfactory.

Simpler output connections may be made without detaching any wiring. These are shown in Fig. 8. An AC meter 0-150 to 0-250 volts may be used in series with a condenser .01 to .5 mfd. Connect it from the output tube plate circuit to ground. The AC voltmeter may be placed from plate to plate in a push-pull stage with one series condenser as shown or from plate to ground in either push-pull or single tube output stages. Maximum meter readings indicate the proper alignment in any of these cases, and a modulated signal must be used at the input.

Full Band Adjustments

Although the tuned circuits may be aligned perfectly at the high frequency end of the dial, it is often noticed that very poor or no reception is obtained at the low frequency end of the dial. For many reasons having to do with the individual receiver design, there will not be the same

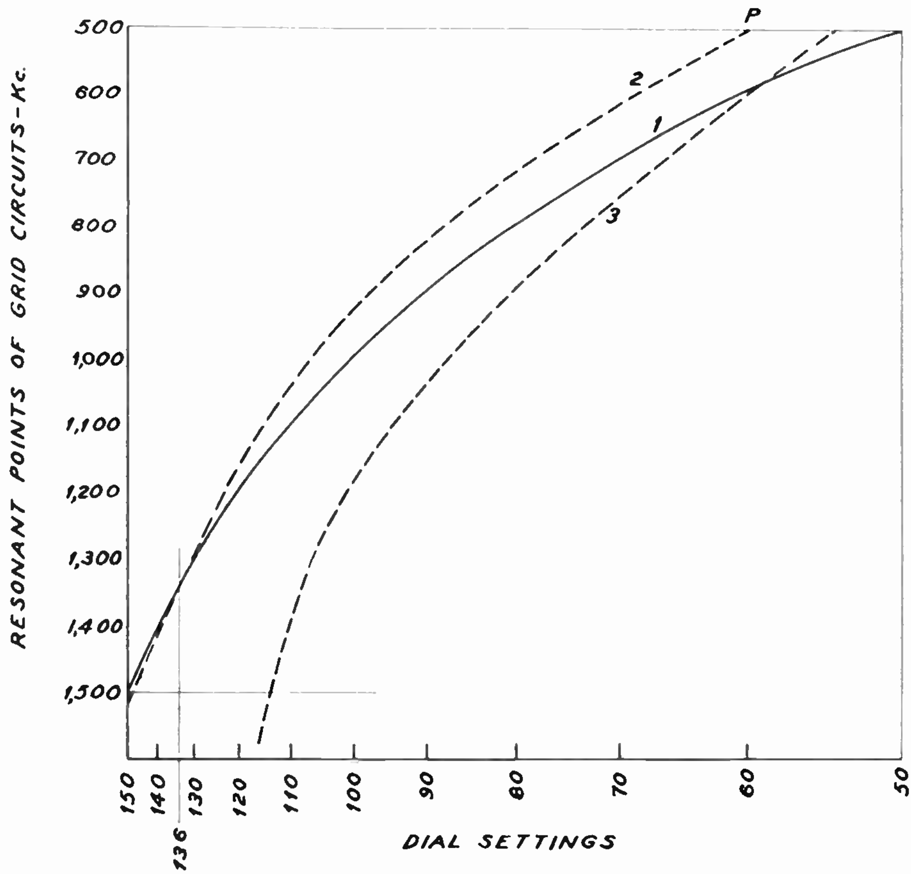


FIG. 9

sensitivity at this end of the band as at the high frequency end as a rule. Moreover, there may be a definite tendency for the receiver to lose sensitivity at the middle of the band. By one method or another, all of these difficulties may be permanently corrected.

Consider first the case where one or more condensers are out of line at the low frequencies. In Fig. 9 is shown one or more circuits correctly aligned as for curve 1, while another circuit has increasingly greater capacity. Note that the receiver has been properly aligned at 1360 KC or where the dial shows 136. It is a little off at 1500 KC which may not be noticed, but considerably off at 60 on the dial as shown by curve 2. In fact, at 60 on the dial, where it should tune to 600 KC, it actually tunes to 500 KC. If the other circuits are tuning to 600 KC at this same dial setting, the signal at 600 KC which is desired may be weak or even inaudible.

The capacity of the average trimmer, which is around 30 mmfd., would probably not be enough to compensate for this defect. Suppose you attempted to align the receiver at 600 KC by means of the trimmer for the circuit or circuits out of line. If you could align it perfect at 600 KC as shown by curve 3 in Fig. 9, it would throw this same circuit considerably out of line *at every point above this line.* This would then be the only place on the dial where reception would be satisfactory (600 KC).

Note that you could align the receiver at any one place on the dial, but it would be out of line at all other places. This matter must be handled by *shifting the stator plates* of the main gang tuning condenser.

First, to identify the circuit or circuits which will not align properly

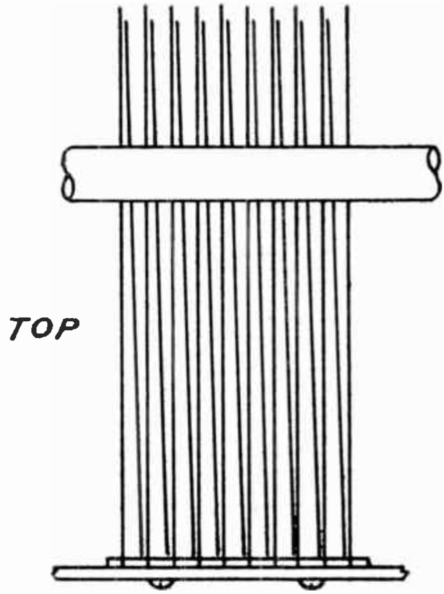


FIG. 10

adjust the trimmers at 1300 KC, then tune the receiver to 600 KC. Note which trimmer adjustments *are not critical* and have no resonant point near their present settings. If any of these can be turned 6 or 8 turns without making any appreciable change in signal strength, or if their adjustment causes a continuous increase or decrease in signal strength, these are the ones that need attention.

Carefully inspect the stator section where the rotors are fully in mesh. You will probably find a condition like that shown in Fig. 10 where the plates *are not evenly spaced.* You will usually find that the stator sections are mounted on the frame of the condenser gang with the screws so that they may be adjusted. Loosen the adjustment screws as shown in Fig. 11, and shift the stator plates either way, noting the signal output. By a small movement, the capacity changes a large amount and you can obtain the exact point of resonance if you do

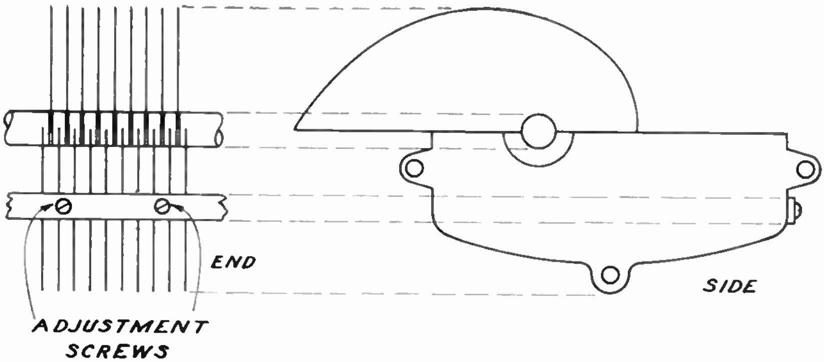


FIG. 11

this work carefully. Note that when the plates are out of mesh (Fig. 11) for high frequencies this will barely, if at all, change the high frequency adjustment. The stator section may now be tightened and to make sure of the adjustment, the receiver should again be aligned at 1300 KC. You will probably find little or no adjustment necessary. This must be done with each individual main tuning condenser until the receiver is in perfect alignment. It is indeed surprising what some of these old receivers are capable of, when correctly aligned. So few of them now in operation are in proper alignment that their age and obsolete circuits are given the blame for poor operation when such is not the case at all.

Now consider still another phase of this matter, in which there is one or more places in the frequency band at which the receiver is insensitive. For example, it may be insensitive in the center of the band or at one or more places throughout the band.

The later and better TRF receivers were provided with *end rotor* plates split radially in *fan shaped segments as in Fig. 12*. These segments each cover about 100 KC of the band. Some have only three or four segments, but the same principle is involved.

Assuming that the circuit is not correctly aligned and tunes as shown in Fig. 13, you must make the following adjustments to tune it corectly. For the condenser represented by Fig. 13 one or both end rotor plates is split into 10 sections. The radial or angular width of each section corresponds to a 100 KC band and each segment (Fig. 12) is numbered to correspond to the band (Fig. 13), which it controls by being just in mesh with the stator plates.

First note that the desired tuning characteristics are shown by the solid line curve (1) of Fig. 13. Note also, that this circuit in question has been properly aligned at 1400 KC—that is, at 140 on the dial it receives 1400 KC stations. It happens by chance, that the stage is also in perfect ad-

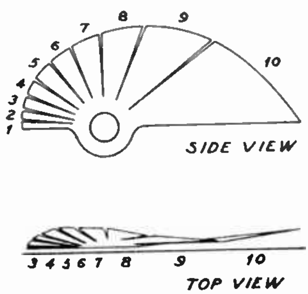


FIG. 12

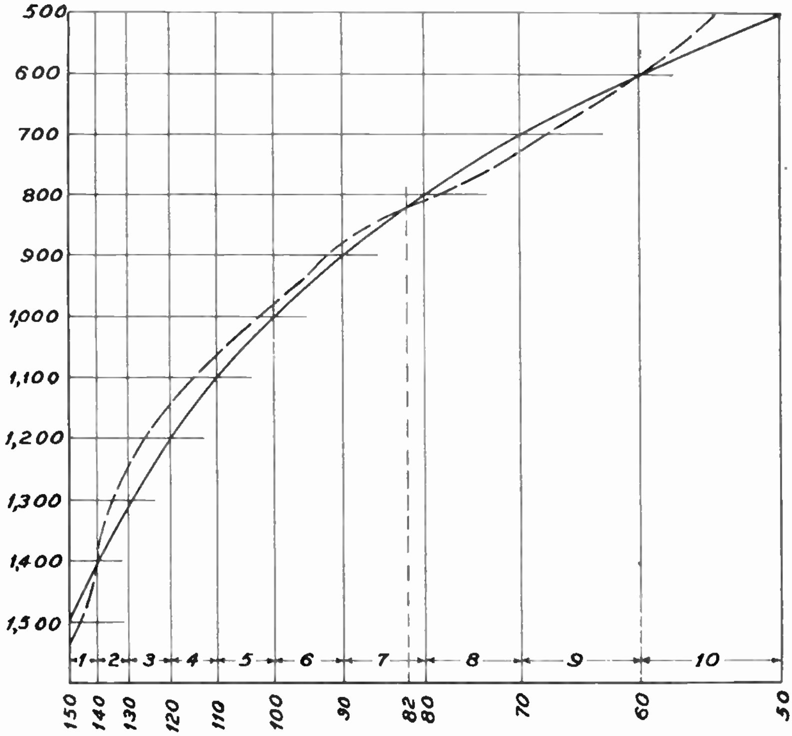


FIG. 13

justment at about 82 on the dial or for 820 KC signals. This is where the dotted curve (2) in Fig. 13 crosses the solid curve (1). At every other point on the tuning range, the circuit is out of adjustment and cannot be brought into alignment by readjusting the trimmers as this will throw the circuit out of line at other points.

Having aligned the circuit properly at 1400 KC, it should be tuned to 150 on the dial. Note that the circuit now tunes above 1500 KC, indicating that the capacity is *too low*. You should therefore, bend plate No. 1, Fig. 12 toward the stator with a split end bakelite rod until the capacity is increased by the right amount for resonance. You will not know which way to bend it until you move it either way, noting which produces the best output signal. If already tuning too low in frequency, the capacity must be decreased by bending the segment away from the stator plates a sufficient amount. If the capacity is too high, the segment must be bent in (toward the stator plates) for best response and proper tuning alignment.

Work on one end of the rotor where possible. Where a maximum amount of bending still will not permit perfect alignment, use the corresponding fan section at the other end of the rotor plate. The two provide adequate adjustment latitude.

Segment No. 2 in Fig. 12 must be left just as it is because at this condenser setting with plate 2 just in mesh, the stage has already been aligned by the trimmer at 1400 KC.

FIG. 14

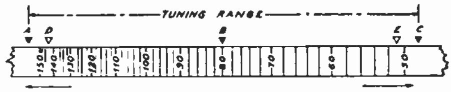


FIG. 15

Now tune to 130, set the signal generator to 1300 KC and bend plate 3 for the best signal. For the case represented in Fig. 13, the receiver tunes too low, so the segments must be bent out from the stator. All of the segments down to and including the 7th should be bent out for proper alignment and in doing so they should be twisted enough so that their ends are adjacent as in the end or top view of the lower part of Fig. 12. They can thus be made to follow the proper tuning characteristics. All signals can be made to appear exactly at the right point on the dial scale and each stage may be aligned perfectly with the others by this method.

Some well designed receivers have a special mounting on the rotor section with an adjustment screw for each split segment as in Fig. 14. In this event, the plates need not be twisted, but a very fine adjustment of each band for each tuned circuit may be obtained by turning the set screws which bear on the split segment to be adjusted.

It will be observed in some receivers there will be one of the tuning condensers in the gang which is lacking in the trimmer and split plate facilities. This simply means that all of the other circuits must be adjusted to the characteristics of the one which is not adjustable. This actually simplifies the work as you have one less stage to adjust. Moreover, the variable qualities of the other circuits are sufficient to bring them to these characteristics. In fact, if all units are adjustable, additional problems are introduced which will now be discussed.

Suppose you have aligned a TRF receiver correctly and find the dial setting for a 1500 KC signal goes off scale at the left end as at A, Fig. 15. And you find also that for receiving a 500 KC signal, the dial must be set off scale to the right as at C in this figure. Slipping the dial scale in this case will do no good as by bringing either end of the scale to the correct setting the other one will be still further off its setting. The scale will have the correct setting for only one intermediate point such as B in the figure.

This is an indication that all of the trimmers are too tightly closed (high capacity setting) and although perfectly synchronized, they are all out of adjustment with respect to the dial scale. except for the one point.

Reduce all trimmer condenser capacities until the length of dial coverage is exactly equal to the scale length and then shift the scale as described formerly *to the right* (toward the low frequency end) until it coincides with this proper adjustment.

If in Fig. 15 the 1500 KC and 500 KC signal settings are within the scale range as at D and E for example, tighten all of the trimmers until this total coverage exactly equals the length of the scale and move the scale *to the left* (toward the high frequency end) until it coincides with the correct condenser adjustments.

The accuracy with which these adjustments may be made, depends to a large extent on the design of the receiver. In general, the better receivers have the greater number of methods for fine adjustment, which of course. allows for better operation. Where the adjustments are limited, the performance of the receiver is limited accordingly.

Receivers Not Equipped With Trimmers

Trimming facilities were not used on many of the very early receivers, some of which are still in use. Unfortunately it is not advisable to attach trimmers to these receivers because it would increase the minimum capacity of the tuned circuits so greatly that they could never be adjusted to operate at the original dial settings or with the same band coverage as before.

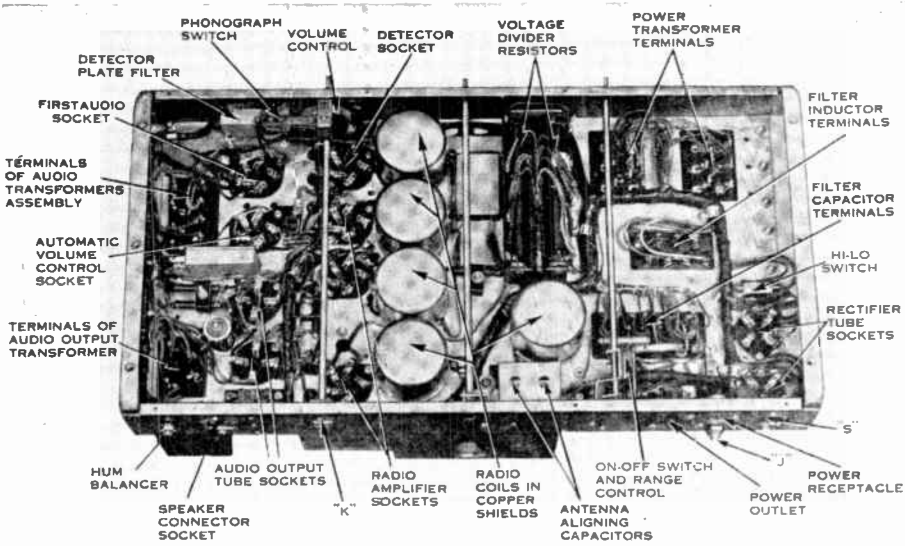
In cases where the design of the receiver is so limited, naturally the operation and adjustment is likewise limited. Some improvement in operation can usually be obtained by shifting the stator or rotor plates. Obviously, for this type of receiver the low frequency alignment may be as accurate as for any other type of receiver, because the same adjustment is used for all types. Moreover, this barely affects the high frequency setting.

The only attempt advised for aligning this type of receiver at high frequencies is to bend the rotor plates as needed for adjustment, making sure not to let them touch the stators at any point in their rotation.

Aligning TRF Type Receivers Not Equipped with Trimmers

Inspection of some of the earlier type broadcast receivers, like the Radiola, Atwater Kent, Crosley and many others, will disclose the fact that the main variable tuning condensers are not equipped with trimmers. Neither are there any other extra variable controls located anywhere in the circuits for aligning purposes. Therefore, aligning in this type of receiver will consist chiefly of shifting the rotor plates.

Practically no specific information has been issued by the manufacturers of these early type TRF sets which

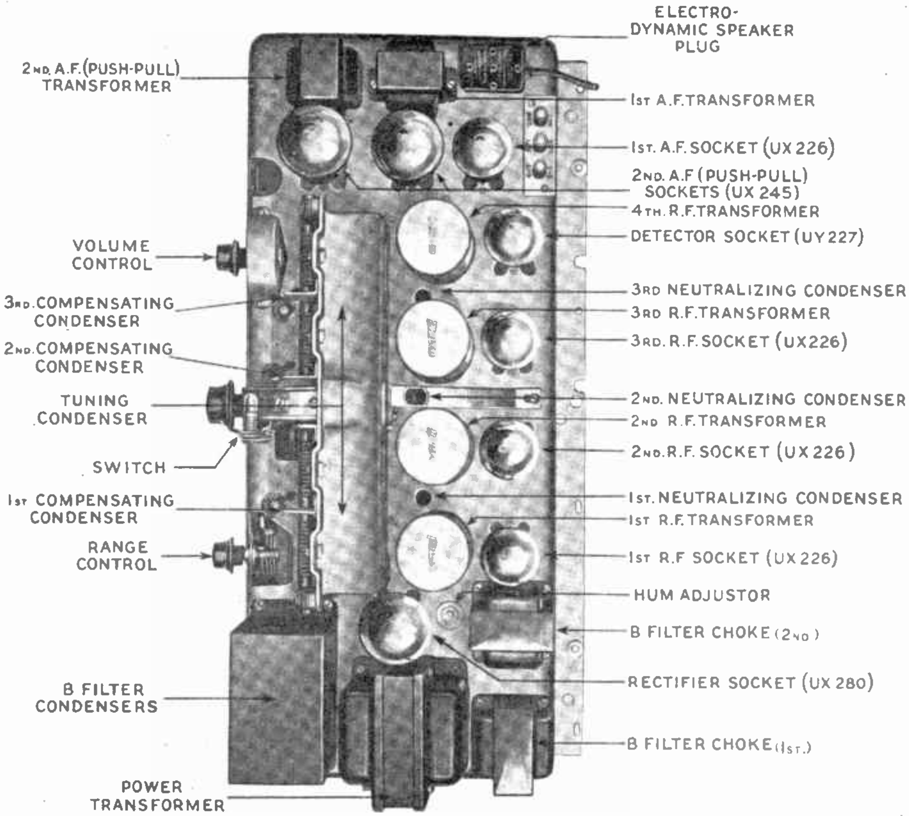


This photograph shows the underside of a typical TRF receiver. The tuned coils are enclosed in their individual shields while the gang condenser and its trimmers are located on the top side of the chassis. The trimmer condensers for the antenna stage are located on the underside of the chassis as noted above.

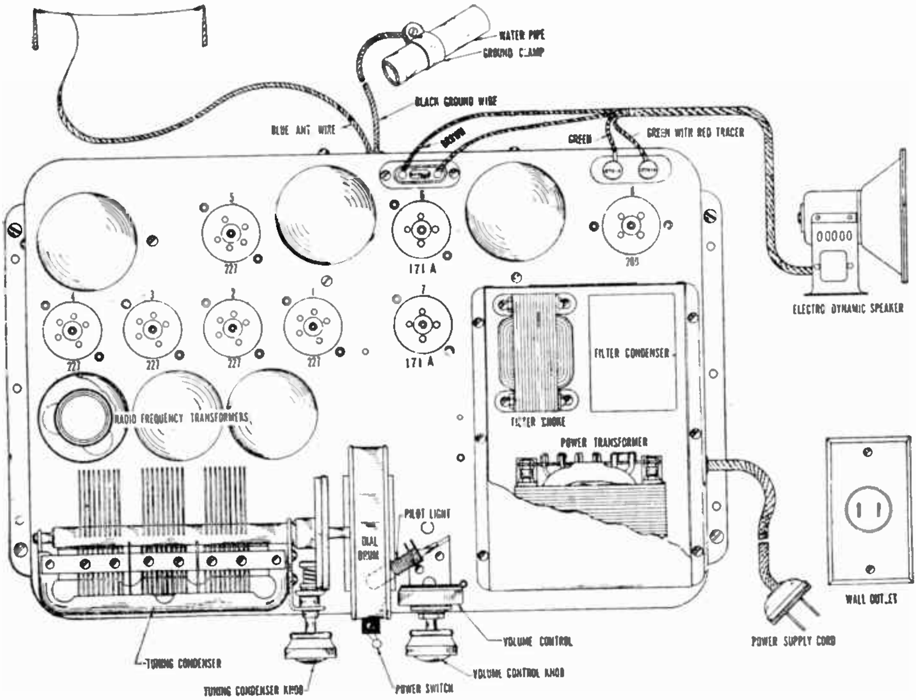
tells whether a receiver is equipped with trimmers or not. Therefore, make an inspection of the receiver, and if your examination shows that there are no trimmers, then scratch a line with the point of a scribe or knife on the shaft and rotor so you can note how much you will shift each rotor when it is loosened on its shaft.

Many of these earlier receivers are easily accessible so the chassis may not have to be removed from the cabinet in order to adjust them. However, where a chassis must be removed from its cabinet, it should always be borne in mind that the chassis should be set up on the work bench with shields and metal covers in place as in actual use to allow the alignment to be made accurately. The reason for this is that the inductance and capacity will alter when shields are removed, and if aligned permanently under this condition, then the receiver will be out of alignment again when the shields are in place. *This applies to all types of receivers, so remember always to keep shields in place and where shields must be removed to make adjustments, then the final check must be made with all shields in place.*

Having marked the shaft and rotor as described, remove shields where necessary and loosen one rotor from its shaft, move this rotor back and



This view shows another layout of a typical TRF receiver. It is an early Philco Model. Note the trimmer condensers are mounted on the frame of the main gang tuning condenser as indicated by the arrows in the photograph.



This view shows the layout of an early type TRF receiver employing a 3 gang tuning condenser. The trimmer condensers are located, as in the other models shown in this lesson, on the frame of the main gang condenser. The tuned RF coils are located in the rear of the tuning condensers and the RF tubes are next in line just in rear of the coils. The 27 type triode tube is used as RF amplifiers and for detection. This receiver is of the type which will employ neutralizing condensers as well as trimmer condensers.

forth, without moving the others, and lock it in place (by means of the set screw) where the output meter reading is greatest. If the meter reading drops when the shield is replaced, you will have to continue by trial to locate the adjustment where the greatest reading is obtained after the shield is replaced. Of course, if moving this rotor has not increased the final output reading, then this stage already was working satisfactorily and you only checked its performance.

Next loosen another rotor and repeat the procedure as described. If any adjustment increases the reading beyond the full scale deflection on the output meter, then reduce one of the volume controls, either on the signal generator or on the receiver to keep the meter deflection again preferably near the half-scale position.

The same procedure should be applied to the third and fourth rotors if this number of tuning controls are used. The receiver then is aligned at its best for receiving broadcast signals near 1400 KC.

Although now aligned for signals at 1400 KC it may not be aligned at its best for other frequencies. Therefore, you must next check the receiver performance at other dial settings. Two extra checks are generally considered sufficient, and these are generally made near 1000 KC and near 600 KC.

The marks you placed on the condenser shaft now will tell you how much you had to move each rotor to

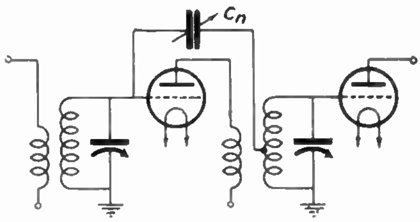


FIG. 16

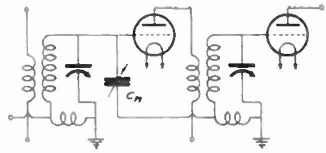


FIG. 17

create alignment at 1400 KC. Most servicemen prefer to make a new set of marks to show the setting for the shaft when the tuning knob of the receiver is turned to receive signals at or near 1000 KC for the second check.

Now tune the signal generator to be in resonance with this setting of 1000 KC, or near the midpoint of the receiver scale, and again loosen the rotor of each variable condenser to see if shifting these rotors will improve results. If you note that shifting the rotor does increase the output, *then reset the rotor to the mark for proper alignment at 1400 KC made previously* and correct for the change in capacity *by bending the outside rotor plates* away from the stator or toward the stator as needed.

Here at this setting for 1000 KC you should bend the plates to give a deflection equal to that produced by shifting the rotor during this last check. However, be sure that the plates are bent only at the middle as otherwise you will disturb the alignment you made first at 1400 KC.

In a similar manner, check the output at 600 KC or near the end of the dial where the rotor plates are almost entirely in mesh with the stator plates of the variable condensers. Again bend the outside rotor plates if necessary, this time near the ends without disturbing the shapes you produced at the center of the rotor plates so you will keep the original alignment at 1000 and 1400 KC.

In some receivers it may be more feasible to shift the stator plates instead of the rotor plates. Where this is possible, it should be done and rotor plates adjusted by bending the outside plates to get individual adjustments at different points in the band. Only in rare cases can complete stator sections be shifted, because as a rule, the manufacturers do not leave enough room in the mounting screw holes to allow for shifting.

Neutralization

Almost invariably when a TRF receiver using triode RF tubes is correctly aligned, one or more of the RF stages will oscillate. The heterodyne or *squeal* which this will set up in conjunction with an incoming signal or a signal generator may seriously interfere with the alignment work. In the alignment work, simply disregard these heterodynes as they can only be taken care of by proper neu-

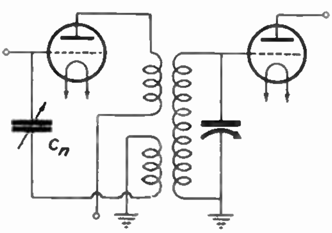


FIG. 18

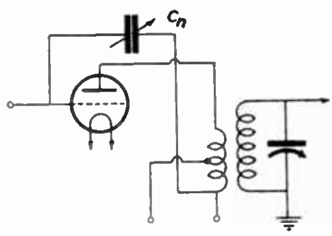


FIG. 19

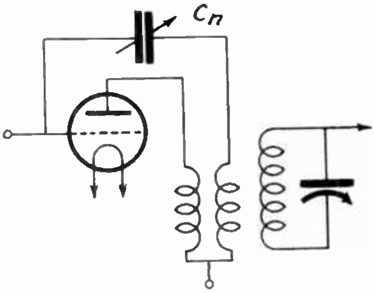


FIG. 20

tralization. Where a heterodyne occurs, adjust the dial for *zero beat* as closely as possible and align as usual. In some cases the reduction of volume of the receiver will usually help in reducing or eliminating oscillation within the RF section and inasmuch as the receiver should be aligned at minimum volume, this is an added advantage. As the sensitivity of the receiver is increased as each stage is brought into alignment. the volume may be turned down even more.

While accomplishing the same thing, there are many forms of the neutralizing circuit. The better known circuits are shown in Figs. 16 through 23. The manner of neutralizing the circuit is the same for all of them.

Tune the receiver and signal generator to 1300 or 1400 KC. Connect the signal generator terminals to the antenna and ground terminals just as you would for alignment purposes. For this work however, you should not use output indicators—it is best to listen to the speaker output signal.

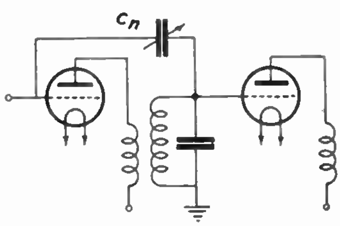


FIG. 22

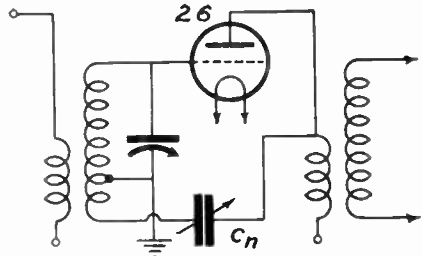


FIG. 21

The signal generator must be modulated. Lacking a signal generator, a local or strong broadcast signal may be used provided it is above 1200 KC. To neutralize a neutrodyne receiver proceed as follows:

Tune in the signal from the signal generator or from the broadcast station, adjust the volume to a comfortable level and remove the first RF tube whose grid circuit is tuned. It may be the first or second RF tube. If it is a filament type tube, such as a 26, place a section of a drinking straw around one of the filament terminals (to keep the filament from lighting) long enough to cover it and place it back in its socket. In some cases. the tube pin hole in the socket is not large enough to admit the covered filament terminal while in others, it is. If this is the case, usually you can use transparent mending tape. Cut a piece that will just cover the filament pin, attach it over the pin, and insert the tube in its socket. Another method is to unsolder one filament lead to the tube socket.

Replace all tube and other shields and covers just as though you were going to use the receiver as a finished

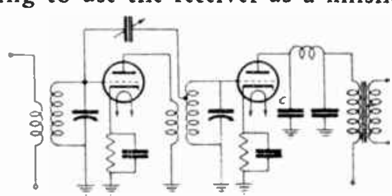


FIG. 23

job. If this is not done the additional stray capacities will usually render the adjustment incorrect.

Next locate the neutralizing condensers, one terminal of which is connected to the grid or grid coil of the tube and advance the volume of the receiver until a signal is heard if this is possible. If the neutralizing adjustment is already exactly right, no signal will be heard provided other considerations are met. Adjust this neutralizing condenser until you can hear absolutely no signal. *This will be a critical setting, each side of which there will be a signal.*

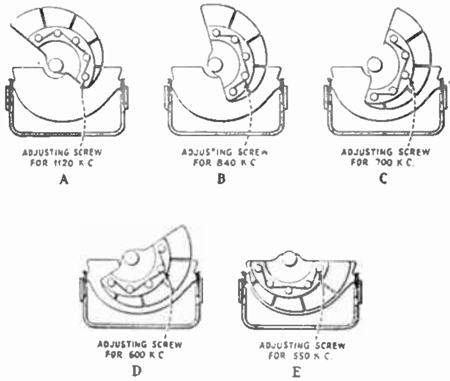
For the cathode type tube, such as a 27 or 56, the same procedure is followed with the insulation either on one filament pin or the cathode pin. The filament insulation should be used as it is preferable.

If the signal steadily increases or decreases as the neutralizing condenser is adjusted, there is a defect in the circuit and this should be corrected before going further with the work. Either the condenser is open or shorted or cannot be adjusted to the correct capacity for neutralization.

Very often a minimum signal can be obtained, but no zero point. There are several possible reasons for this and as many ways to correct the matter.

When it is impossible to adjust the circuit to zero signal, there is some distributed capacity carrying it over to the next stage. The presence of such a signal does not necessarily mean that the stage being adjusted is not correctly neutralized, nor does it mean that this stage will go into self-oscillation when restored into proper operation.

Inspect the wiring of the stage in the chassis and bend each wire as far away from its neighbor as possible. Make each wire follow metal bracing,



This drawing illustrates the split plate type of tuning condenser as used on many RCA receivers. Note there are individual adjustment screws for each segment of the cut plates. Thus, instead of bending the plates, a screw adjustment is used which in most cases will permit a finer adjustment.

shields and the chassis so that its RF field will be confined by absorption as much as possible. Where it is feasible, make the plate lead run at right angles to the grid or neutralizing lead. In some cases it will be necessary to replace the lead from B+ to the plate coil with a shielded lead, with the shield grounded. The plate to plate-coil lead is much more vital than this and quite often this must be shielded, if it cannot be made to run along a corner of the chassis or along a shield or metal brace or even along the chassis flat surface.

While making the neutralizing adjustment, it is well to place a piece of tin foil or a small copper or aluminum plate between the plate to plate-coil lead and other wiring if it is exposed to other wiring, so that the zero signal setting may be obtained. If it is obtained by this means, the metal should be mounted permanently in this position.

Another way in which the signal might traverse the *inactive stage* during neutralization is by direct induction from the signal generator lead or by picking up the signal directly.

This should suggest the importance of shielded leads from the signal generator and a well shielded circuit.

As each stage is neutralized, the insulation must be removed from the filament pin and the tube must be placed into operation. It is difficult, if not impossible, for the signal to traverse more than one stage, especially when the capacity through which it must pass is so exceedingly low. As much gain as possible must be used either before the inactive stage or after it or both so that the signal may get across the stage being adjusted.

The order in which the stages are neutralized has no importance as long as every tuned stage is adjusted. Although the detector has a tuned input circuit, the plate circuit is by-passed so that this stage cannot start into self-oscillation. However, if the plate by-pass condenser of the detector is open, it may oscillate and there is no way of neutralizing it. If the other stages have been properly neutralized and oscillation still persists, identified by the heterodyne whistle, the detector circuit should be investigated.

In Fig. 23 is shown a typical detector circuit in which an open of condenser C will usually cause oscillation. There are, of course, other causes of self-oscillation besides faulty neutralization of coupling by distributed capacity between circuits. Failure of a cathode or plate by-pass condenser, lack of a good ground and

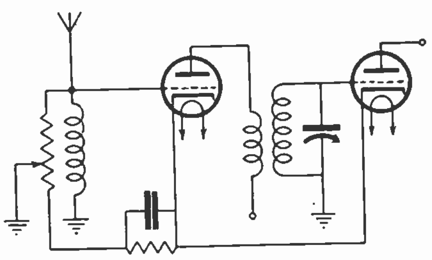


FIG. 24

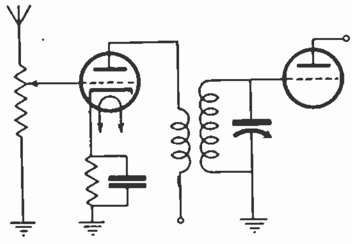


FIG. 25

still other more obscure causes exist.

In many receivers there is what is known as an antenna coupling tube at the input of the receiver. Two types of antenna coupling stages are shown in Figs. 24 and 25. The one in Fig. 24 is subject to oscillation and because the grid is untuned it is not adapted for neutralization. *A long antenna will in the majority of cases so load the grid circuit that the stage will not oscillate.* Therefore, with this type of circuit, it is essential that you use a long antenna both for adjustment and for the final installation. If a signal generator is used for adjustment of the circuits, this will load the grid sufficiently so that the coupling tube cannot oscillate while attached to the signal generator. Then as soon as this is detached and a short piece of wire is used in the shop as a temporary antenna the antenna coupling stage starts oscillation at high volume.

It is not practical to try neutralization of this stage, so a long antenna is the only solution to its proper operation. It has no means of neutralization and none could be added effectively because it would require a different adjustment for every dial setting.

There are a number of possible ways to perform neutralization, but inasmuch as it is the plate-grid capacity of the tube actually used in the receiver which must be compensated out of the circuit, this method of insulating the filament or heater pin is preferred. It is possible, of course, to use another tube of the same type in which the filament has been burned out or to break off one filament pin of any new or old tube of this type for the purpose. This *dummy* tube is placed in each socket in succession and the circuit is neutralized with its use. The proper tube for the receiver is then placed in the socket for operation. In some cases the grid-plate capacity of this dummy tube is not exactly the same as that for the tube to be used in the stage. In a few cases the capacities will be identical for all practical purposes, but in other cases, they will be sufficiently different that the stage will not be correctly neutralized for the tube which is to be used in the circuit. The first method mentioned is, therefore, recommended.

The screw driver or wrench used for neutralization must be of bakelite or other insulating material. It is not sufficient to use one with only an insulated handle. The shaft as well must be of insulating material. If you use a metallic tool, a perfect adjustment may be obtained but on removal of the tool from the condenser, the adjustment will be destroyed.

If the adjustment appears to be not critical, that is, the signal remains at zero for half a turn of the adjustment screw, set the condenser at the center point of the *no signal zone* so that it may be turned equally far either way before a signal is heard.

The tendency for RF stages to oscillate is greater at the higher frequencies simply because the tube and other distributed capacities have lower reactance values at high frequencies and can transfer more energy. Therefore, if you neutralize the amplifier at 1400

This photograph shows a modern signal generator as made by the Precision Apparatus Company. It may be used to adjust the tuned circuits of not only TRF and Neutrodyne receivers but also it may be used on modern superheterodyne receivers.

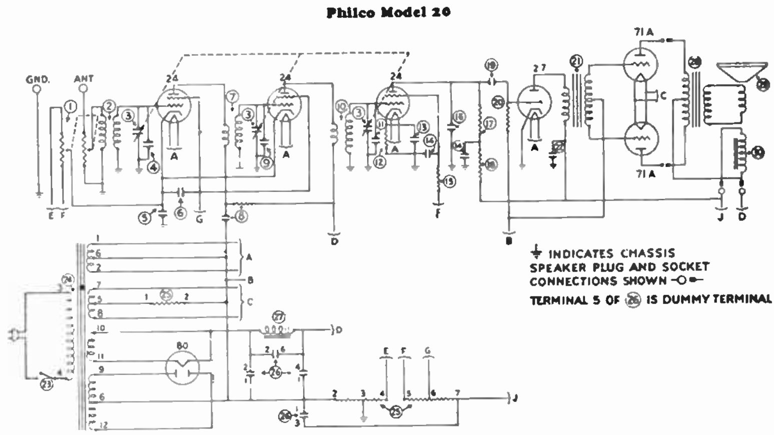


FIG. 26

KC or thereabouts, it is very unlikely that it will become unbalanced anywhere in its range. This is why neutralization must be done at a high frequency part of the band. If oscillation occurs elsewhere, look for some other circuit defect as mentioned in the foregoing.

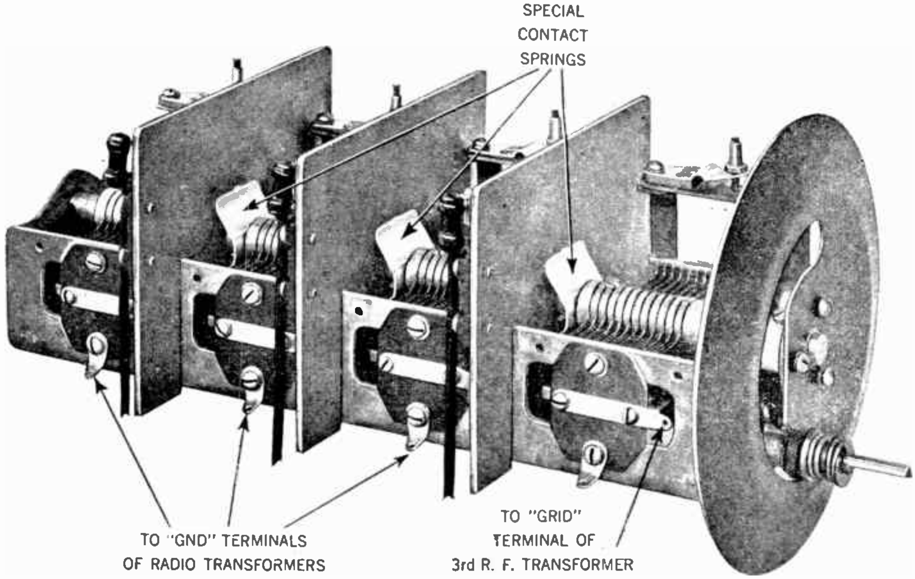
Typical TRF Alignment Procedures

At this point the alignment procedure of a few typical TRF receivers will be given in order to emphasize the main points of TRF receiver alignment. The receivers chosen represent the most common types used and what is said of these particular receivers can also be said of other makes and models of the same general type. Make sure you understand each step in the alignment procedure. It is important to observe here that in all cases of receiver alignment wherever the receiver manufacturer gives a specific procedure to follow it should be followed. Usually you will find, however, that the aligning procedure of any TRF receiver, regardless of make, will follow very close to the procedures outlined in this lesson.

A very popular type of TRF receiver of a few years back of which there are many still in use today is the Philco Model 20. The schematic diagram of this receiver is shown in Fig. 26. It consists of three 24, one 27, and two 71A type tubes. This receiver was one of the first to use tetrode tubes in the RF amplifier. To understand the function of this receiver it is well to discuss the function of each tube within the receiver.

The first two 24 type tubes are RF amplifiers and the third 24 tube is the detector. The 27 type tube is the first audio amplifier and the two 71A tubes form a push-pull audio output amplifier. There are no neutralizing condensers or grid suppressors necessary with this receiver because of the type screen grid RF tubes used. This simplifies the circuit as well as simplifies the receiver aligning procedure. The aligning procedure is very simple and is followed in the conventional way. If a signal generator is available it should be used for the RF alignment.

Connect the signal generator output to the antenna and ground of the receiver making sure to connect the ground connection of the two units together. Usually the generator is



This photograph is similar to the one shown on page 4 with the exception that a clear view is shown of the special contact springs. These springs establish a constant electrical contact between the rotor of the tuning condenser and the frame of the main gang. This form of connection was found to be necessary in order that a constant electrical contact would be established between the rotors and ground. These spring type contacts are often the cause of noise as the receiver gets older. So when you repair one of these receivers, make sure that these spring contacts are in good order and that there is no dirt and dust collected between them and the frame of the condenser.

coupled directly to the antenna and ground of the receiver. This practice, of course, depends upon the type generator used. It is best in all cases to connect the generator to the receiver as recommended by the manufacturer of the generator.

After the generator is connected, tune the receiver between 1200 KC and 1400 KC (120 and 140 on the receiver dial). After allowing sufficient time for the receiver and generator to warm up, tune both signal generator and receiver to the same frequency. A modulated signal should be used and an output meter should be connected to the output of the receiver for best results. If no output meter is available and you are tuning by ear, keep the output of the generator at a very low level because your ear is much more sensitive to amplitude changes at low volume. By following this method a much better alignment can be made when it is necessary to do the aligning by ear. The volume control of the receiver should be turned full on when aligning with the use of a signal generator and the receiver output should be controlled by the output or attenuator control on the signal generator. It is possible to align this type of receiver with the aid of a strong signal in place of the signal generator with your ear acting as an output indicator. This method isn't preferred but will allow a fairly accurate alignment. The accuracy of aligning by this method is improved upon practice. With larger receivers, using many stages of RF, this method is not as practical as with smaller receivers. However, an approximate alignment can be obtained by using a radio signal in place of the signal generator (test oscillator) and your ear for the tuning indicator. When this is done, the volume control of the receiver will have to be adjusted to give a very weak output from the speaker. Often with the larger type of TRF receiver, it is very difficult to get the proper alignment by ear. In cases of this sort, you may have to use a signal generator and output meter to get the proper alignment. Many times the tubes in a TRF receiver will oscillate if the receiver isn't tuned as it should be and in making the adjustments by ear, stopping them from oscillating, may prove almost impossible. For this reason it is much better and quicker in the long run to use a signal generator and output meter for aligning TRF receivers where there are several RF stages of amplification.

If the receiver is very much out of alignment, to begin with, it may be necessary to increase the output of the generator to a high level before an audible note can be heard through the speaker. If an output meter is used, the output level of the signal generator should be high enough to give a good indication on the meter.

As the receiver is tuned closer to the proper resonant point the output level of the generator should be reduced to keep the sound level at a low value for audible tuning and at a convenient meter reading when the output meter is used. When the output meter is used watch that you do not permit the meter needle to read off scale. It may be necessary to place the output meter on a higher voltage range as the correct alignment point is approached.

The trimmer condensers to adjust in Fig. 26 are numbered on the diagram as parts 4, 9 and 11. As with many other receivers of this type the trimmers are located on the frame of the three gang variable condenser. The adjustments should be made with an insulated tuning tool. The trimmer number 11 should be adjusted first until the maximum output is indicated—then 9 and last 4. Each time a trimmer is adjusted the preceding trimmer adjustment should be checked. After all three trimmers have been adjusted, go back over them carefully to make sure you have them all peaked. After the final alignment has been made, check the receiver performance by tuning in several stations noting that they all come in at the right place on the dial. If not correct repeat the alignment, and make sure that the dial reading is at the correct point for the signal being fed to the receiver. When making the tuning adjustment make sure all the shields and tube cap connections are in their proper places. If you align a receiver without the shields, when they are replaced, the receiver will be all out of alignment. With many TRF receivers the RF tubes will oscillate if the tube shields are not in place. Oscillating RF tubes will usually cause audio squeals and howls which are a result of the beat notes between the frequencies of the oscillating tubes.

Often a complaint of a howling receiver can be traced to someone removing the shields from the tubes when old tubes are removed and then failing to replace the shields after the new tubes are inserted. Always check to see if shields should be used when aligning TRF receivers. Many of the older receivers used one shield to cover several tubes. Thus if it is removed several tubes will be unshielded and the RF tubes in the receiver are sure to oscillate.

The diagram of Fig. 27 shows a TRF AC-DC receiver, manufactured by Allied Radio Corp. The model number is F-9525. This is one of the first AC-DC TRF receivers made. It

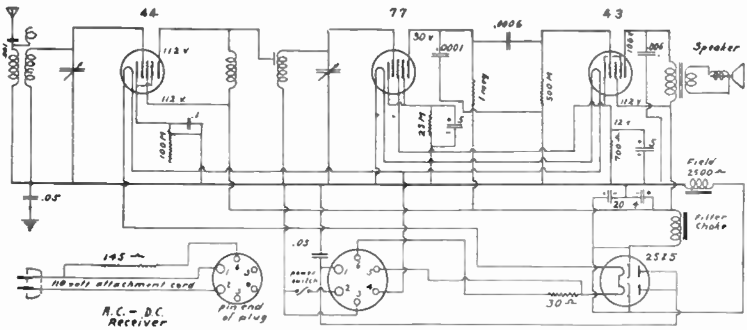


FIG. 27

is a much later model than the Philco 20 shown in Fig. 26 as is obvious by the type tubes used. This receiver has good sensitivity and uses four tubes —a type 44 RF amplifier, a type 77 RF amplifier and detector, a type 43 audio output tube and a 25Z5 rectifier tube. The circuit is very simple as you can see. The trimmer condensers are not indicated on the diagram but are, as in most TRF receivers, located on the variable condenser frame. The alignment of this receiver as recommended by the manufacturer is as follows:

Remove the receiver chassis from the cabinet, turn the tuning condenser rotors completely out of mesh with the stators. Attach a signal generator to the antenna and ground connections of the receiver. Adjust it to 1700 KC. Then adjust the trimmer condensers on the tuning condenser frame until the loudest signal is heard. Next change the signal generator to 1400 KC. Now turn the gang condenser until the signal from the signal generator is heard. With the gang condenser held in this position, check the trimmer condensers again. If after making the check with the signal generator at 1400 KC, the receiver dial indicates the wrong frequency, adjust the dial to the correct reading.

The dial readings, however, are usually correct and unless the dial has worn or someone has tampered with it, it should be correctly set. So make sure you have properly aligned the receiver before making any changes upon the dial scale. In many instances, the dial numbers are just a reference and are not meant to indicate the actual frequency of the received signal. When this is the case you need not worry about the dial reading as long as the receiver functions properly.

Figure 28 shows a diagram of one of the latest type TRF AC transformerless receivers using high-voltage-heater type tubes. This receiver is a Silvertone model 6326. It uses a type 12K7GT as an RF amplifier, a type 12J5GT as an RF amplifier and detector, a type 35L6GT as an audio output tube, and a type 35Z5GT as a rectifier. This receiver although of the power transformerless type operates from an AC source only. It has a phonograph motor and pick-up attachment for playing records. There are a number of receivers of this type which although of recent design are TRF receivers. For this reason many servicemen are mislead as to their type. If you are not already familiar with the identification of these receivers, pay special attention to the hints to follow concerning the identity of TRF receivers.

The alignment of this receiver is very much the same as for those al-

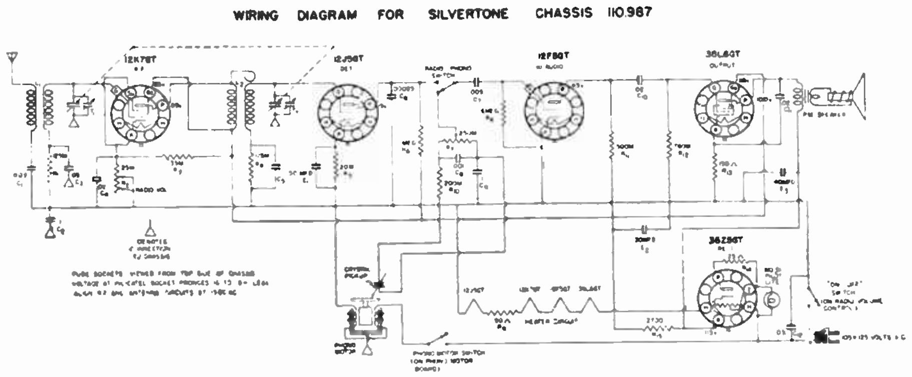


FIG. 28

ready discussed. The test oscillator or signal generator should be coupled very loosely to this receiver and a frequency of 1500 KC is recommended for alignment. The coupling from the signal generator can be made by attaching a wire to its output and laying this wire parallel to, but insulated from, the receiver antenna wire.

With the signal generator connected in this manner, tune it to 1500 KC and adjust the receiver tuning until the signal from the test oscillator is picked up. Always allow plenty of time for both the test oscillator and the receiver to warm up to their normal operating temperature before making any adjustment on the receiver. After this is done, turn the volume control on the receiver to full volume and make the adjustments on T1 and T2 of the receiver (See Fig. 28A). These two condensers are located upon the variable gang condenser of the receiver. They are indicated on the schematic diagram of Fig. 28 and also on the chassis layout diagram.

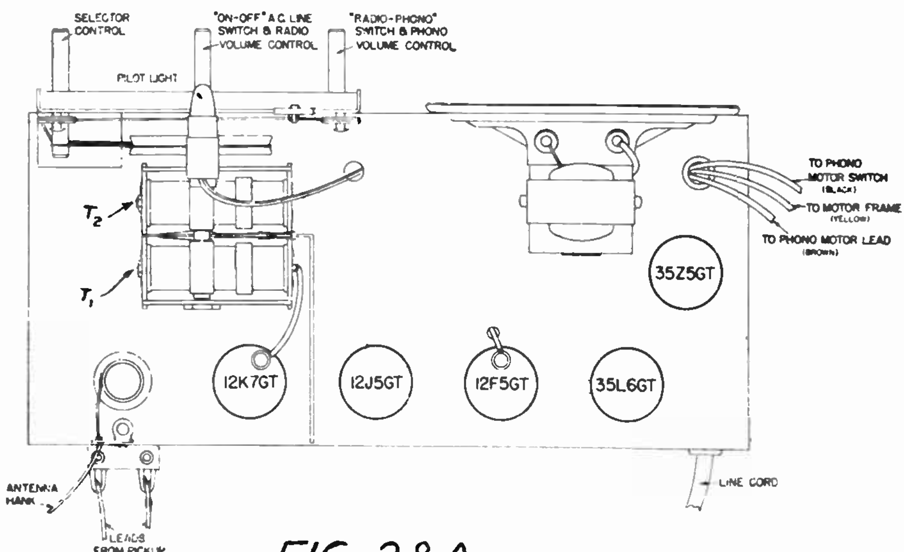


FIG. 28A

When the preceding steps have been taken and the receiver has had sufficient time to warm up, increase the output of the signal generator until a signal is heard through the receiver or if an output indicator is used, increase the output of the generator until an indication of voltage is noticed upon the meter. The alignment consists of making the proper adjustment upon condensers T1 and T2. T2 is adjusted first to maximum output as indicated by the ear or preferably by an output meter. After T2 is adjusted properly T1 is then adjusted. T2 should then be checked and readjusted if necessary. Again make a recheck of T1 if it was necessary to change T2. Do this until you obtain the maximum output. The receiver should then be tuned or adjusted properly. However, always check the alignment by tuning the receiver across the broadcast band, noting if any station comes in at more than one setting of the dial and that all stations come in at the right point on the dial.

The aligning procedure for Figs. 26, 27 and 28 as given here is typical of practically all TRF receivers. Thus, the information given can be applied to all other TRF receivers.

The neutrodyne receiver is obsolete at present, but there are many of them still in use. These receivers are identified by the type tubes used in the RF section of the receiver. If triode tubes are used in the RF section, there must either be a method of neutralizing the plate to grid capacity or some means of suppressing oscillation must be employed. As mentioned in the foregoing these receivers are of the older type. This offers another means of identification. Thus it should be very easy to identify these older type neutrodyne receivers from later type TRF receivers.

The TRF receiver has lost its popularity due to newer and better designed receivers—yet there are many of these receivers still in use today. Some of the modern receivers are of the TRF type. For this reason you should know how to identify these receivers so that time won't be wasted when servicing them. Figure 28 shows one of the more recent type TRF receivers. They are identified by the type tubes used and by the size and type of tuning condensers used. The lack of IF transformers, oscillator coils, and padder condensers are also good clues to watch for when determining whether the receiver is of the TRF type or not.

TRF receivers rarely employ more than one tuning band. This also aids in identifying them. When one of the variable tuning condensers is made smaller than the other, you will know definitely that the receiver is not a TRF but a superheterodyne.

The older superheterodyne type receivers are misleading and sometimes their identity is not so obvious. Therefore, they are often mistaken to be a TRF receiver. It is, of course, very important when servicing a receiver to know which type of receiver you are servicing for the alignment procedure of the two (superheterodyne and TRF) is considerably different. Following the previously listed items concerning the identity of a TRF receiver (both by the components present and by those not present) you will, no doubt, be able to easily determine which type of circuit any receiver employs.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 Are RF trimmers connected in series or in parallel with the main tuning condensers?

No. 2 At which end of the broadcast band does the trimmer have the greatest effect?

No. 3 When the receiver chassis is out of its cabinet what precaution must be observed before proceeding with the tuning alignment work?

No. 4 Under what conditions is it necessary to shift the tuning dial scale?

No. 5 Why is it necessary to adjust trimmers at 1300 or 1400 KC instead of at 1500 KC where the circuit is most critical to the adjustment?

No. 6 What is the most common method of correcting the alignment of one RF stage at the low frequency end of the band?

No. 7 What provision is sometimes made for an adjustment of the tuned circuit at intermediate points in the tuning range?

No. 8 At what point or area in the tuning range should an RF stage be neutralized?

No. 9 Can a power detector or antenna coupling stage be neutralized?

No. 10 With reference to Fig. 18 describe how condenser Cn is to be adjusted.

HOW TO MAKE SUPERHETERODYNE TUNING ADJUSTMENTS

LESSON TV-8

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

SUPERHETERODYNE TUNING ADJUSTMENTS MUST BE DONE IN A PRECISE MANNER FOR LASTING RESULTS

You will remember from your basic study of the superheterodyne receiving system that beat frequencies result from mixing the incoming signal with the local oscillator. You will remember also that as a result of this mixing of frequencies that two beat frequencies result — one equal to the incoming signal minus the oscillator frequency and one equal to the incoming signal plus the oscillator frequency. These are called the difference and plus frequencies. For the broadcast band it is standard to use the plus frequency. Thus for a received signal of 1000 KC and an IF of 456KC the local oscillator in the receiver must be set to 1000 + 456 or 1456 KC. In certain other ultra high frequency applications, the difference frequency is employed. To illustrate if the received signal is 1000 KC and the IF is 456 KC, the local oscillator must be set to 1000 —456 or 544 KC in order to utilize the difference frequency. These examples are given here to impress upon you the necessity of being as accurate as possible in your tuning alignment work. Thus, you must first make very sure the IF stages are adjusted for maximum performance at the correct IF. Then just as important is the fact that the oscillator stage must be adjusted correctly in order to form the right beat frequency so it will be admitted to the IF stages with ease. From this you can see that if either the IF stages or the oscillator stage is adjusted at the wrong frequency proper performance will not be obtained even though one or the other may be adjusted correctly. This is an important point to be remembered for all FM, AM and television receivers employing the superheterodyne system.

The proper procedure is to first make sure the IF stages are adjusted correctly at the right frequency. With this done next adjust the oscillator trimmer remembering that for the broadcast band it operates at a frequency above the incoming signal—namely, at a value equal to the incoming signal plus the value of the IF. There are some few exceptions to this general rule in special receivers and in television receivers. These will be pointed out to you in later lessons dealing with FM and television receivers.

SPRAYBERRY ACADEMY OF RADIO

CHICAGO, ILLINOIS

K 2562M

This photo shows a typical tuning adjustment being made on a small AC-DC superheterodyne receiver. In the background on the shelf reading from left to right are an analyst, combination analyzer, signal generator, and multimeter. These are typical test instruments accumulated by the technician over a period of time.

HOW TO MAKE SUPERHETERODYNE TUNING ADJUSTMENTS

Lesson TV-8

Although basically the same as for a TRF receiver, the adjustment of superheterodyne tuned circuits in general is more complex. This is due to the wide variation in circuit design and the innumberable auxiliary circuits such as AVC amplified AVC, AFC, regenerative IF, high fidelity circuits, 2nd detector circuits, all-wave circuits, etc. Each of these introduce variations in the practical work of alignment (tuning adjustments).

The superheterodyne receiver that is properly aligned will give a high quality output with a relatively low signal input. In order for the receiver to operate most efficiently, all of its tuned circuits should be properly adjusted. It must of course be assumed that the receiver is free of any malfunction or defect other than poor alignment. The student should understand not only what adjustments should be made but also *why* they should be made. In the process of servicing many different radio receivers you will encounter various types of superheterodyne circuit arrangements. Older sets will be more apt to be in need of tuning adjustments, and so it is important that all types of receiver circuits be covered. As you gain more experience, you will develop the ability to classify a circuit as to its purpose, function, and operational characteristics. To help you to develop this ability, you should not hesitate to refer to this or other lessons in your course for reference.

The fact that a receiver is misaligned (or out of tune) is not always due to a defective part. More often it is the result of a gradual process that occurs over a long period due to normal wear or aging. The small vibration that any radio receiver is subject to may be enough, over a period of time, to cause a part to vary in size. Often this is such a slow process that even the owner of the set is not aware that it is taking place. Many servicemen make it a practice to check the alignment or tuning of every radio receiver before it leaves their shop.

A radio receiver that has been carefully adjusted will not only have a good output, but also it will receive the proper stations at the correct settings of the dial. (You will recall from your lesson on Superheterodyne Tracking why this is important.) The alignment and adjustment of tuned circuits is made easier by the use of certain pieces of test equipment. An RF signal generator with a modulated output is used to replace the broadcast station signal. This makes it possible to control both the frequency and the intensity of the input signal. An output indicating device such as the multimeter, a VTVM, or an oscilloscope is used in place of the speaker because the human ear is insensitive to slight changes in amplitude. Specific procedures as well as the use of certain test equipment will be discussed in this lesson.

The IF amplifier is always adjusted first, followed by the oscillator and RF adjustments in that order. The output of the signal generator must in most cases be modulated. Most signal generators have an output which is controlled by an attenuator. In this way the output level can be decreased as the receiver output increases with tuning adjustments. The signal from the generator is fed through a cable to the receiver. A condenser is used in series with the input lead to prevent the plate voltage from being shorted to ground through the generator. This is usually built into the unit, although sometimes an external capacitor is needed. Because of this, it is not desirable to connect the output of the signal generator to the plate circuit of the first detector of a superheterodyne. *This connection would probably result in the plate circuit being detuned after the signal generator was removed due to the reactive effects of the series capacitor.* The output of the generator is fed into the grid (or the input) to the IF amplifier circuit.

In making the tuning adjustments of a superheterodyne receiver it is the accepted practice to work back from the speaker to the antenna stages. The audio stages do not contain any adjustments and so it is only necessary to determine that this section is operating properly. Usually the first tuned circuit to be adjusted is found in the input to the second detector. The signal at this point is at the intermediate frequency (IF) and so this is the first concern.

The Intermediate Frequency

One of the principle reasons why the superheterodyne radio circuit is so effective is the use of the intermediate frequency. This permits the IF stages to be of simple design and yet have greater amplification because there is no variation in output frequency. The broadcast signal may be fed from the antenna through an RF or preselector stage to the mixer or first detector. The signal is combined with the output of the local oscillator in this stage to form the intermediate frequency. This signal contains the amplitude modulations that were present in the original input but its frequency is of a different value.

The value of the intermediate frequency of the receiver must be determined in some way. This is usually available from a number of sources such as the manufacturer's label or from magazines, diagram manuals, manufacturer's literature or parts manufacturer's folders. If the circuits are not too far out of tune, the IF value can be found by test. If the circuits have not previously been tampered with, they are not likely to be out of tune more than a small percent away from the proper value. You can, therefore, turn on the signal generator with a modulated signal and tune it from the lowest frequency which it will produce to the highest, listening for maximum output of the signal. In this way you can usually identify the intended or assigned IF value from the frequency to which the signal generator is tuned.

A few important points in this identification work may prove very helpful. Figure 1 is a list of most of the intermediate frequencies in present and past use. They cover superheterodynes of every manufacturer in this country. The frequencies which are identified with an asterisk are by far the most widely used values.

IF	IF	IF
45 KC	182.5 KC	459 KC
105 KC	235 KC	460 KC
110 KC	250 KC	462.5 KC
115 KC	252.5 KC	463 KC
125 KC	260 KC	*465 KC
130 KC	262.5 KC	476.5 KC
132 KC	264 KC	472.5 KC
140 KC	265 KC	480 KC
170 KC	345 KC	485 KC
172.5 KC	370 KC	490 KC
*175 KC	445 KC	517.5 KC
177.5 KC	448 KC	1.000 KC
178 KC	450 KC	1.525 KC
180 KC	*455 KC	1.580 KC
181.5 KC	*456 KC	1.600 KC

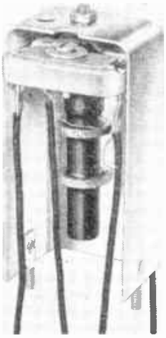
FIG. 1

If you connect the signal generator to a receiver and adjust it to give a maximum signal and find that its frequency reads, for example, 368 KC or 376 KC, or somewhere between these values you may be quite certain that the IF intended by the manufacturer was 370 KC. It is very doubtful, if not impossible, that the intended IF frequency could be 445 KC or 345 KC as the tuned circuits could hardly be adjusted to these values, much less drift into these values through use of the receiver. Moreover no frequencies between 345 and 370 KC have ever been used for IF values at this writing and none have been used between 370 and 445 KC.

Considering 175 KC the situation is not the same. If your signal generator shows, for example, 178 KC the receiver may be exactly in tune or it may have been intended for 175 KC or 177.5 KC. The 177.5 KC and the 178 KC frequencies are rarely used, and it is interesting to note that the receiver will operate just as well as a rule at 177.5 or 178 KC as at 175 KC. These odd frequencies were chosen instead of 175 KC in later productions of many early receivers to avoid certain harmonic disturbances before other means were developed to overcome them. On later receivers the 455 KC frequency was quite practical and was widely used.

In general, it is a good idea to retain the IF intended by the manufacturer where possible or at least within a small percent of it as pointed out in the foregoing case of 175 to 178 KC.

With the signal generator properly connected to the receiver, adjust the trimmer in the input circuit of the second detector first and progress toward the plate circuit of the first



Here is shown a cut-away view of a typical IF transformer. The entire unit is enclosed in a metal shield. The two coil windings are mounted on a round insulating form. The trimmer condensers are mounted in the top of the unit, only one being visible in the above view.

detector with your adjustments. IF trimmer condensers should be adjusted in the reverse order in which the signal passes through the IF transformers—that is, start with the second detector input and work toward the first detector. Simply skip the circuits which are not tuned. It is always a good policy to repeat these adjustments, going over each one again in the same order to compensate for the possibility of one circuit influencing the adjustment of another.

The usual type of IF trimmer condenser is mounted inside of the shield containing the IF transformer windings. It consists of two or more plates of tempered copper, brass or other suitable material, spaced with mica or other insulating sheets. These are mounted on a ceramic block which in many cases also act as the end support of the wood coil form of the IF coil.

Some of these have a machine screw projecting from a stationary flat stator plate on which is turned down a *hex nut* with a *slit* for screw driver or wrench adjustment. In turning down the nut it bends the curved rotor plate successively down onto the stator (flat plate) with a thin mica separator between them, thus increasing the capacity. Care must be taken so that this mica strip does not become loose from the assembly and fall out and that it is not cracked. Very often the mica sheets will crack and slip out of the condenser plates, resulting in a short. If the receiver is very noisy or intermittent while the trimmer adjustments are being made, it usually indicates trouble of this nature.

Socket wrenches or screw drivers with bakelite or other insulating material shafts and handles must be used for these adjustments. Later on in this lesson detailed information will be given on tuning adjustment tools. A round head machine screw turning down into the insulated base in a threaded bushing is sometimes used for trimmer adjustments. In every case the capacity is *increased* by turning the screw or nut to the right or *clockwise*.

Another type of trimmer consists of a midget air type dielectric variable condenser, the shaft of which is provided with a slit for turning the rotors. These are very critical in adjustment, but have several advantages. Make sure that all of the plates, bearings and supporting mechanism is tight so that the plates cannot touch one another.

In still other types of IF transformers, fixed capacities are used and the tuning is done by moving the iron or *permalloy or magnetic cores* which they use. There are no plates to short as the condenser is usually of the moulded mica type in this case.

You may not be able to distinguish one type of trimmer from another from the outside, and it really makes no difference what kind of a trimmer is used, as the adjustment is the same for all of them. However, if you run into mechanical difficulty. the foregoing points are well worth considering. In some cases. the coupling of the primary and secondary coils is made adjustable for tuning characteristics. independent of the tuning facilities.

After the tuning adjustment. in receiver circuits where a separate tube is used as an oscillator. it is sometimes necessary that the IF amplifier be neutralized according to the procedure given for neutralizing such circuits in another lesson.

General Tuning Procedure

The tuning adjustments of a superheterodyne receiver can best be made when an accurate input signal of a known frequency is used. This. plus the fact that both the amplitude and the frequency of the output can be carefully controlled makes the use of a signal generator more practical as a source than a broadcast station signal. The generator signal is fed through the various stages of the receiver to the speaker where the output is measured. A VTVM or a multimeter (such as the SAR multitester) with an OUTPUT jack is used as an indicator to give a comparative reading. The complete operation of the test equipment used is discussed in detail in other lessons. Only the proper connections are given here.

The tuning procedure follows a set pattern regardless of the particular intermediate frequency that is used or the complexity of the receiver. Usually the manufacturer will give any important information in the operating instructions or in the service literature. Almost without exception. the first adjustment is made with the signal generator set to the IF. The output signal is modulated with a fixed audio note. 400 cycles being the most commonly used. The output of the

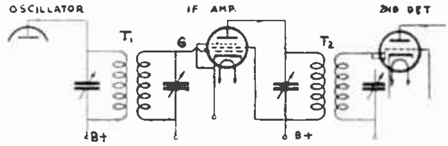


FIG. 2

generator is fed to the control grid of the last IF stage. Best results will be obtained when the local oscillator and the AVC circuits are made inoperative. In Fig. 2. the complete IF stage. and the input and output circuits are shown. When the signal from the generator is connected between the control grid (G) and ground of the IF amplifier. the output must pass through the transformer (T_2). The tuning capacitors connected to the primary and the secondary resonant circuits of this transformer can be adjusted to give the best output. If the local oscillator were operating. its output signal would also appear at grid (G). To prevent this. the oscillator is disabled in some manner. In many receivers. the tube filaments are connected in series so it is not possible to merely remove the local oscillator (or convertor) tube from the socket. This would break the series string so that none of the tube filaments would light. One sure way to disable the oscillator is to remove the source of B plus voltage from the tube. This would mean that a lead would have to be unsoldered. and so it is not recommended. A simpler method is to short circuit the oscillator tuning capacitor plates. This can easily be done with a small piece of hook up wire. This will prevent the resonant circuit from operating without having any other effect on the receiver. With this capacitor short circuited. the receiver volume control is turned to its maximum position. the AVC circuit is also disabled, and the signal generator is adjusted so that its output is just enough to give an indication on the output meter. The tuning adjustments of the transformer or the capacitors are varied so that an increase in the output can be noted. Should this increase be great enough to cause the meter to read full scale, the output of the signal generator can be reduced.

AVC Circuits

Before proceeding, mention should be made of the AVC circuit. This circuit, as you have learned, has been designed to increase the output of a receiver when there is a small signal input and to decrease the sensitivity when the input signal is large. In this way the volume of the receiver remains constant over a wide range of input signal strength. The AVC voltage usually originates in the second detector stage. The circuit must be disabled during alignment or it would try to keep the output level as the tuning adjustments were made. This would prevent accurate peaking of the resonant circuits so that there would be no indication on the output meter when the circuits were properly aligned.

The application of AVC to the superheterodyne started with separate tube AVC circuits. Typical among these types is Fig. 3. If the AVC is left in operation during tuning alignment, the AVC action will tend to level out the effect of peaks at resonance and prevent proper alignment. As each circuit is tuned away from resonance the received signal going into the AVC grid will be reduced. This will result in a reduced AVC voltage and the gain of the receiver will rise until the signal is almost as strong as before. Thus it is impossible to find the correct resonant point with the AVC in operation.

Sometimes it is possible to align a receiver with its output volume so low that the AVC is inoperative. This is made practical by the fact that many receivers employ a *voltage delay* circuit. If it is found possible to align the circuits below the *threshold AVC level* it should be done. Otherwise, the AVC must be prevented from acting. Following are described means of preventing AVC action during tuning alignment.

This circuit (Fig. 3) shows that if the AVC tube were simply removed from its socket, there would be no AVC action and the circuit would not be altered in any other way. Alignment is, therefore, done with

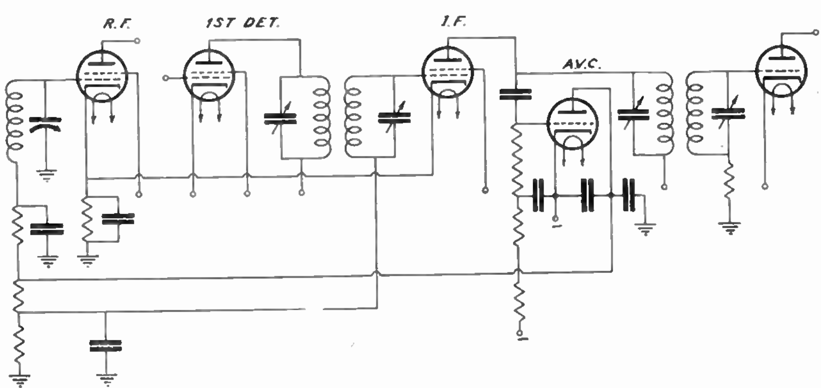


FIG. 3

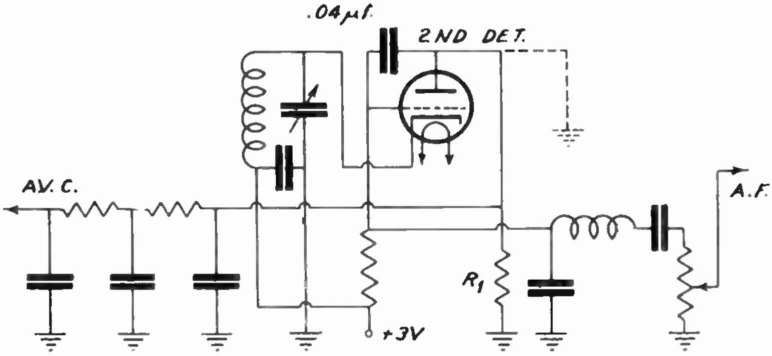


FIG. 4

this tube removed. In general, where the AVC tube is a separate tube, having no function but AVC, it may simply be removed when tuning adjustments are being made.

Where the AVC function is in combination with the 2nd detector, the tube cannot be removed. Other means must be employed for preventing AVC action during tuning alignment.

Consider next the matter of preventing AVC action in several circuits, where the 2nd detector and AVC circuits are intimately related. Figure 4 shows such a circuit. By analyzing the wiring in this circuit, it is evident that you can short the 2nd detector plate to ground and thus prevent AVC action. The AVC voltage is developed across R1.

In Fig. 5 there is a circuit making use of a separate AVC tube, which includes the manual volume control. If you removed the AVC tube, the volume would reduce to minimum and adjustment of the IF stages would be difficult if not impossible. The best thing to do in this case is to short the plate to the cathode. With this done the tube may remain in its socket as it is thrown out of operation or it may be removed.

In Fig. 6 the AVC and 2nd detector functions are intimately combined so that the tube, of course, cannot be removed. Moreover, you cannot short the AVC feed line to ground as this would also short the signal. If you grounded the AVC lead (A), an AVC voltage would still be developed at P and Q and AVC feeders B and C would still be active,

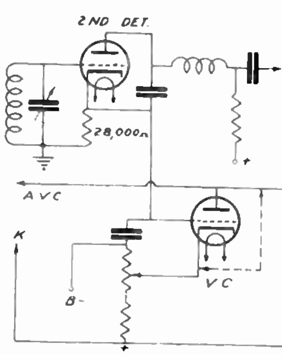


FIG. 5

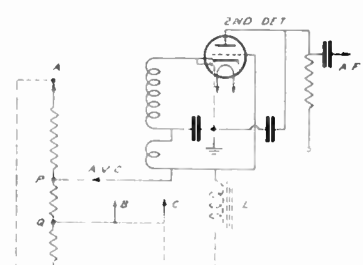


FIG. 6

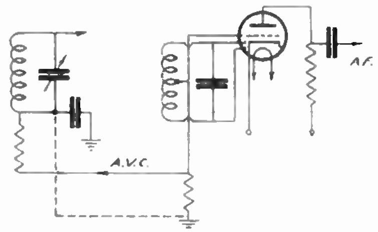


FIG. 7

although at a lower voltage. Likewise, if you grounded (B) or (C), an AVC voltage would be developed at (P) and would act at (A). Therefore, in this type of circuit you must ground both (A) and either (B) or (C). A simpler method would be to ground the grid of the triode tube through an inductance such as the secondary of any good audio transformer. This would substantially prevent AVC action and yet allow a signal to be developed to a certain extent, although it might be distorted.

In Fig. 7, the ground shunt may be placed as shown by the dotted line. If there is more than one AVC feed line, each must be grounded in the same way.

Connections such as those shown in Fig. 8 are easily adapted to AVC elimination. The two diode plates in Fig. 8 are capacity coupled in parallel, one being used for the signal and one for AVC action. The signal diode plate is simply left as it is.

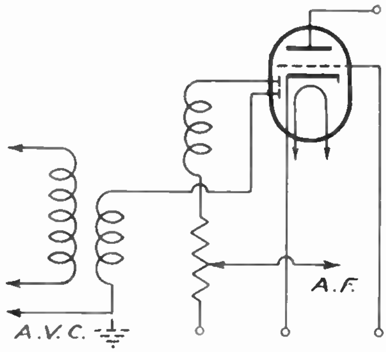


FIG. 9

while the AVC diode plate is grounded. This takes care of all the AVC circuits. In Fig. 9, the same is true, although the diode plates are inductively coupled. Ground shunts are shown in dotted lines on both circuits in their proper positions.

Because of the presence of the high resistance R (from 250,000 ohms to 2 megohms) in Fig. 10, all of the AVC circuits may be shunted out at the remote end as shown by the dotted line without affecting materially the detector action.

All of the foregoing circuits assume that the AVC controlled tubes have their conventional *minimum bias provision* with cathode resistors, so that when the AVC is not used, the tubes will operate correctly at proper

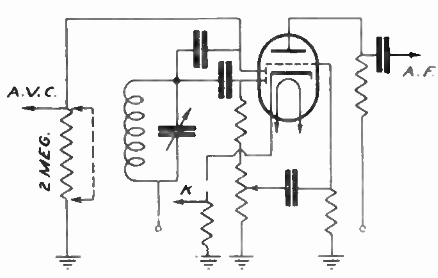


FIG. 8

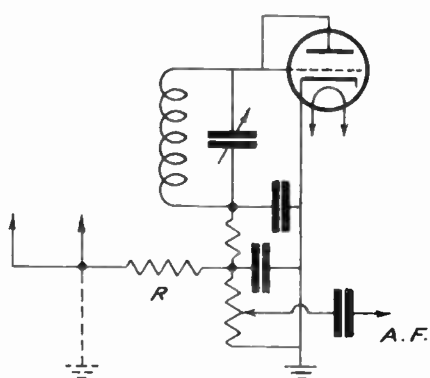


FIG. 10

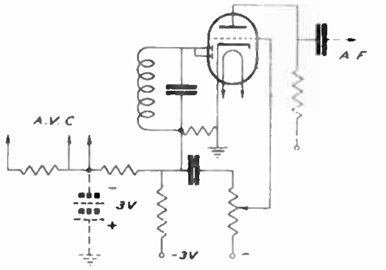


FIG. 11

negative bias for maximum sensitivity and gain. However, there are many cases where the minimum bias is supplied through the AVC system. the cathodes of the AVC controlled tubes being grounded.

Figure 11 will illustrate this connection. When no signal is coming in the tubes will all be biased at —3 volts. As soon as the signal strength at the diodes exceed 3 volts peak. additional bias is added acting as AVC. If you attempt to stop the AVC by shorting the AVC feeder line to ground, the controlled tubes would have no minimum bias and their operation would be poor. This —3 volt bias may be included (as a battery) in the short as in Fig. 11. With this connection, all AVC controlled tubes are held at —3 volts regardless of the signal strength and the action of the 2nd detector takes place very much as usual.

In battery operated receivers, having wiring as in Fig. 12. the problem is simplified through the fact that the signal and AVC circuits are separated at the 2nd detector. Regardless of the minimum bias battery shown, the entire AVC may be stopped with a ground shunt as shown by the dotted line.

An analysis of Fig. 13 shows that since there are two AVC sources, each must be grounded separately. You cannot cut out the flow of DC and AF through the manual volume control. as this would prevent the signal passage to the AF circuits. The proper ground connections are shown here for each AVC feed line.

In a few receivers, there is a *muter tube or inter-carrier noise suppressor* as it is sometimes called, associated with the AVC system. Grounding the AVC system would place a minimum bias on this muter tube and the audio signal would be entirely cut off. One conventional muter circuit is shown in Fig. 14. The problem is solved by shunting out the AVC as shown by the dotted line and removing the muter tube from the circuit.

If the tuned circuit employs a delay AVC system. such as in Fig. 15. the AVC may be stopped by connecting

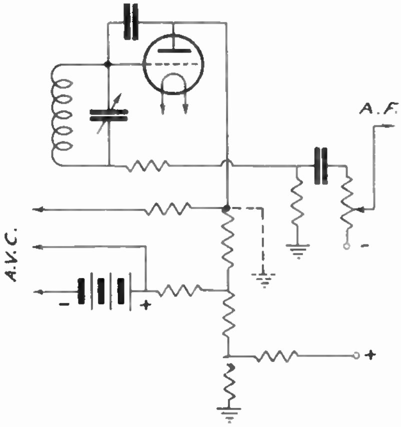


FIG. 12

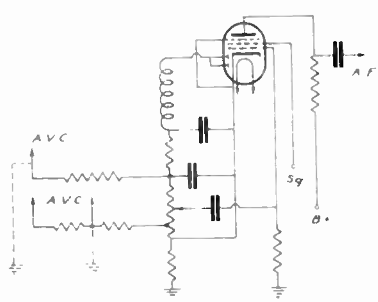


FIG. 13

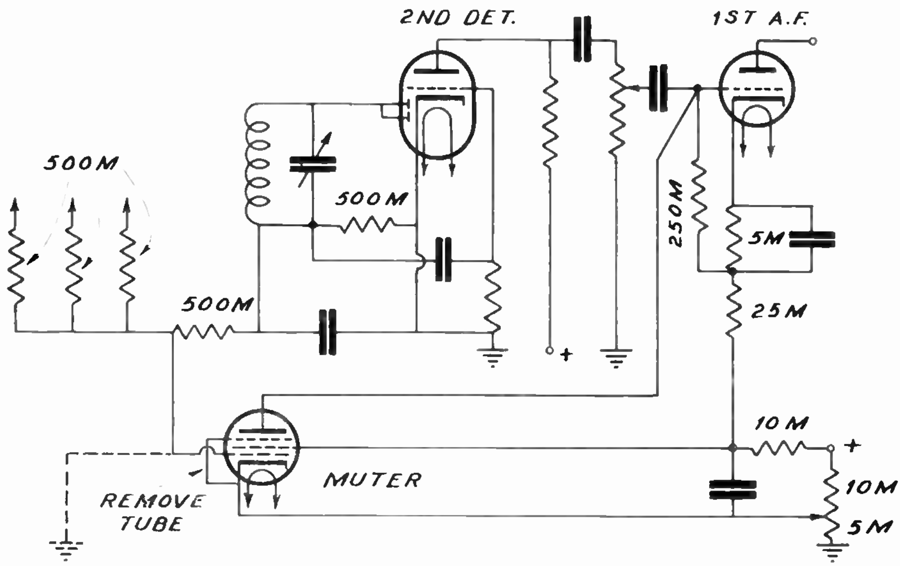


FIG. 14

the AVC delay diode plate to its cathode as denoted by the dotted line. This will hold the RF and IF bias values to —3 volts or very near this value constantly. The connection will not affect the AF.

Some of the receivers employing AVC are provided with some kind of tuning indicator. This may be an electric eye, a neon lamp, a shadowgraph, a tuning meter or a reactance dimmer. Regardless of its kind or design, if it works properly, the AVC of the receiver need not be stopped for adjustment as the tuning indicator may act as the resonance indicator (it being the purpose of the device to show the resonant point of the dial irrespective of the output level). Such apparatus operates from *the carrier signal* and so it is not necessary to use a modulated test signal unless you wish to do so. It is often convenient to use a modulated test signal so that the audio output may be checked simultaneously by ear with the adjustment, so that any heterodyne or motorboating or other abnormal trouble in the RF or IF may be detected.

For receivers equipped with AFC, the AFC shorting switch is simply shorted while IF adjustments are being made. A shorting switch is always provided with AFC for this and other purposes. Adjustment of the AFC requires the use of an output meter or indicator that is past the 2nd detector or in the audio system or receiver output where the carrier alone cannot have any effect on its reading. After the regular IF alignment is made as usual with the AFC switch in the *out or shorted position*, the station selector dial is turned as accurately as possible to resonance with the modulated signal generator tuned to any frequency in the broadcast band. The output is noted and the AFC switch is turned to the *on or in* position. The secondary of the discriminator transformer (IF) is then adjusted for maximum output. If there is a fidelity control in the receiver, it should be set for maximum selectivity. A tone control if used, must be set for the broadest coverage or to its highest frequency response.

When these adjustments are made, switch the AFC *off* and *on* noting if there is any change in the output sound or intensity. If any change is noticed, the entire adjustment must be repeated until there is no difference when the AFC switch is thrown either way. This procedure will be adequate for the standard AFC circuits.

Adjusting The IF Circuits

In most superheterodyne receivers, each IF transformer consists of at least one, but more often two resonant circuits. These circuits must be adjusted to give the maximum output over the entire frequency bandwidth of each broadcast station. When more than one resonant circuit is to be tuned to the same frequency, there are several factors which must be considered. The Q of the circuits, the sharpness of the resonant curves, and the mutual coupling between transformer windings will all result in the final output being a compromise between selectivity bandpass and fidelity.

First consider the case of an untuned plate winding in an IF amplifier as in Fig. 16. Note that there is only one IF trimmer to adjust. With this alone to consider there could be only one possible adjustment of the circuit under any condition. The

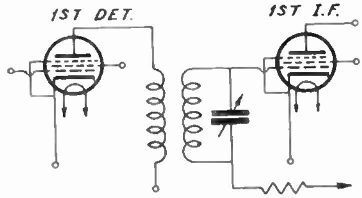


FIG. 16

resonance characteristics of this part of the amplifier would always show, but one point (in its tuning range) where maximum signal could be obtained. This may not seem unusual except by comparison with certain types of double tuned circuits where this would not be true.

In Fig. 17, if you were to separately tune the plate tuned circuit C1-L1 and then L2-C2 to 465 KC before they are coupled together, they would individually have ***single-peak*** characteristics as shown in Fig. 18A. Now when first bringing them into the magnetic influence of each other, you might have a combined characteristic of the two as at B of Fig. 18. If you further increase the coupling between the two coils without changing the tuning of either and without changing the signal input intensity, there would be more energy transfer as at C, Fig. 18. This shows a much higher peak at the output and a single point where the signal transfer is maximum. This may be noted by shifting the signal generator to a nearby frequency and noting how the output meter needle reduces in reading either side of the peak resonant value of 465 KC.

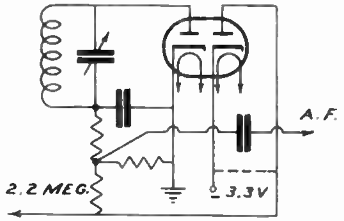


FIG. 15

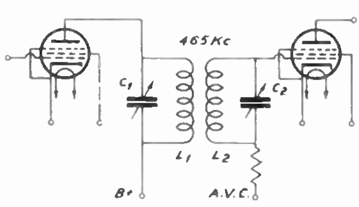


FIG. 17

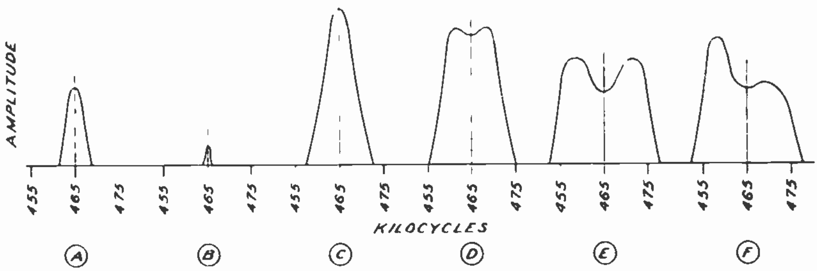


FIG. 18

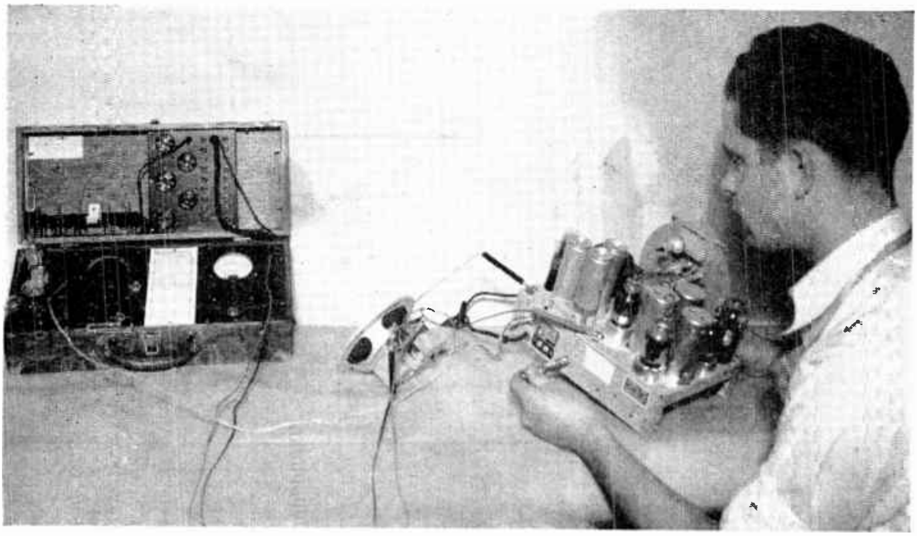
By further increasing the coupling a characteristic such as at D. Fig. 18 would be obtained. Note that no peak is as high as the one at C. Fig. 18. and that at 465 KC or the resonant frequency of either circuit individually there is less output than at a slightly higher or slightly lower frequency. By varying the signal generator frequency from 455 KC upward to 475 KC the output rises to a maximum at about 462 KC and then reduces slightly at 465 KC only to rise again at 468 KC. From here up to 475 KC the output again reduces to a very low value.

There is a certain amount of coupling of these circuits just before the characteristic at D is obtained which will produce the maximum output at resonance and will have only one resonant peak as at C. Fig. 18. This is called *critical coupling* and any coupling in excess of this produces the double-peak effect shown at D and E of Fig. 18, Note at E that as the coupling is further increased, the peaks separate in frequency, lower in amplitude and the resonant amplitude in the center of the two peaks is considerably lower. (This is given more detailed treatment in your SAR lessons on the Oscilloscope).

At any coupling greater than critical coupling if one of the circuits is detuned the amplitude-frequency characteristics would be as at F in Fig. 18. Neither peak would be at resonance (465 KC in this case). and they would produce unequal output values. both above and below the resonant signal amplitude.

The total selectivity of any IF system is accumulated by the individual action of all tuned circuits. Hence, in a small receiver to get the required selectivity, each IF transformer must be adjusted to a peak value and the double peak adjustment must be avoided. The coupling of the IF coils in such receivers is usually critical coupling and is fixed by the coil mountings which should not be changed. However, if one or more of the tuned circuits are out of adjustment, a double peak tuning characteristic such as that shown in Fig. 18 at D. E or F might be obtained. To avoid this action, first adjust the 2nd detector input circuit and proceed backward toward the 1st detector output as described formerly. Then tune the signal generator through 20 or 30 KC each side of resonance, noting the output meter deflection. If it rises at any point other than resonance the work must be repeated until a single peak of the meter is established.

In large receivers, the selectivity often accumulates to such an extent



In the above is shown a typical set-up for a superheterodyne tuning adjustment. The test instrument is of the combination type with a signal generator to the left and meter to the right. Both are connected to the receiver under test while the serviceman makes the tuning adjustment with the tuning alignment tool. Correct adjustment is obtained when the meter reads maximum—it being connected across the voice coil of the speaker.

that the circuits will admit a band of frequencies smaller than required for the modulation frequencies transmitted. In this case, the selectivity of the IF amplifiers must be reduced or broadened by some method of *over-coupling* (greater than critical coupling). For circuits having fixed *over-coupling* several methods are used such as placing a copper ring between the primary and secondary, using a permalloy magnetite or other filled metal core in the transformer or with another winding called a *tertiary winding* adapted to the circuit in various ways.

The *fixed-coupled tuned circuits* are over-coupled by a definite amount to produce a characteristic such as for example at D. in Fig. 18. Perhaps only one or two or all of the IF transformers are of this type, depending on the design of the original circuit. It must be understood here that the characteristics of one circuit of this type in an IF system will make its entire response like this which will seriously interfere with the adjustment of any regular critically coupled circuits used. Therefore, the circuits must be aligned separately. If the last stage is of the flat-top or double-peak type, as in Fig. 19, attach the signal generator to the last IF grid and align the last IF transformer first—tune the signal generator to the exact IF and adjust the diode section, noting the output meter. Tune it to various values and you will note that there are apparently two resonant values. Leave it set midway between these two at a lower output value. Now adjust the primary in the same way. Next shift the signal generator frequency above and below resonance. If the peaks in the output are not uniform, repeat the work just mentioned until they are equal.

Now attach the signal generator to the IF input as usual and adjust the

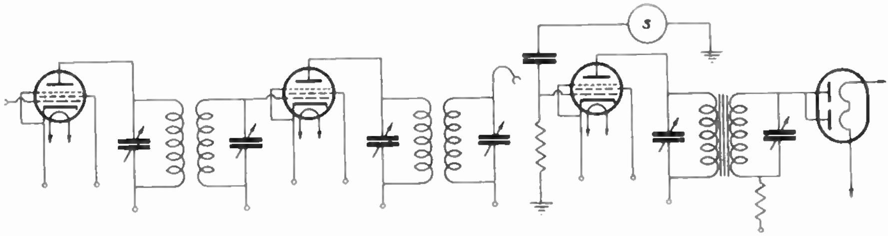


FIG. 19

other trimmers for maximum output. If you shift the signal generator by mistake away from resonance, all of the stages will be aligned off resonance. Before they are all properly adjusted each one may show these double peak characteristics and when the entire job is done the entire amplifier will show this characteristic. The work may be done more exactly by adjusting only one stage at a time with the signal generator at the input of that stage and the output indicating device at the output of that stage. This work is made more convenient where a tuning indicator is used simply by detaching the plate connection or removing all but one tube or the ones under adjustment. The tuning indicator in this case serves as the output indicator.

Some superheterodyne receivers used variable coupling arrangements for the IF, which serve to allow individual settings of coupling for various degrees of fidelity. In general, these circuits are constructed so that their minimum coupling settings are always equal to critical coupling to allow for maximum selectivity for which the receiver is capable. In this case, the fidelity control is adjusted for maximum selectivity and all of the stages are single-peaked as explained formerly.

It will be interesting to note just how this minimum coupling is attained for various arrangements. In Fig. 20, a tertiary winding L3 with its trimmer C3 has a resistance in series with it and is mounted between L1 and L2. As the resistance R in this circuit is *increased* the selectivity is increased, as there is much less coupling between L1 and L2. This maximum resistance setting should be used for alignment of C1 and C2. Without changing the signal generator setting, but reducing R until a barely noticeable change in output is discernable, adjust C3 for minimum output within the resonant zone, that is, between the two peaks formed by reducing R.

A third winding is often used as in Fig. 21. A switch is provided in the grid input circuit so that the winding may be switched in or out for high or low fidelity. When in the circuit, tuning is broadened and fidelity is high while out of the circuit fidelity is low and selectivity is sharper due to lower coupling. Without the coil L3 being in the circuit, the coupling is at the critical value. This, then is the position of the switch for alignment purposes.

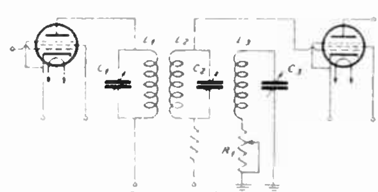


FIG. 20

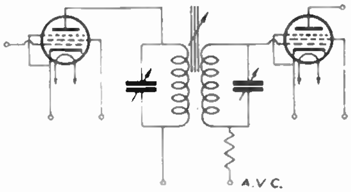


FIG. 21

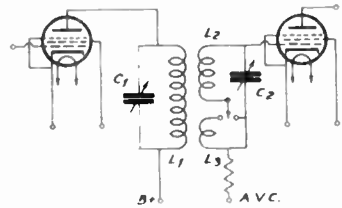


FIG. 22

The permeability method of varying coupling is illustrated schematically in Fig. 22. As the core material is moved out of the windings, whatever its material may be, the coupling is reduced. All the way out, the transformer is designed for critical coupling. At any other position the fidelity is better while the selectivity is lowered as over-coupling is obtained. Adjustments must all be made at minimum coupling where the selectivity is greatest and in general *single-peak characteristics are obtained*.

The IF transformers used in radio receivers may vary somewhat in size and shape depending upon the application and the type of circuit in which they are to be used. One example of this is the miniature IF transformer designed for use with printed wiring. These units are usually designed for machine mounting and dip soldering. They have built-in silver mica tuning capacitors and printed wire coils. The whole transformer can thus be made very flat. Another type of IF transformer which is being used is shown in the circuit of Fig. 23. This is the schematic diagram of the IF and detector circuits of an all transistor radio receiver built by the Raytheon Mfg. Co.

The three IF transformers are very small in keeping with the design of the receiver. They can be of fewer turns and smaller wire since the current through them is very low. This

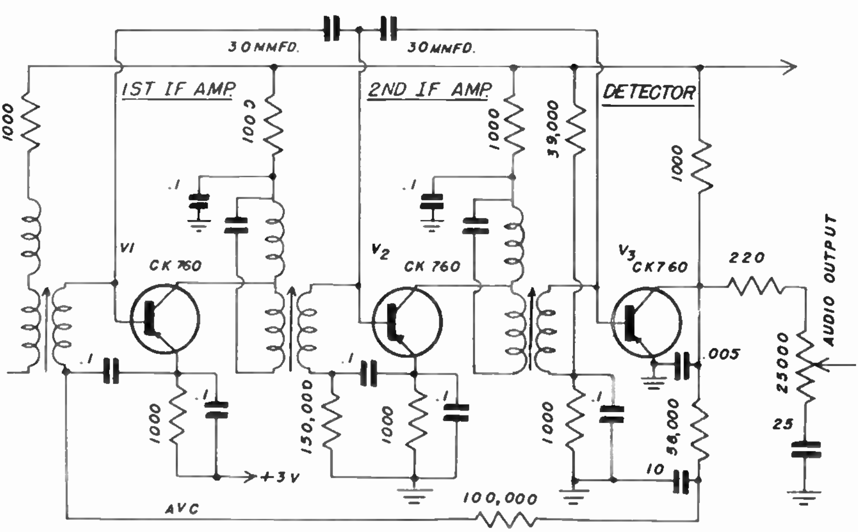


FIG. 23

particular receiver operates on a 6 volt battery made up of four 1.5 volt cells. The emitter of the first IF transistor is connected through the 1000 ohm resistor to the 3 volt tap of the battery. The B plus circuits to the collectors is connected to the 6 volt tap. The positive terminal of the battery is grounded in this receiver. The IF transformers are tuned by means of the adjustable core and the 125 mmfd. fixed capacitors. It is interesting to note that neutralization of the IF amplifiers for this radio is necessary. This is because the transistors exhibit regenerative properties similar to the triode vacuum tube. Neutralization is accomplished by means of the 30 mmfd. capacitors which feed back energy from the base of the second detector (V3) to the base of the first and second IF transistors.

The alignment of this type of receiver is essentially the same as for one using vacuum tubes. These are all basic IF circuits and the procedures apply to almost all types of radio receivers. There are of course few exceptions but these still follow the same general procedures. In some instances you will find receivers which are really too selective for high fidelity reception if correctly aligned to peak at resonance. Some. as in Fig. 23. are provided with a means for over-coupling of the transformer windings and some are not.

For the first type, align exactly to resonance and adjust the coupling between the two coils for a double peak response by shifting the signal generator setting each side of resonance, noting the double peak characteristics. If the original alignment has been done correctly with the coupling at the critical value or below, the signal generator should be set exactly to the IF and the coupling adjusting screw turned in the *increasing coupling* direction until the signal output drops 5 or 10%. It will also drop in the decreasing coupling direction as the energy transfer will be decreased. The coupling change can be determined either by shifting the signal generator off resonance or by inspecting the transformer being adjusted. If the signal rises after adjustment in either direction of signal shift even slightly. over-coupling has been acquired. while if it drops. the coupling is the critical value or lower.

Now in the case where no coupling adjustments are available. an entirely different method is advised for improving fidelity. A receiver which has too high selectivity may be identified by a characteristic *hissing* or *rushing sound*, as it is being tuned in to a station and by its failure to reproduce high frequencies when tuned in. This *hissing or rushing* noise remains with the signal unless AVC equipped and if so equipped. the lack of good fidelity may not be noticed.

Of course, in any superheterodyne there will always be a certain amount of this *hissing*, due to emission modulation, but experience with receivers will soon familiarize you with this defect. Its remedy lies in a special method of adjustment, wherein at least two of the trimmers are purposely thrown off resonance. One trimmer is tuned about 2½ to 3 KC above resonance, while the other is tuned the same amount below resonance. This method of broadening the tuning characteristics of the IF stages is called *staggering* the stages.

This system is used in most television receiver video (picture) IF amplifiers.

If the receiver has been found to be too selective, adjust the signal generator to 2½ or 3 KC *below reso-*

nance of the IF. This must be done as accurately as possible. Now adjust the trimmer in the plate circuit of the last IF stage for maximum signal. Next, tune the signal generator to 2½ or 3 KC *above resonance* with the IF and adjust the grid trimmers for the last IF or the plate trimmer of the preceding IF winding for maximum signal.

It will be observed that the sensitivity of the receiver is slightly reduced, but the fidelity is thereby improved greatly. It should never be necessary to adjust more than two trimmers in this way. Moreover, these two trimmers should be in different transformers, not in the 2nd detector input, but otherwise as near the 2nd detector as possible. Either plate or grid trimmers may be adjusted as described.

If there are only 2 to 3 trimmers, the possibility of loss of fidelity due to sharp tuning is very unlikely as this requires a good many stages. Therefore, there will always be a sufficient number of trimmers to pick from for this adjustment. For each trimmer out of tune there should be at least one in tune, and usually there are more.

Quite rarely regeneration will be found in pentode IF circuits. If so, adjustments are available for their setting. A typical circuit is shown in Fig. 24. For the proper adjustment of Cr, the regeneration control condenser, the signal generator must be turned to the lowest possible minimum signal which can be just detected at the

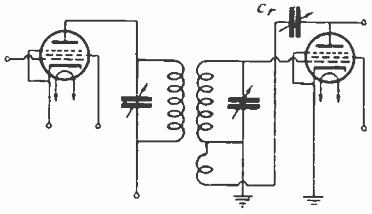


FIG. 24

output with the receiver's volume control at maximum. Turn the adjustment screw of Cr in until a heterodyne *squeal* is heard and then turn back until it is absent. Turn it another quarter turn outward toward lower capacity and the proper setting will be obtained.

On rare occasions too, you will find receivers equipped with beacon oscillators for accurate tuning. While you have the signal generator set up for IF alignment this may be adjusted. Turn on the beacon oscillator by the push button or switch provided and listen for a heterodyne. Then adjust the beacon oscillator trimmer for zero beat.

Oscillator Alignment

In any superheterodyne the adjustment immediately following alignment of the IF must be for the oscillator. The signal generator output connection is now shifted to the antenna-ground connection of the receiver using the LOW or attenuator connection so that the signal input may be lowered any amount desired. Except for the provisions for stopping AVC action, working below the AVC threshold level or taking advantage of any tuning indicator that the receiver has, the entire circuit is restored for normal operation. The output meter is, of course, left connected in case there is no tuning indicator to work with. For this adjustment the following must be done: Turn off AFC control; tune to lowest fidelity (*sharpest tuning*) setting; set volume control to lowest position consistent with a readable output on the meter. If you are working below the AVC threshold level the receiver volume control will be near maximum.

Now in the conventional oscillator there are but two adjustments to be made for each band. For some of

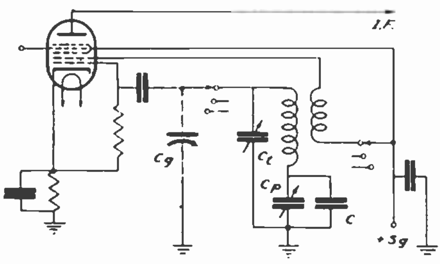


FIG. 25

the bands there may be only one adjustment as will be explained. You may start with the broadcast band, although the separate tuning bands may be aligned in any order as the adjustments are relatively independent.

A typical oscillator circuit for a multiband receiver showing connections for only one band is shown in Fig. 25. Note one variable condenser, Cg, which is the oscillator section of the gang tuning condenser; Ct, which is connected in shunt with the gang section Cg on this band and Cp, which is in series with the oscillator grid coil. The latter is shunted by C so that the total capacity here may be quite large and yet the variable part of the capacity Cp is still effective.

As you have learned in previous studies, as condenser Cg is reduced in capacity, Ct becomes more and more important as the tuning agent of the circuit and its adjustment becomes more critical. Therefore, set the signal generator to 1400 KC—tune the receiver dial to exactly 1400 KC, and adjust trimmer (Ct) for maximum output. Ordinarily you would not need to adjust the RF trimmers because they would be close enough to allow sufficient signal through for this adjustment. However, if you like you can adjust the RF trimmers also at this time. The final adjustments for these come later.

In many receivers, especially those using IF values below 200 KC there will be two possible adjustments at 1400 KC, which will produce a maximum output. One will be where the trimmer is nearly closed (adjustment screw near maximum turned to the right) and the other will be obtained with the trimmer condenser more open (adjustment screw turned out or to the left). It is this left-hand or out setting which must be chosen. Therefore, turn the adjustment screw all the way out (counterclockwise) being careful that you do not disassemble the trimmer condenser and adjust by turning it in to the right (clockwise) until the first maximum output setting is reached. In this way the wrong setting will be avoided.

Next, tune the signal generator to 600 KC and tune the receiver dial to *resonance with it disregarding the dial setting.* It is at this frequency that the *oscillator padding* is done as a rule, although some manufacturers may advise some other frequency at the low frequency end of the dial. Where no advise is available from the manufacturer, you are perfectly safe in using 600 KC for this work.

At this setting the padding condenser Cp in Fig. 25 is adjusted in connection with the moving dial. To clarify this action, assume that Cp is somewhat out of adjustment. If the total capacity (Cp + C) is too high in value the IF will be low, but *will increase toward the correct value as the dial is tuned to higher frequencies.* For example, the intended IF or 175 KC may be 155 KC at a dial setting of 500 KC; 160 KC at a dial setting of 600 KC; 165 KC at a dial setting of 670 KC; 170 KC at a dial setting of 750 KC and so on. Thus while you tune toward the high frequencies

This photo shows a model 288X Hickok crystal controlled signal generator. It is of the combination type providing both AM and FM (amplitude and frequency modulation) outputs. This instrument may also be used in connection with an oscilloscope for adjusting wide band, high fidelity tuned circuits.

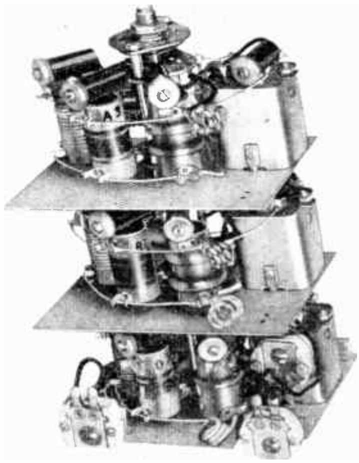
various RF signals will be favored.

Now, if at 600 KC on the dial you set the receiver oscillator for maximum signal output, this will not necessarily mean that the IF is proper, because you have altered the oscillator total capacity with regard to the RF section which requires another adjustment. You may not have achieved the correct IF, but simply one which will show maximum signal for two maladjustments.

Therefore, in the adjustment the entire gang condenser must be *rocked* frequently each way (moved rapidly each side of resonance) until the combination of padding adjustment and dial setting produce the maximum possible output. The actual tuning dial figures may be 10 to 40 KC off from the proper scale marking or the dial pointer may indicate the exact frequency. At any rate, the receiver dial markings must be entirely disregarded for this low frequency adjustment. After the maximum output has been established the dial scale may be shifted to make the index marker fall at exactly 600 KC.

If the adjustments are good enough to begin with, this may be done first as you must now go back to 1400 KC and re-set the RF and oscillator trimmers as described. The oscillator adjustments are then completed for this band.

Switch the band selector switch to the next band and repeat the same process where both trimmers and padders are provided. In many of the short wave bands the padders for the oscillator will be omitted as the oscillator grid coils are wound with less inductance and will track well enough without a special padder adjustment. Where the manufacturers recom-



In the above photo a compact multi-band tuning unit is shown. A switching system is used which shorts or grounds the tuned circuits not in use for a particular band. Trimmer and padder condensers for each band are mounted on the assembly and they are adjusted just like those for a single band receiver with the exception that different frequencies are involved.

mendations are available for the frequencies at which trimmers should be adjusted, they should be followed. If they are not available, it will be safe to select frequencies about 10 or 15% from either end of the dial for each band for the tuning adjustment.

The dial designs are usually such that if the tuning scale is shifted properly for the broadcast band, they will also be correct for other bands. The dial scales are most commonly made in one piece and each scale cannot be shifted independently.

It may be found that the dial scale will be too long or too short for the correct band coverage of the receiver in which case the instructions for padding and aligning the RF system of the receiver as given in a previous lesson must be followed. The correct frequency or electrical alignment, however, is much more important than the dial indications and in the

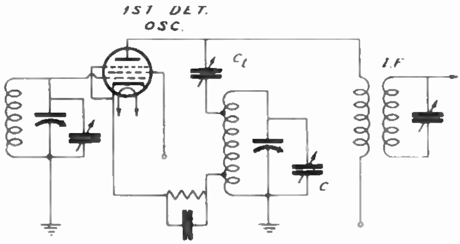


FIG. 26

majority of cases it will come out very nearly correct anyway if the work has been done as specified.

No special attention need be given to the oscillator circuit or tube except that the trimmers and padders be clearly identified. These are best located from information supplied by manufacturers or may be traced in the circuit from a knowledge of the conditions as outlined.

Circuit Variations

A few of the more common variations of oscillator circuits are given herewith to assist you in identifying the various circuit parts. In Fig. 26 the primary of the IF transformer appears to be untuned. The condenser Ct serves this function along with its action to feed-back energy from the plate to the cathode for producing os-

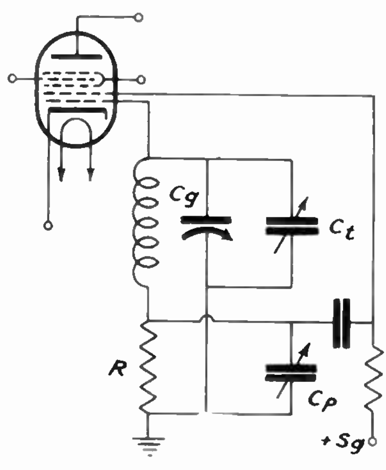


FIG. 27

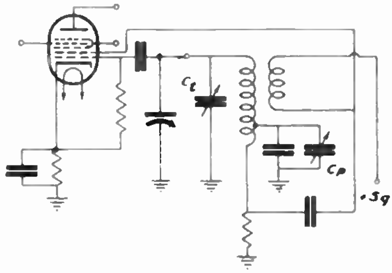


FIG. 28

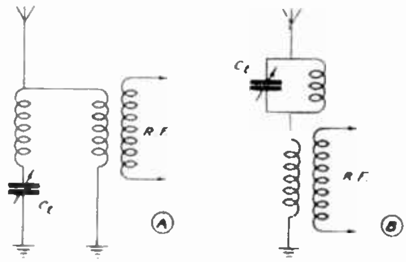


FIG. 30

cillation. It is adjusted along with the other IF trimmers.

The arrangement in Fig. 27 is almost self-explanatory. The high frequency trimmer Ct is in shunt with the oscillator gang tuning section Cg while the *low frequency* padder Cp is in series with the coil to ground.

Often you will find the padder connected at some tap on the oscillator grid coil as in Fig. 28. Once you recognize this as a padding condenser (Cp) for low frequency alignment, it is adjusted as usual.

In the circuit of Fig. 29. the high frequency oscillator trimmer has been shifted over to the AFC coupled circuit and still tunes the oscillator grid coil L1 by induction. The other condensers are marked as usual. While such oscillator circuits are almost endless in variation, they all follow the basic principles as shown in this lesson.

The RF System

The adjustment of the RF system of a superheterodyne is not entirely unlike that for a TRF circuit. The use of the superheterodyne, however, introduces certain other circuit arrangements unnecessary for the TRF type of receiver. These are chiefly the IF wave trap or rejection circuit.

The IF wave trap is simply a tuned circuit adjustable by varying its capacity which is the regular type of IF trimmer or by varying its inductance by moving its center core material if it is of that type. It is wired as in Fig. 30 at either A or B. At A, the unwanted signal of IF value is shunted to ground while at B it is isolated, due to the extremely high impedance offered to it by the circuit (parallel resonance).

For adjustment, therefore, leave the signal generator attached to the antenna-ground connection and the output indicator just as for the oscillator alignment, but set the signal generator exactly to the IF frequency and adjust trimmer Ct in Fig. 30 for *minimum signal output*.

The customary RF input circuit is

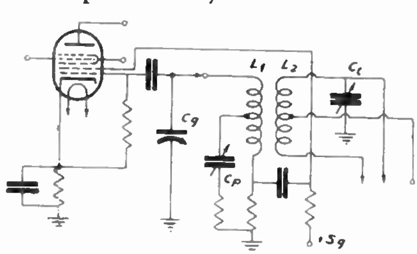


FIG. 29

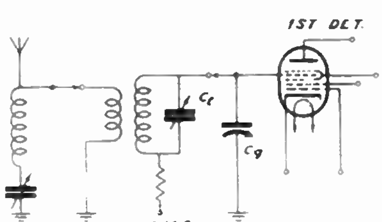


FIG. 31

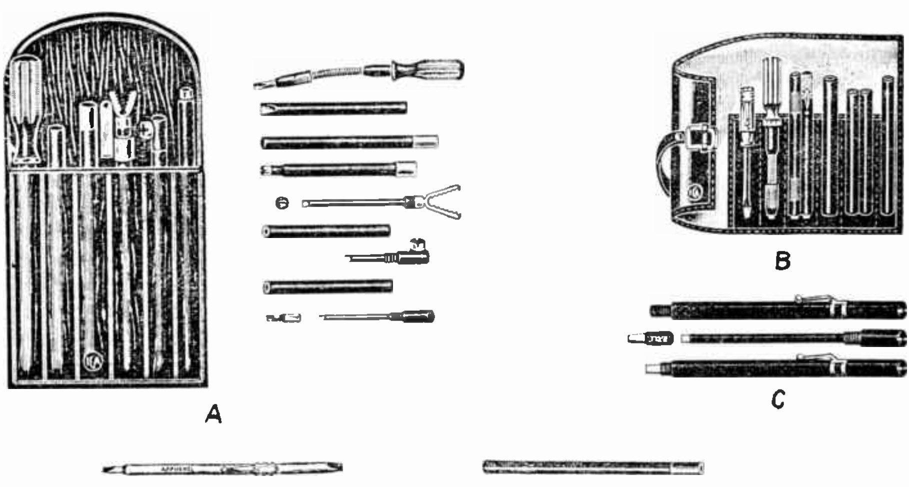
shown for one band in Fig. 31. While there will be variations from band to band, the essentials shown will be maintained. Note as in the oscillator circuit the RF trimmer Ct is separate from the gang unit Cg. It is adjusted for maximum signal at 1400 KC for the broadcast band and all of the other RF trimmers *for the other bands* are adjusted for maximum signal within 10 or 15% of the highest frequency to which the stage is designed to tune.

The Tuning Wand

Shifting of the signal generator output an equal amount below and then above resonance as a test of good alignment is possible, but requires some time to accomplish. A rapid check of alignment without shifting the signal at all and having the advantage of selective testing of each stage separately is possible through the use of a special tool known as the *tuning wand*. This is more applicable to RF and oscillator coils than IF coils, although it can be used with either.

The tuning wand consists of an insulated rod 6 to 7 inches long loaded at one end with iron filings and with a brass or copper cylindrical ring at the other end. When the metal ring is placed inside an RF coil, the inductance of the coil will be *decreased* and without changing the tuning condenser or trimmers the signal should reduce and it will reduce in volume if the stage is properly aligned. If the signal rises when the metal ring end of the wand is placed in the coil, it is an indication that the tuning or trimming capacity is *too large* or *too high* in value and must be reduced.

Now when iron filings are placed in the center of the coil's field the inductance of the coil is *increased* and without changing the condenser settings, the signal will reduce if previously set correctly. If the signal increases, it indicates that the capacity is too low and should be increased.



Here is shown an assortment of tuning alignment tools not all of which are required by the serviceman. At A and B is shown two types of neutralizing and alignment tool kits. At C is shown a five-in-one fountain pen style alignment tool. At D is shown a high frequency tool for short wave circuits and at E is shown one type of tuning wand.

Now very rapidly each end of the tuning wand can be placed in each coil, noting the output volume level. If the output reduces for each test and for each coil, the tuning is correct. If not, the trimmer capacity may be adjusted as explained in the foregoing. Those coils whose trimmer condensers are out of line may thus be quickly identified.

Intermediate frequency coils are usually mounted in metal cans and are not accessible for this test. Otherwise, they will respond in the same manner. To avoid the possibility of high fidelity circuits destroying the effect of this test, it is always best to set the fidelity adjustment to the position of minimum fidelity or highest selectivity while making this test.

Tuning Adjustment Tools

There being considerable variation in mechanical arrangement from one receiver to another, it is only natural to expect that a number of special tools must be used in many instances.

There are many trimmer, padder or other alignment adjustments which cannot be reached *straight in or straight down vertically*. The design of such receivers involves some part or shield in the way of the adjustment tool. For this job, a *right angle* wrench or screw driver must be used. Both of these tools are part of every complete set of alignment tools.

For turning a *hex nut or bolt head* continuously, a latitude or space of at least 60 degrees must be available so that when the wrench handle comes to the end of its turning arch it may be removed reversed 60 degrees and set on the nut or bolt head for another 60 degree turn. Very often this much turning space is not available for the wrench handle. Here is where an alligator wrench must be used, which will catch on corners of the nut or bolt head every few degrees, so that adjustment may be done in a very confined space. Tools of this type are made for cases where an ordinary pair of pliers would not fit and where long nose pliers would not do the job because of their flat surface. In still other instances the holes provided in the shields for adjusting the trimmers are smaller than average and a special small shaft insulated tool is required.

Some alignment condensers are provided with an adjustment bushing with a *hex socket* into which a hex head fits for alignment. This hex head may be obtained as a separate tool with handle or as an attachment for a standard socket set. Others are provided with an adjustment flange which can be turned only with a saw-slit type end wrench. This is just opposite to the conventional screw driver and bolt head. The bolt head is on the tool while the screw driver *bit* is on the adjustment screw.

Attention is again called to the fact that all of these adjustment tools should be made of insulating material, and that during any and all adjustments of any receiver all shields and covers must be properly in place. Such alignment tools as have been described may be obtained from all radio parts jobbers.

Adjustment Resume (Summary)

Having covered all of the details of adjustment a complete procedure may be given by which every superheterodyne may be properly adjusted. The following summary of the procedure is in outline form and includes all possible circuit conditions. They are to be used only where the receiver in question has these facilities. Where not used the instructions may simply be disregarded.

ADJUSTMENT PROCEDURE SUMMARY

I. IF Adjustment:
   1. Attach signal generator to IF input circuit.
   2. Attach output meter.
      (a) Use Tuning indicator.
      (b) Output meter connection.
   3. Determine IF and set signal generator to this frequency.
   4. AVC
      (a) Operate receiver below AVC threshold level.
      (b) Suppress AVC action.
   5. Block out muter action.
   6. Turn AFC switch to out position.
   7. Turn fidelity control to selective position.
   8. Block out oscillator if it interferes.
   9. Peak all trimmers from 2nd detector to 1st detector.
   10. Adjust over-coupling by setting fidelity switch to low, shifting signal generator.
   11. Adjust highly selective receivers by staggering the tuned stages.
   12. Adjust variable coupled receivers by coupling adjustment and shifting signal generator.
   13. Neutralize IF.
   14. Adjust regeneration.
   15. Check alignment adjustments again.
   16. Adjust beacon oscillator.
   17. Adjust AFC.

II. Oscillator Adjustment:
   1. High frequency adjustment.
      (a) Attach signal generator to antenna and ground of receiver.
      (b) Set signal generator to 1400 KC unless otherwise instructed.
      (c) Set band switch to broadcast band.
      (d) Tune in signal and adjust oscillator and RF trimmers to peak.
      (e) Note dial position.
   2. Low frequency adjustment.
      (a) Set signal generator to 600 KC unless otherwise instructed.
      (b) Rock tuning condenser gang and align for peak with padder condenser.
      (c) Note dial scale and index and shift as necessary.

III. RF or Preselector Adjustment:
   1. Adjust high frequency trimmers to peak at 1400 KC unless otherwise instructed.
   2. Band sensitivity.
      (a) Adjust stator plates by moving if necessary.
      (b) Adjust fan segments every 100 KC or at every sector.
      (c) Check adjustments with tuning wand.

IV. All-Wave Adjustments:
   1. Repeat items II and III for each band at 10 or 15% from each end unless other frequency values are specified.

* * * *

While this outline or summary covers every possible circuit, you may never make use of all of them on any one circuit. For example, on a simple AC-DC superheterodyne you may use only items 1, 9 and 15 of I; 1a and 1b of II and 1 of III. For others you will use another group of adjustments, depending on the design of the receiver.

A Typical Alignment Procedure

As mentioned at the beginning of this lesson, the tuning alignment procedure for a superheterodyne is much more complex than that of a TRF receiver. The alignment of a superheterodyne receiver requires not only a knowledge of the methods of making the particular adjustments but also a very thorough understanding of the operating principles of the receiver; and with some of the more elaborate test instruments it requires considerable knowledge of the equipment to be used for the alignment. It isn't the object, however, of this lesson to discuss the more elaborate methods of alignment. These methods will be given due consideration in a later lesson. They are mentioned here so that the student will not get the impression that the method outlined here is the only method used in aligning superheterodyne receivers. It should be pointed out, however, that the methods of alignment given in this lesson are used more often than the other more elaborate methods. The receiver to be used in this discussion is the RCA model 17K. This receiver is a three band 7-tube receiver of standard design.

Figure 32 shows a schematic diagram of this receiver. The tubes used are indicated in the diagram. The RF amplifier is the first 6SK7 tube at the left, the 6SA7 tube is the 1st detector and oscillator. The second 6SK7 tube is the IF amplifier. The 6H6 is the second detector and the last two tubes, the 6SF5 and 6K6, make up the audio section of the receiver. This receiver is equipped with a push-button tuner and has a phono-tel jack for introducing a phonograph pickup for playing records through the radio. This jack can also be used to adapt the receiver for television AM sound reproduction. There is a special in-

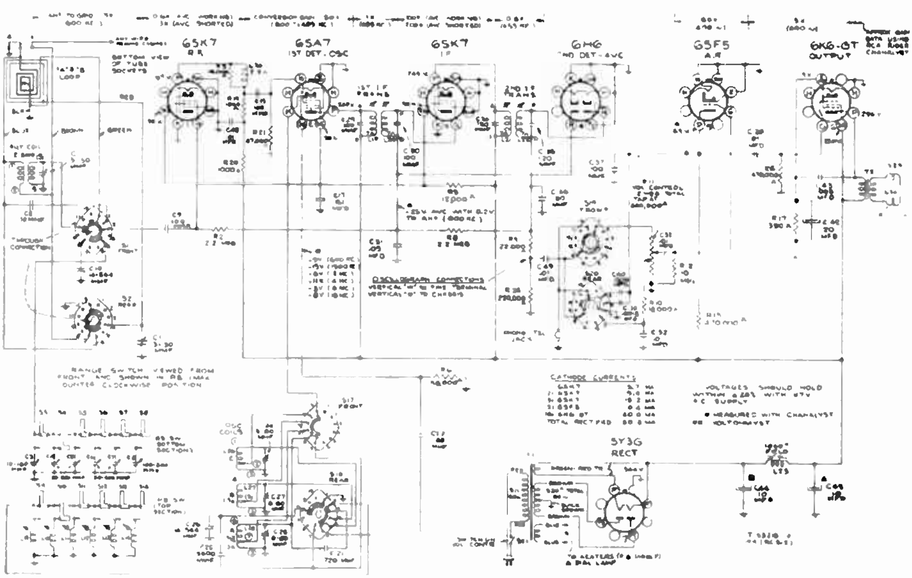


FIG. 32

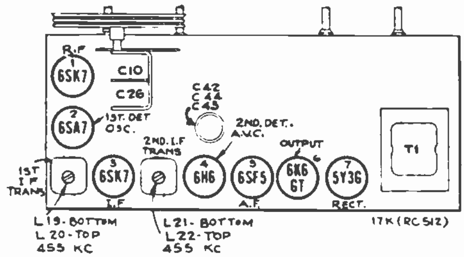


FIG. 33

stalled antenna in the cabinet of this receiver, thus an outside antenna isn't necessary. This antenna is used as part of the RF coils on two of the bands. The push-button tuning circuit of the receiver is located in the lower left hand corner of the diagram.

The first step in making a receiver tuning alignment is to allow plenty of time for the receiver and signal generator to warm up before making any adjustment. While they are warming up make sure that all shields of tubes and coils are in their proper places and clamped down where they should be. The next step is to determine which section of the receiver should be aligned first. The IF section of a superheterodyne is always aligned first, starting with the last stage and working forward towards the antenna stage. Thus the last IF transformer is aligned first.

It is important to properly connect the signal generator to the receiver for each stage of the alignment procedure. These connections vary some from receiver to receiver.

The correct alignment procedure as given by the manufacturer of this RCA receiver is as follows. After allowing plenty of time for the receiver and signal generator to warm up to operating temperature, connect the signal generator to the grid of the 6SK7 IF amplifier tube and connect an output meter across the voice coil of the speaker. The low side of the signal generator output leads should be connected to the receiver chassis and the high output lead of the generator should connect to the grid of the 6SK7 IF tube through a .01 mfd. condenser. After all connections are made, tune the signal generator to 455 KC which is the IF frequency of this receiver. Now tune the receiver to a quiet point near the low frequency end of the dial, and adjust L-21 and L-22 of the 2nd IF transformer for maximum (peak) output. The location of the adjusting screws, which in this case are the cores of variable inductors, is shown in the chassis layout of Fig. 33. They are also shown in the schematic diagram of Fig. 32. This IF transformer is the iron core type. L-22 is adjusted first, then L-21. After L-21 is adjusted recheck L-22 and then return to L-21 again. Continue this until you are sure you have the peak setting of both adjustments.

Next disconnect the lead of the generator from the grid of the 6SK7 IF tube and reconnect it (leaving the .01 condenser in series) to the 6SA7 control grid (pin No. 1). Now adjust L19 and L20 for maximum output in the same manner as L21 and L22 were adjusted. When these four adjustments are made, the IF amplifier is correctly aligned. The dial of this receiver is fastened to the cabinet and when the receiver chassis is removed from the cabinet for alignment there is no dial to indicate the correct setting of the frequency. One way to overcome this is to remove the dial scale from the cabinet, by sliding out the two spring pieces which clamp it in its mounting position. The tuning condenser plates should then be turned into full mesh. The pointer should be adjusted to the scratch line at the left end of the dial backing

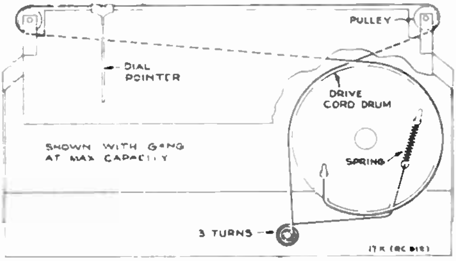


FIG. 34

plate and the dial slipped under the pointer so that its extreme left calibration mark coincides with the pointer. The dial may be held in place with scotch tape. In this manner the actual receiver dial is used for the alignment. When the receiver is aligned the dial should be replaced in the cabinet with the fibre light shields, which are folded under the ends of the glass scale. Figure 34 shows the chassis dial pulley assembly of the receiver with the dial pointer in place. It is obvious from this diagram how the dial is to be mounted. See Fig. 36 for a view of the actual scale.

Another method is to calibrate a scale and attach it to the tuning drum of the tuning condenser. This scale is just a 180° scale marked in degrees. The position of the scale should be adjusted in such a way that the zero degree mark on the scale is horizontal when the gang tuning condenser is in full mesh. A pointer of some kind should be improvised for indicating the position of the condenser upon the scale. A piece of wire mounted on the chassis and bent so that it points to the 0 degree mark on the calibration scale when the plates of the tuning condenser are fully meshed is sufficient. The alignment procedure to follow will give both settings—one for the regular dial and one for the improvised scale in degrees. Next connect the signal generator to the antenna terminal in series with a 47 mmfd. condenser and then set the signal generator to 15.2 megacycles and turn the receiver dial to 15.2 mc. (If an improvised scale is used, turn to 149°). Adjust C24 the oscillator trimmer of band C and C1 and the RF trimmer of the same band for maximum output. While making this adjustment, rock (rotate) the variable tuning condenser back and forth across the 15.2 mc mark, making sure that the maximum adjustment is obtained at this point on the dial. Use minimum capacity peak of C-24 if two peaks can be obtained. To check that C24 has been adjusted to the correct peak, tune the receiver to approximately 14.29 mc with signal generator still set to 15.2. If it is correct, a weak signal should be received. 15.2 mc is the image frequency of 14.29 mc on this receiver.

Figure 35 shows the location of RF trimmer and padder screws upon the receiver chassis. The next step is to align band B. Connect the signal generator to the antenna terminal through a 200 mmfd. condenser. With the generator set at 2.44 mc turn the receiver dial to 2.44 mc or to 97° on the improvised scale and adjust the oscillator trimmer C27 for maximum output.

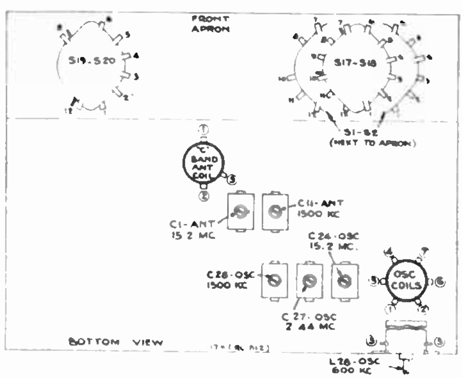


FIG. 35

To align band A which is the broadcast band, leave the signal generator connected as for band B but set it on 600 KC. Now turn the receiver dial to 600 KC or to 30.5° on the improvised scale. Adjust L28 to maximum while rocking the variable tuning condensers back and forth slightly across the 600 KC dial marking, making sure that the peak tuning is obtained at the 600 KC setting. This tunes the low frequency side of the broadcast band. The next step is to align the receiver at the high frequency side of the broadcast band. With the signal generator still connected as before, adjust it to 1500 KC and turn the receiver dial to 1500 KC (158° on the improvised scale) and adjust C28, oscillator trimmer, and C11 RF trimmer to maximum output as indicated by the output meter. After this is done, repeat the last two steps. When this is done the receiver should be completely aligned on all bands.

The alignment of the RF and oscillator section of this receiver is the reverse of most alignment procedures but as it is the method recommended by the manufacturer, it should be followed. As mentioned before the correct procedure to follow is the one recommended by the receiver manufacturer.

After the alignment is completed, disconnect the signal generator and tune in several stations noting that they come in at the right position of the dial.

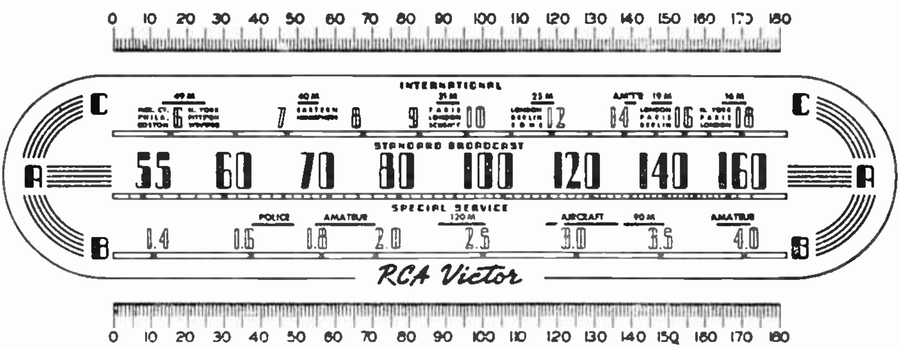


FIG. 36

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

Questions

No. 1 Why is it not desirable to connect the output of the signal generator to the plate circuit of the first detector of a superheterodyne?

No. 2 In what order or sequence should IF trimmers be adjusted for best and quickest results?

No. 3 Why should a series coupling condenser be used in a signal generator output lead for attaching to a grid or plate circuit?

No. 4 Why cannot tuning alignment be done with the AVC circuit operating normally?

No. 5 In what way can tuning alignment be carried on without altering the AVC circuit in any way?

No. 6 In a receiver having IF wide band selection, should alignment peaking be done on the high fidelity or the high selectivity position of the selectivity switch?

No. 7 How may the tuning characteristics of a multistage IF amplifier be broadened if there is no provision for it in the original design?

No. 8 Should you be guided by the station selector dial markings in making RF adjustments?

No. 9 Is the padder adjustment all that is necessary for alignment at low frequencies in an oscillator circuit?

No. 10 If one end of the tuning wand placed inside an RF coil increases the output, is the stage correctly aligned?

ADJUSTMENTS FOR AUTOMATIC TUNING CIRCUITS

LESSON TV-9

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

USE OF PUSHBUTTON TUNING WIDESPREAD

The desire of the American public for conveniences and automatic devices has firmly entrenched push button operation in the radio and television field. There has been a gradual development of automatic devices as applied to radio receivers over a period of years and it was natural for this to extend to television and FM receivers. Thus, as in any development stage, improvements have been made over the years and as a consequence many types of automatic tuning devices will be found on the receivers which you will be called upon to service. It is for this reason that we have included in this lesson the older types of automatic systems as well as those of a more modern vintage. It follows that the older types will probably require more servicing than the later types and this, of course, is important to you because it is part of your job to keep such receivers in good repair. Thus while it may not seem necessary to you to regard these older automatic tuning systems as important, yet you should keep in mind that you probably will be called upon to service them most often. Looked at from this viewpoint, you will see that they can be a lucrative source of income from a repair and maintenance viewpoint and as such you need, of course, to study them and so be prepared to handle them in an efficient manner. Many of the earlier types of automatic tuning systems made use of small electric motors wherein the main gang tuning condenser was made to move by motor motion instead of by hand motion. These are subject to mechanical wear and in time usually become defective. However, there are only a few things that can go wrong with them and if the directions of this lesson are followed, you should be able to put any one of these motor tuning systems in first class condition. The more modern automatic tuning systems are usually of the push button type and as long as they are in good mechanical order about all you need do to them is to adjust the trimmer condensers or the adjustable iron core tuning coils. From time to time these get out of adjustment and often the owner will want the buttons readjusted to permit the reception of a certain station or stations not being received at that particular time. You are urged to study this lesson carefully so that you may become acquainted with the automatic tuning systems in general use.

SPRAYBERRY ACADEMY OF RADIO

CHICAGO, ILLINOIS

K 2542M

This view shows a modern receiver employing push button automatic tuning. The receiver is of the radio-phonograph type including recording facilities. Push button tuning may be found on all classes of receivers from the lower priced units to the most expensive types in use today.

ADJUSTMENTS FOR AUTOMATIC TUNING CIRCUITS

Lesson TV-9

Over the past few years the accurate tuning of radio receivers has been greatly simplified. At one time in the development of the RF and Neutrodyne receivers each tuned stage had to be adjusted by hand. This was a tedious process and few people actually learned how to correctly tune a receiver. Later it was found possible to gang together on one shaft all of the tuning condensers which a given receiver employed. This was made possible by using small trimmer condensers connected in parallel with each section of the gang. Thus. it was possible to adjust the trimmer condensers for capacity value and in that way small differences in each tuned circuit could be nullified. Later this same idea was extended to the superheterodyne type receiver and today virtually all receivers employ a single tuning control.

In addition to the single control tuning idea it was found advantageous from a sales viewpoint to even more simplify tuning and thus various automatic methods of tuning were developed.

The single manual control is still retained on modern day receivers and in addition automatic methods of tuning are also included. The first automatic methods of tuning took several forms. However, these have been standardized for most receivers to some form of push-button control. This lesson will describe most of the systems in general use and from the information given you will be able to repair and correctly adjust any automatic tuning system.

Do not be mislead in the following descriptions of the tuning systems into thinking they are difficult to adjust. While you may get this impression from studying the different systems in use, they really are very simple and are easy to adjust as you will find upon making the actual adjustment. Usually nothing more is required than adjusting a few screws for maximum volume of the output of the receiver as noted by ear or through use of an output meter. Thus while the tuning system itself may be complex (either mechanically or electrically) it is well to remember all of these complexities have been worked out for you in advance and in most cases you will be concerned only with adjustments.

For a thorough going study of automatic tuning systems, it will be advantageous to classify such systems. It will be most helpful to classify automatic tuning systems into two major electrical groups; (1) those which make use of the main tuning gang condenser for automatic station selection and (2) those which make use of auxiliary circuits.

Discussing item (2) first, there are two principle auxiliary circuits in common use; (a) adjustable trimmers and (b) adjustable permeability iron core coils. The first type involving the use of the tuning gang condenser includes three main variations; (a) hand operated with selector dial, (b) hand operated with push-buttons and (c) motor driven. Thus the tuning systems generally regarded as automatic may be considered in one of the following groups:

1. Tuning gang condenser types
   - (a) Hand driven with selector dial.
   - (b) Hand driven with push-buttons.
   - (c) Motor driven.
2. Trimmer types
   - (a) Capacity changes.
   - (b) Inductance changes.

Several years ago there appeared a push-button tuner on some few receivers. At that time, circuit development and techniques for adoption of this form of tuning were not as practicable as they are today. This was before AVC, or AFC or the general use of the superheterodyne circuit. It was before the present day need for high selectivity, due to the great number of stations operating.

The complications arising out of the very rapid development in radio broadcasting have brought about more precise and more extensive tuned circuits. The return to automatic tuning was ushered in through the development of AFC together with more precise techniques in manufacturing and assembly of receivers.

A Philco Type of Automatic Dial

This tuning arrangement makes use of a multi-section main dial geared down to drive the main condenser gang. It turns almost a complete revolution for each band range. It has 19 perforations set around in a circle and is provided with a crank and knob as well as a main knob for tuning. Behind each of the perforations is placed the call letters of a station. To automatically tune the circuit, the knob is slid around to the perforation for the desired station, pushed in and then rotated while being held in, to the bottom of the dial where it will stop. The knob is then released and the desired station is received.

This does not interfere in any way with the regular manual tuning of the dial. There is one blank space in the dial in line with the call letter designations which determines the direction in which the dial may be moved. The blank section cannot pass the bottom

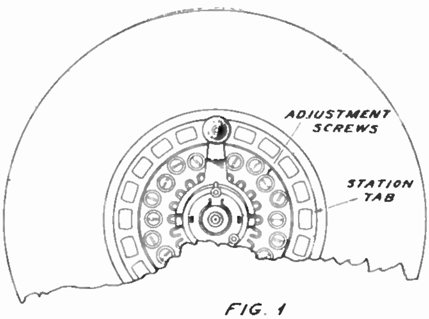


FIG. 1

center position of the dial. Therefore, if it is clockwise from the position of the station selected, the dial must be moved counter-clockwise and vice versa. The dial for manual or automatic tuning is always moved away from this blank section toward the bottom position of the crank.

Adjustment For Station Setting

A sectional drawing of the face of the dial is shown in Fig. 1. Note that for each of the station tabs, there is an adjustment or control screw. After adjustment, these screw heads are obscured from view by a cover plate.

For adjustment the receiver is tuned with:

1. The band selector in the broadcast position.
2. Magnetic tuning control (AFC) to the *out* position.
3. Fidelity control in the selective position.

Take the next following steps:

1. Remove tuning knobs.
2. Remove control handle cover (3 screws).
3. Replace tuning knobs and tune exactly to desired station.
4. Insert screw driver in control screw nearest to the bottom position.
5. Press in the control screw and turn it until a click is heard.
6. Adjustment of this screw will now turn the dial and in this way the station desired must again be tuned in perfectly.
7. Release control screw allowing it to spring out as originally found.
8. Insert station call letters in window adjacent to this control screw.
9. All other settings are made in the same way.

In some special cases. it will be found necessary to adjust the dial *away* from a powerful signal, that is, in the opposite direction on the dial, to avoid interference and to prevent the powerful station from influencing the AFC circuit.

Philco Cone-Centric Tuning

This is a semi-automatic tuning method for precise tuning. A tuning handle at the edge of the full vision dial is revolved around the dial. It is fixed to the finder and turns the tuning condenser gang. Outside of the frequency markings are station markings for easy reference. The tuning handle is stopped near where the finder hand points to the desired station and it is pressed in. This last operation causes a cone and socket to perfectly align the station setting.

Adjustment for station setting—the following steps will assure the proper adjustment of this tuning dial:

1. Turn receiver on and list the stations desired to be tuned automatically in order of frequency.
2. Select the lowest frequency station first and revolve the tuning knob until it is over the first tuning cone.
3. Press knob in to engage stop.
4. Insert special Philco wrench in the hole of the tuning knob. turning it counter-clockwise to loosen tuning cone.
5. Now revolve the tuning handle until station finder hand is on lowest frequency station desired.

6. Tighten tuning cone, remove screw driver and release knob.
7. Set all other stations in the same way in order of ascending frequency.

An IF oscillator may be used to accurately set the stations by the heterodyne method. An RF signal could be used, but the IF method is preferred, as it needs only one setting of the IF of the receiver for all stations. It may be coupled to the receiver in a number of ways, as explained elsewhere in your SAR course.

Emerson Automatic Dial

This dial (Fig. 2) provides a selection of 10 stations and is semi-automatic, that is, hand operated, but with a precise method of stopping the dial at the correct place. A station is tuned in by pressing a button on the dial marked with the desired call letters and rotating the dial, moving the button toward the top until it stops. The button is then released and the station is properly tuned in.

There is one large blank space between the buttons which determines the dial stop. Although it rotates 360 degrees, this blank area will not cross over the top dial position. Therefore, tuning must be done in such a way that this area need not pass the top position. Turn the dial in a direction always away from this blank area, but toward the top. The dial with its bakelite faceplate removed is illustrated in Fig. 2.

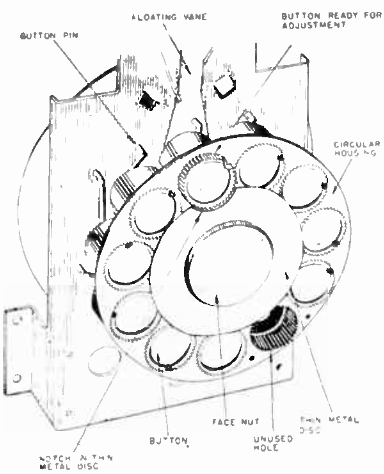


FIG. 2

Adjustment For Station Selector

The necessary steps to take to preset the automatic dial for station selection are as follows:

1. Slightly loosen the large central face nut under the dial cover so that the disc under it having a semi-circular notch in its edge may be rotated.
2. Tune in the lowest frequency station to be set, turn the disc until its notch releases the upper button.
3. Allow it to spring out and attach the station tab under its celluloid cover for the station being received.
4. Insert the button turned so that its pin in the back projects to the center of the floating vane at the top pushing it in until its teeth engage with the teeth in the dial.
5. The large notch in the buttons indicate the position of the pin when it is obscured from view. The notch in each button used must lie outside of the common center line circle of all buttons so that the pins will be stopped by the vane when pressed and rotated.
6. Holding the button, rotate the metal disc just enough so that it holds the button in place.
7. Test the setting by rotating the dial one way toward the top with the button pressed until it stops. Note the tuning. Release the button, turn the dial past the center, press the button

again, bringing it back to the top position where it will stop. If the tuning of the station is the same for each setting, no further adjustment is needed. If not, remove the button and set up again as before with the pin in a slightly rotated position.

8. Each successive button is set in the same way continuing with the next successively higher station.
9. With the dial placed in a horizontal position, remove the large center face nut, remove the metal disc and put the bakelite front plate over the buttons, making sure that its blank space is placed over the button not in use and that this is at the end of the dial where it will not cross the top center position.

Two buttons are provided with the receiver having longer than usual pins. They are intended to reach unusual positions of stations which the short pins will not reach. If there are 3 stations fairly close together, one of them will be found necessary for the proper setting. When to use one of these buttons can be determined by simply noting the setting of the dial for a station desired to be set and the distance from the button hole to the floating vane at the top of the dial.

Any buttons not used should be placed with their pins toward the center of the dial.

Wilcox Gay Automatic Dial

As for the other types of hand operated dials for semi-automatic station selection a button labeled with the call letters of the desired station is pressed and the dial is rotated toward the bottom position. The preset stop automatically locks. The station should then be correctly tuned.

The dial consists of 10 flexible fingers, each terminated with one of the buttons. It is shown in Fig. 3. Each button is actually the head of a locknut and provides a means of clamping a cam to the end of the finger. As shown, the cam may rotate about the button as a center, so that its end may cover any angle between itself and the next cam. Each cam is punched at the end to form a ball knob. When the button is pressed carrying the cam, it travels over a metallic surface in which a slot has been cut. When the rounded end of the cam falls into this slot, it locks the motion of the dial until the button is released. This dial is one of the simplest of all to set. Simply loosen the cam by unscrewing the button, tune in the desired station and turn the cam until its rounded end will fall in the slot. Holding the dial in this position, tighten the button and cam. The dial will be stopped near the bottom position, but not necessarily at the bottom center position. Obviously, the stations chosen for setting-up must be near enough the button so that its cam may reach the slot while it is in tune. All 10 stations are set up in the same manner.

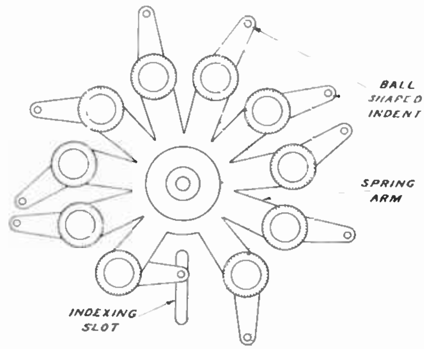


FIG. 3

Colonial Automatic Dial

The operation of this push-button dial is similar to the operation of those already described. A button is pressed and the dial is rotated so as to bring this button toward the bottom. Here it locks into a special latch which stops it accurately at the preset position.

Adjustment of Colonial Automatic Dial:

1. Turn dial locking lever (off center, but within circle of push-buttons) until buttons are released so that they may be pushed in beyond the *splined or serrated* sections where the individual button may be turned.
2. Tune in a station desired to be set-up and select the button nearest the bottom until its actuating pin locks into the latch gate at the bottom of the dial and allow the button to move outward until it engages the dial teeth where it cannot turn.
3. The same is repeated for each station to be set and there the dial locking lever is turned to the right so as to lock all of the tuning buttons in place in the dial so they cannot turn individually.

Trav-ler Dial

In the Trav-ler dial, the buttons are simply locknuts arranged in circular arc slots. There are 8 slots, 4 on one radius and 4 on a larger radius. The buttons have stop pins on them which when pressed project behind the dial to come in contact with a *floating vane.* This floating vane idea is commonly used so that the dial will be stopped at the same place in either direction of rotation. For a fixed stop and pin this would not be possible. Setting on one side would differ from that on the other by the diameter of the pin and width of the stop.

Stations are set by tuning them in, selecting a button near the bottom of the dial, unscrewing it, pressing it, moving it in the dial slot to the stop and tightening it in this position. Due to overlapping of the slots, eight stations on the dial may be set up if four of them are in adjacent channels to four others.

Erla-Sentinel

This button dial resembles mechanically the one just described, although the buttons are placed on the rim of the dial and they are adjusted by means of set screws which will tighten into the edge of the dial. Otherwise, the adjustment and operation of this dial is the same as for the one just described.

The Erla-Sentinel *tune wheel* is essentially the same, but using round knurled metal studs in the edge of the dial instead of push buttons. They are self-adjusted by turning to loosen or tighten.

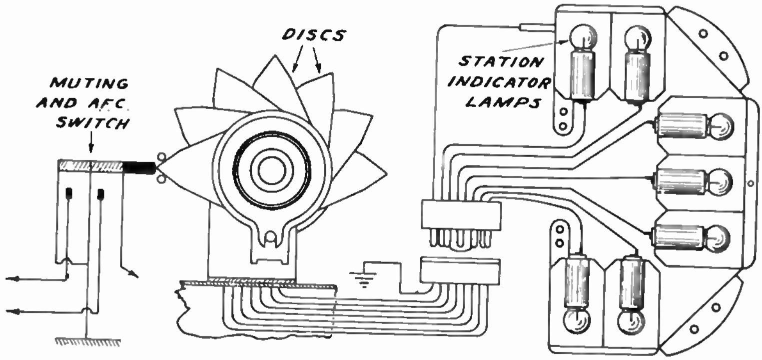


FIG. 4

Stromberg-Carlson Flash Tuning

A similar system is used by some of the Stromberg-Carlson receivers. The arrangement of the discs is shown in Fig. 4. In the tuning indicator models, discs with projections are spaced by insulating material on the tuning condenser extension hub. The projections on these present discs operate a switch system which controls the AFC, the audio muting and the flash tuning lamp. All of the discs are locked as in a multi-plate clutch by one nut.

Motorola Spot Tuning

A type of mechanical tuning indicator is used with this automotive receiver. At the chassis where the tuning cable enters there is a spring steel cylinder housing a threaded brass bushing. A steel ball retained in the thread by a lengthwise slit in the cylinder makes it follow the thread which turns with the cable. A station is tuned in and the steel ball is pressed into the bushing by means of clamping with pliers. When this point in the tuning range is again reached, the ball will drop in this depression and increases the friction of turning the dial at the points where it has been formerly pressed into the brass thread.

There are other forms of mechanical and spring latches or locks and magnetically operated latches. They are semi-automatic as they simply stop the hand operated dial at some prearranged setting.

Hand Driven With Push Button

This is a type of push-button tuning in which the operator does not rotate the dial, but simply pushes the button straight down. The buttons are arranged in a row or keyboard style and by means of a mechanical system, they rotate the tuning gang to the exact position for correct tuning. This arrangement consists of a lever mechanically similar to a typewriter key which actuates cams or *eccentrics* as they are sometimes called. These are tightened on the condenser shaft when the button is depressed to its maximum depth and the station desired is properly tuned in.

This system was used on some of the very early Zenith receiver models, but did not reappear again until other models were made. The Belmont *Belmonitor* tuning system is of this type. Set screws will be found for each cam and for each station to be set up, the cam is loosened from the condenser gang shaft by means of the set screw, and the station is tuned in with the push-button depressed. The set screw is then tightened and the station is set.

Unlike most of the button dial semi-automatic types, this type may be set for any eight or ten, etc. stations (depending on how many buttons are provided) even if they all occupy adjacent channels. The others are somewhat limited in this respect, although stations are usually separated in such a way as to make this unnecessary for general use.

Motor Driven Tuning Systems

In the electric motor driven types of tuning systems the basic electrical circuit of the receiver remains unchanged. No capacities are switched in or out and no inductances are changed. In many cases, however, the signal output is completely cut off during the tuning operation and in all cases where AFC is used, this is rendered inoperative during automatic tuning.

Push-buttons in these devices serve to control the operation of a small electrical motor. When a button is pressed the motor must start in the *correct direction* and its circuit must be automatically opened when the condenser gang reaches the proper position as determined by the button pressed.

Before going into the circuits of this automatic tuning method, it would be well to study the motors first to see by what methods they may be operated and reversed.

The majority of the motors used for this purpose are known as *induction motors*, which means that their armatures receive their voltage supply by induction as in the secondary of a transformer without any electrical connections. There are, therefore, no commutators or other electrical connections to the armatures. They are usually supplied with AC from a secondary of the power transformer at from 6 to about 25 volts.

To create a turning force for the armature, *a rotating magnetic field must be produced*. By this is meant a field, the direction of which changes throughout the AC cycle. The effect is the same as though you were to actually rotate a *motor shell* as in Fig. 5. Note the indication of *change of position* as shown by the dash lines of the motor shell. For the purpose of illustration, consider an iron cylinder as the motor armature (see Fig. 6) and as the magnetic field shell. From a study of Fig. 6, you will see that if the magnetic field shell was rotated, that the direction of magnetism within the armature would change throughout the cycle of rotation of the field shell exactly as shown by the N and S poles. When the field shell is moved 30 degrees, the magnetism would be impressed at 30 degrees from the vertical. Just why and how the armature rotates in this way will be described shortly.

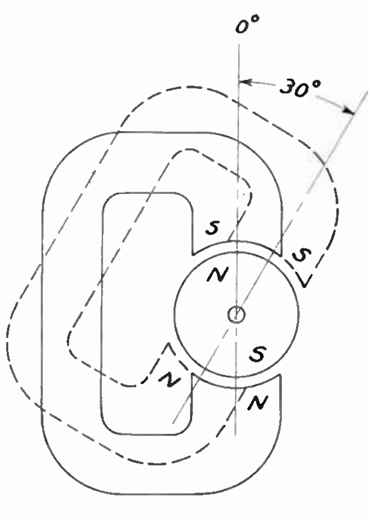


FIG. 5

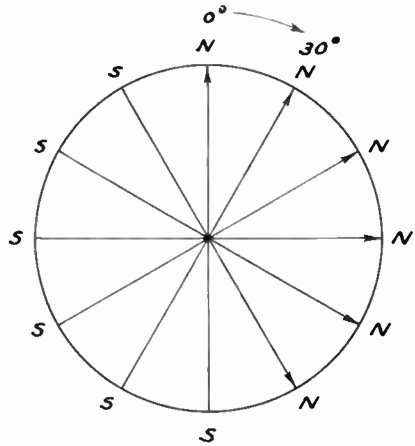


FIG. 6

First you must understand how this field direction may be changed electrically *without actually moving the motor frame or shell*.

There are two common ways in which this is done in practice for small motors. They amount to the same thing, but one method is called the *split phase* method and one the *shaded pole* method. To do this magnetism is simply produced in the motor frame in one direction for a short time and as it diminishes, *more magnetism is produced a little later in another direction*. The second field mentioned must, of course, follow the first in the time it would take to move the motor frame for the same speed of rotation.

From the supply voltage at a low voltage transformer secondary, current may be drawn either in phase or ahead or behind in time with respect to the voltage. This as you know, is controlled by the nature of the load impedance, whether it is inductive or capacitive.

Now as in Fig. 7, one winding of the motor must be supplied direct from the transformer secondary while the other one is supplied through an inductance, resistance or condenser. With an inductance in the circuit, the current in field F1 in Fig. 7 will lag the voltage applied to it and to field F2. This means that the magnetism at first rises in F2, and as it dies down, it rises in F1 about one-fourth cycle later. *The magnetic field will therefore rotate counter-clockwise.*

The condenser will delay the magnetism in F2 because the current and magnetism will lead the supply voltage in F1 and the field will rotate clockwise. With the resistor, because the F1 circuit is practically in phase, the current in F2 will lag that of F1, causing clockwise motion. A *two phase current* is thus created from a *single phase voltage supply*, and the motor armature can be made to rotate in either direction.

Another method of getting *two out-of-phase currents* from the same

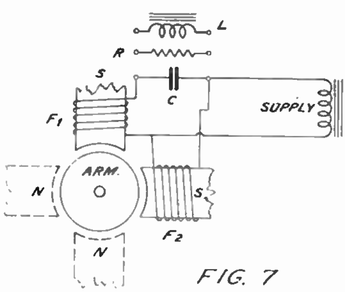


FIG. 7

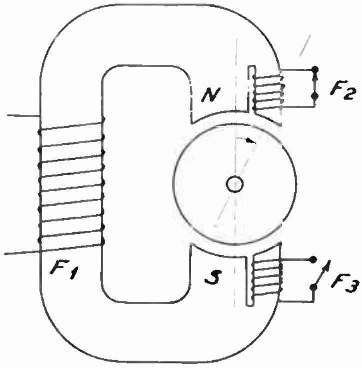


FIG. 8

supply voltage is to induce one of them in an auxiliary pole having different inductance characteristics. This is called *pole shading*, and is basically illustrated in Fig. 8. The main field F1 is split at each pole tip so as to provide a separate pole for a high current winding having a small number of turns of wire or even a single turn of large wire. The direction of its magnetism is different from that of the entire pole as a whole.

The winding about this auxiliary pole is supplied by induction just as a transformer secondary and the current in it being high, its field lags the main field a few degrees. Thus in Fig. 8, with field F2 shorted so that current may flow as a product of induction, the field will rotate clockwise. The field actually assumes every direction in its complete rotation, although when horizontal to the main poles, its strength is very low. The total field is of course, the combined action of the two fields.

An actual graph of this rotating field appears in Fig. 9 for definite construction specifications and theoretical operating values. For the purpose of this drawing, 90 degrees phase difference has been assumed between F1 and F2, 30 degree angle between the

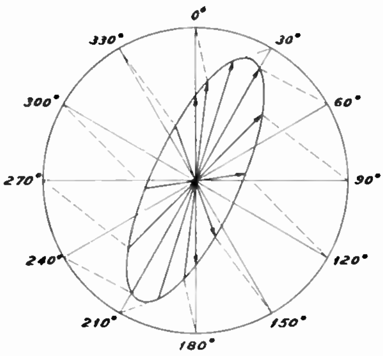


FIG. 9

vertical field due to F1 and that of F2 alone, and equal strength for both fields. The drawing shows that the field changes direction, intensity and even speed of revolution throughout each cycle.

To *reverse the direction of rotation* (a necessary factor in electric motor tuning) of the field, the auxiliary shading field F3, Fig. 8, is shorted while F2 is opened. If both are shorted or open at the same time, the motor will not turn. In some cases where more turns are used in both of the shading windings, they may be placed in series with the main field, one at a time, for reversal purposes. Fig. 10 shows this application.

If you press button 3 for example, the button simply closes a single-pole single-throw switch, grounding one arrow contact on the selector disc D. This will complete the circuit from the *half sector* of the disc D to F3, to F1 and back to the supply winding whose other end is grounded. The motor will turn counter-clockwise, and through a train of gears will drive the selector disc D clockwise as shown by the arrow in the lower sector of the disc for every contact on this sector. The control insulating segment M of the disc is driven toward contact 3. Its right end moves down slowly and it is directly secured to the condenser gang shaft. As long as the lower segment of disc D is grounded, the disc will turn but when the insulation segment passes under the contact the circuit is broken and the motor circuit is opened. Then if button 4 or any higher number is pressed, contact will be made to the other half sector (upper one) and the motor will turn in the reverse direction because this time field F2 will be supplied. In the position shown, buttons 7, 8, 9 and 10 will supply field F2 causing clockwise rotation of the motor and counter-clockwise rotation of the selector disc. If, however, buttons 1 or 2 are pressed, the motor and disc will continue in the same direction as for button 3.

In the position shown, button 6 has been pressed and is locked in place by the mechanical system in the button mechanism. This device locks only the button pressed, releasing all others on being pressed. The condenser shaft is affixed to the selector disc and the contacts are set about the disc so that they will be at the insulating segment when the desired station is in exact tune. In this way, the condenser rotors turn the shortest distance direct to the desired station. Button 6 remains closed, and the disc remains in the position shown with the station identified by button 6 tuned in, until some other button is pressed, releasing 6 and making a contact elsewhere on the disc, which will turn the motor.

One common method of construct-

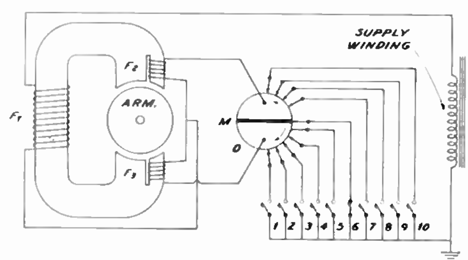
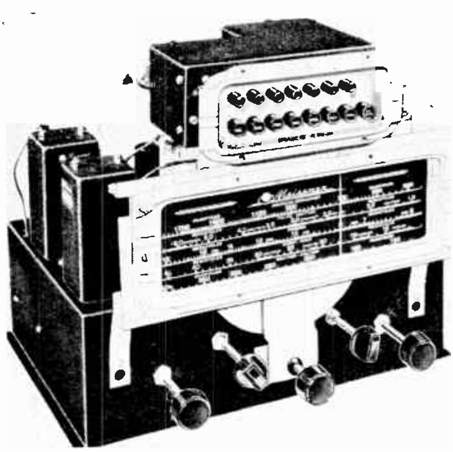


FIG. 10



This view shows one adaption of the push button tuning system. The automatic tuner is a separate unit such as will be found on many of the RCA and General Electric receivers.

ing the rotor of an inductive motor, such as are used here, is to punch a number of round holes in the edge of a number of steel discs, stack them and slide large copper conductors in the series of holes. These copper conductors project out of each end of the armature and serve as rivets with which to clamp the laminations together. On each end are placed a number of copper discs so that each copper conductor is shorted at either end to all the others. The armature shaft goes through the center of this *squirrel-cage* like rotor. This type of motor is often referred to as a *squirrel-cage* motor.

Now as the *magnetism rotates,* it sweeps past the rotor conductors, sidewise inducing voltage in only those in the field. Armature current results, taking the return path through conductors which at that moment are not swept by the magnetic flux. This is the path of least resistance. The iron of the armature is, of course, to complete the magnetic circuit of the field as much as possible. The magnetism thus produced tends to oppose the force originating it and the force is converted into mechanical force, tending to turn the armature. It always turns in the direction of rotation of the moving field, but never as fast as the field because if this were so, there would be no relative motion between the field and armature and no voltage would be induced in it. Thus the more slowly the armature turns the more power it can supply, because the relative motion of the field and armature is greatest.

Having reviewed the principles of electric motor tuning you are now prepared to study the exact mechanical applications of motor tuning.

Admiral Touch-O-Matic Tuning System

Starting at the lower right of the circuit in Fig. 11, there is the motor supply winding. The transformer is indicated here as separate from the power transformer in the receiver. This is done in some receivers but in most of them using motor tuning the motor supply winding is simply a winding on the power transformer. This one supplies 24 volts with a 6 volt tap.

In the position shown in the diagram, the off switch is pressed in, which grounds the AFC discriminator cathode and an automatic tuning indicator light (L). However, the 6 volt circuit of this light is completed only through the motor, fields, contactors, push-buttons, etc. to ground. Therefore, for setting of stations, press the *off button* and one of the other station selector buttons. This will permit the indicator light to light when the button contact at the selector disc is closed, but will not permit sufficient current to flow to run the motor. Therefore, in this position the desired station is tuned in and the insulating point on the selector disc corresponding to the correct tuning is set to open the circuit so that the pilot

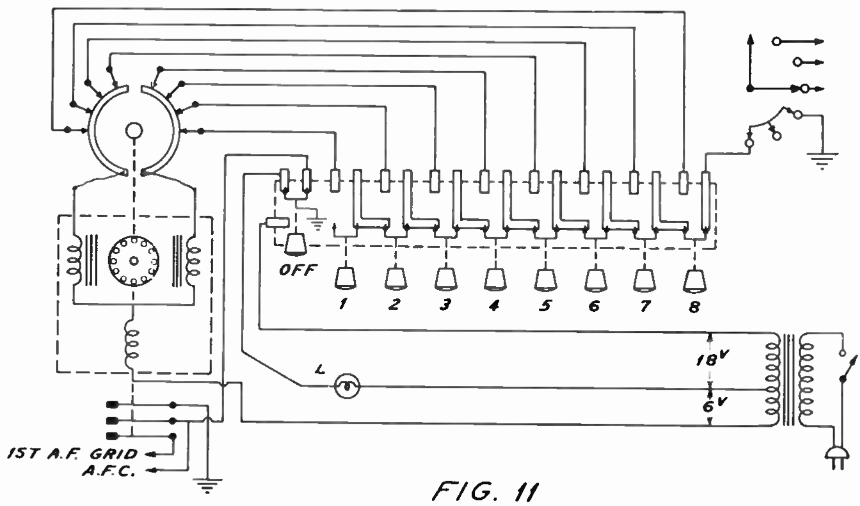


FIG. 11

light goes out. This pilot light obviously is for the purpose of setting the stations only.

The mechanical locking mechanism of the buttons is such that when one is pressed it will release all others. However, two or more buttons can be pressed simultaneously and will remain in contact. To avoid any difficulty due to this, the grounding circuits of the push-buttons are all in series so that when one is pressed it opens all of the circuits to its right. Thus no matter how many buttons are pressed, only the one furthest to the right will actuate the motor and tune in the station to which it has been set. Most push-button circuits for motor tuning are arranged in this way.

Another thing happens when the button is pressed. The motor armature is mounted *on a shaft a bit longer than necessary* and the armature is arranged *so that it can slide in the direction of the shaft*. This mechanism is illustrated in Fig. 12. Furthermore, it is provided with a low tension spring contact (S) at one end which pushes the armature slightly out of the motor field and thus increases the magnetic reluctance across the air gap. As soon as the motor field is excited, a force is applied tending to decrease this reluctance to as low a value as possible. *This means that the armature is drawn lengthwise into the field* (in the direction of the arrow) *against the spring action as it starts to rotate*. This action is, of course, identical to that of the solenoid relay or dash-pot mechanism.

Now this solenoid action is put to a useful purpose. The spring against which it pushes is part of a switch which grounds the high side of the volume control or first AF grid and grounds out the AFC action as soon as this motor is supplied with power. It also serves to connect to the reduction gear train driving the tuning condensers, either by means of a small pinion gear on the motor shaft or a crank and pin coupling arrangement.

The way these items cooperate in the tuning system is of great value in *quiet*, precise tuning. Almost at the instant the push-button is pressed, the receiver is made completely silent and the AFC, if such is used, is made inoperative. The motor then couples with the gear train and rotates the

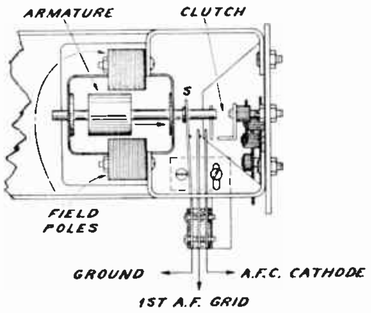


FIG. 12

condenser gang to the preset position as set for that button. Almost instantly when the motor contact is broken the mechanical coupling to the gear train is broken by the spring action in a fraction of one turn of the motor armature. Since the gearing down to the condenser shaft is often greater than 100 to 1 the tuning gang does not *override* the proper tuning position. One type of mechanical system for this purpose is shown in Fig. 12 with the other things mentioned.

Stewart-Warner Magic Keyboard

The Stewart-Warner motor tuning system is a mechanical arrangement which operates switches to determine in which direction the motor will turn for any station, and to operate the AFC, muter and power switches. A cross-section of the entire mechanical arrangement is given in Fig. 13.

Tracing the operation from the button, the first thing that takes place when the button is pressed is that the key stop bar springs up in front of the stop cam, preventing release of the button until another button is pressed. This key stop bar has the same relation and position for all buttons. The key slides horizontally in its bearings causing the rotation of the pawl about its pivot; both of which are clearly identified. Rotation is caused by the pull of the spring, so that the limit of its motion is determined only by the stop on the key. The upper end of the pawl is stopped by the station selector cam, there still being spring tension tending to keep it on this cam.

Moving with the pawl and on the same pivot is a bakelite switch operating cam. If the pawl falls on the station selector cam on its large radius side, the bakelite cam will be rotated far enough clockwise to permit switch lever 5 to fall in slot C, but not far enough to change the position of switch lever 8. Contacts 8 and 9 of the motor reversing switch then drive the motor and gear train in such a direction that the station selector cam, coupled to the condenser gang shaft, will move clockwise until the upper end of the pawl will fall into the slot shown. This will further rotate the bakelite cam until contact 5 is raised by point A on the cam thus immediately cutting off the power to the motor.

While switch contact 5 is in slot C, the first AF grid is shorted to ground by the muter contacts 3 and 4, and the AFC is grounded by contacts 1 and 2. When 5 is again raised, the AF circuit is again opened and the AFC is thrown into action and the power to the motor is cut off.

If the pawl happens to fall on the small radius side of the station selector cam, contact arm 8 will be raised by section D of the bakelite cam, closing contacts 7 and 8, and thus reversing the motor. The station selector cam will therefore turn counter-clockwise to the slot. Contact 5 will then rest as before on section A of the bakelite cam starting normal reception. Thus for any position of the slot in the station selector cam, it rotates the shortest distance to the pawl when the pawl falls into it and stops the tuning motor.

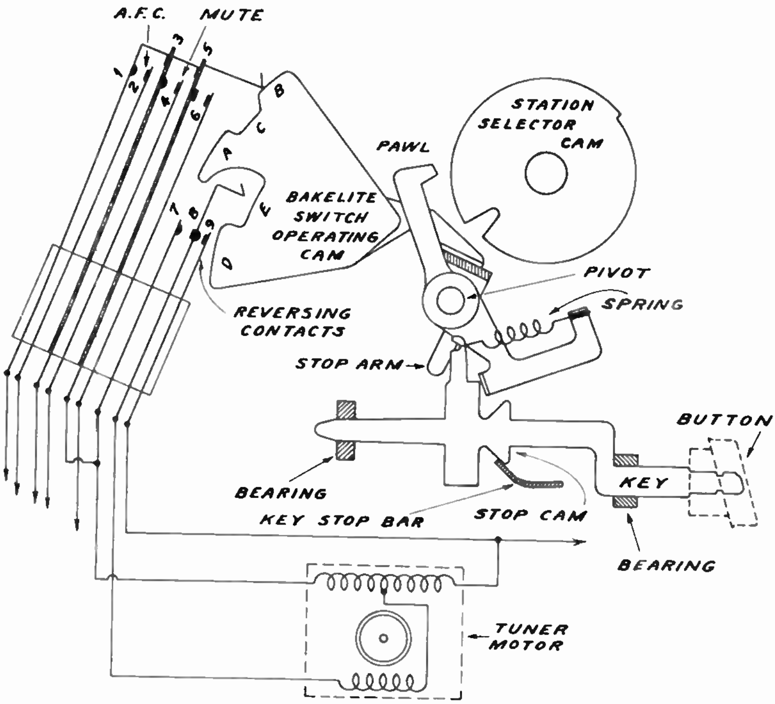


FIG. 13

The following contact spacings should be checked in case of trouble with the mechanism:

1. Pawl on large radius of station selector cam.

   (a) Contact lever 8 to base E —1/16″.

   (b) Contacts 8 and 9 closed.

   (c) Contact lever 8 just clears riser D.

   (d) Contacts 1 and 2, 3 and 4, 5 and 6 closed.

   (e) Contact lever 5 clears C—1/16″.

   (f) Contact lever 5 clears B —3/64″.

2. Pawl on small radius of station selector cam.

   (a) Contacts 7 and 8 closed.

   (b) Contact lever 5 same as mentioned but clears A instead of B by 3/64″ approximately.

   (c) Contact lever 8 slides on D.

3. Pawl in slot of station selector dial.

   (a) Contact lever 5 on section A of bakelite cam.

   (b) Contacts 1 and 2, 3 and 4, 5 and 6 open.

   (c) Contacts 7 and 8 closed.

   (d) Contact lever 8 on section D.

Setting Stations

The following procedure is recommended when the back contacts have the correct adjustment:

1. Turn on receiver and allow to heat for 10 minutes.
2. Pull out main tuning knob from front panel.
3. Pull out the *set-up* knob immediately behind it and rock to engage gears.

4. Turn this *set-up* knob clockwise until a stop is encountered.
5. Press any one button and wait until the motor stops.
6. Carefully tune in any desired station with the set-up knob.
7. Mark the depressed button with the call letters of the station just tuned. Continue with other buttons in this way until all automatic tuning has been set. No attention need be given the arrangement or spacing of stations for this mechanism.
8. Push the set-up knob in and replace the main tuning knob.

In the earlier models of this mechanism the bakelite cam in Fig. 13 was the reverse of that shown—that is, portions A and B were lower and C was the raised portion. The three switches which it controlled were reversed also—that is, they made contact to the left instead of to the right as in Fig. 13. Bear this in mind when making adjustments.

There is an auxiliary side switch over the tuning shaft for shorting out the AFC and lighting a pilot light when the receiver is manually tuned.

The setting of stations with the selector drum disc on many receivers is done with the help of a station adjustment key. A friction mechanism holds the discs to the condenser shaft so that they may be held stationary while the condenser gang is moved. The key is lightly pressed down against the disc desired to be adjusted and the condenser gang is turned until the key drops in the grooved slot in the tuning disc. The station desired to be tuned with that disc and its associated tuning button is then tuned in correctly, with the selectivity of the receiver as sharp as possible and the AFC if one is included, off or out of operation. The disc is now in the proper position on the shaft for tuning that station and the key is removed and used for adjustment of another.

There are many modifications of these basic ideas, principally differing mechanically from one another. One, for example, makes use of a number of bakelite wheels with pins on the side of each to actuate contacts when rotated to the right positions.

Midwest Receivers

One of the circuits of Midwest receivers makes use of a regular wound armature and commutator type motor. The circuit is shown in Fig. 14. It uses two reverse wound series fields, one for each direction of rotation. It uses a separate motor supply transformer and is provided with ten sockets (P1 and P2) so that a remote push-button control may be plugged in. Motor tuning is switched in at a certain setting of the tone control switch and muting of the output while tuning is provided.

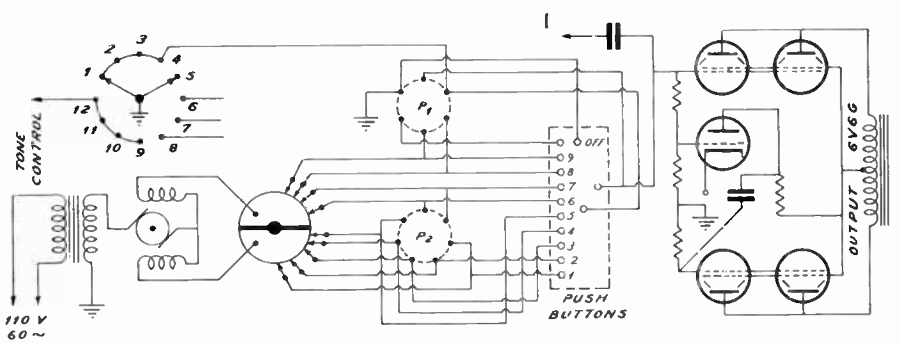


FIG. 14

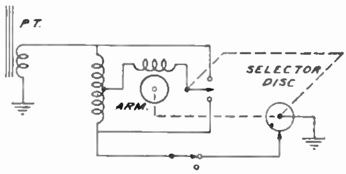


FIG. 15

RCA Motor Tuning

The basic motor tuning circuit as used by RCA is shown in Fig. 15. The motor supply winding is part of the receiver power transformer and a split phase induction motor is used. Only one selector disc and push-button is shown. Here there is a separate selector switch for each button and reversal of the motor is accomplished by a switch on the tuning gang shaft operating at each end of the dial.

Continental Tuning

Typical of many circuits is the Continental circuit as in Fig. 16. At one position of the band switch the push-button circuit is switched into use. Button No. 1 is for station setting with a 6 volt pilot lamp as described for a former circuit.

The other buttons are for station setting. The solenoid action of the armature grounds the AFC and AF leads while the motor is in motion. See Fig. 17. For either direction of rotation of the tuning motor the voltage drop across the main field F1 will be sufficient to induce the 60 cycle voltage (20 to 24 volts) through C1 to diode plate D2. Thus D2 will acquire a negative potential approximately equal to the peak voltage across F1. Applied through R1 this negative voltage will bias the AF tube grid considerably beyond plate current cut off value. When the motor fields are not supplied, this voltage vanishes and the receiver is tuned for reception.

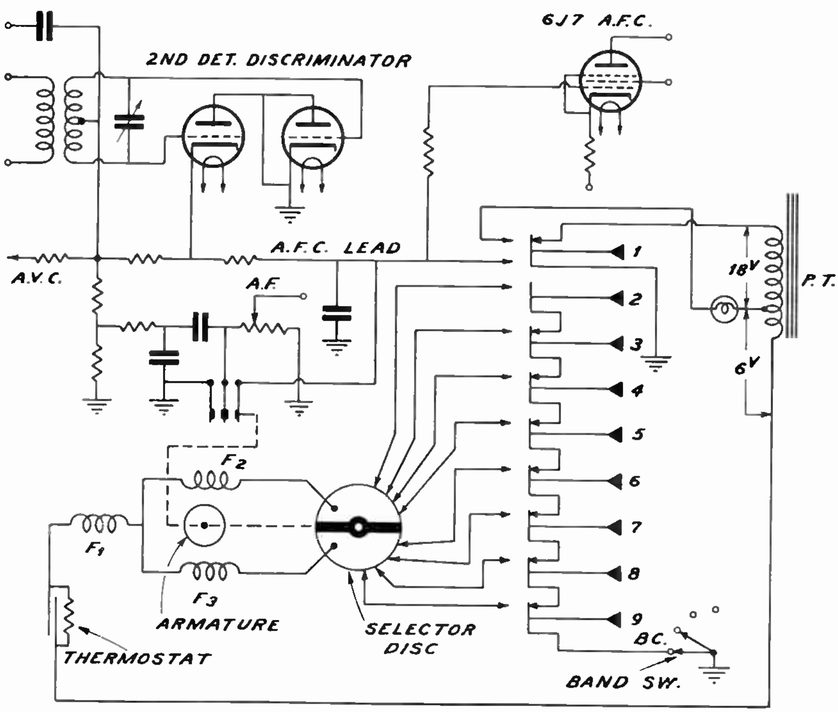


FIG. 16

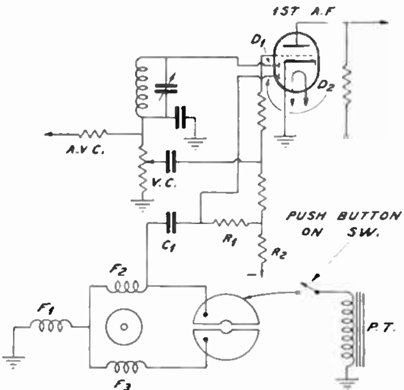


FIG. 17

Trimmer Push-Button Tuning Systems

Quite different from motor or dial operated devices the *push-button operated trimmer tuning system* is much simpler and cheaper to build. It has other outstanding advantages which will become clear as you study it.

All of these systems automatically substitute another tuning unit *in place of the regular tuning gang in at least two places*—that is, in the first detector and oscillator circuits. The tuning gang is always switched out and electrical units are switched in the circuit which have been pre-adjusted to definite values. Fig. 18 illustrates one of the simplest possible cases as used in the Garod Prestomatic tuning system.

This circuit is a two band circuit with a first detector oscillator input. The wave band switch has two sections SW1 and SW2, each of which has three positions and two poles. The positions are indicated by number. Two main tuning condensers (C1 and C2) compose the manual tuning gang. In position (1) both switches SW1 and SW2 contact both the short-wave coils for the detector grid and oscillator and the two main tuning condensers. Trimmer T1 is for setting the band correctly according to the dial scale. In position (2), the switches contact the broadcast coils (BC) and tuning condensers (C1 and C2). In position (3) however, the connections to the broadcast coils remain but the tuning condensers are left free or unconnected except to ground. In their places are connected common leads to six adjustable condensers. One set is for the first detector grid circuit while the other is for the oscillator grid circuit.

Both of the condensers in the group of twelve trimmers similarly numbered are for tuning in one station. A single push-button grounds the lower end of two of them, one for the detector grid tuning and one for the oscillator tuning. They are adjusted exactly as RF and oscillator trimmers with an incoming signal or signal generator. They are set at the precise tuning value for the station desired to be automatically tuned by the button which connects to them.

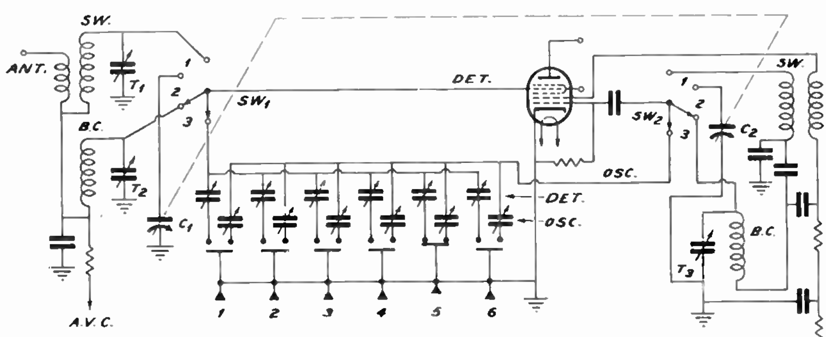


FIG. 18

For any one station the two trimmers which are used for tuning one station are in most cases alike as are the two condensers of the gang for the detector and oscillator. Where cut plates are used for the oscillator (receivers using no oscillator padder), the two may have different values but at any rate the oscillator section can be adjusted for the lower capacity as required.

Now if each of the condensers of the entire group has the proper range through variation—that is, can be set to a capacity as high as the main tuning gang equivalent, at maximum or as low as at minimum, they could all be exactly alike. This, however, is not practical and entirely unnecessary. One condenser need only have enough variation to cover 1/6 of the frequency spectrum and each can easily cover this amount. In case *too many* desired stations are close together as in some localities, it has been the practice to make each group of two sets of condensers alike to cover 1/3 of the broadcast band and the three sets of 4 condensers each completely cover the band.

Marked on the condensers or manufacturer's instructions, you will, therefore, see that two condenser groups will be marked 550 to 770 KC, 770 to 1080 KC and 1080 to 1500 KC, or approximately by these divisions. For the same maximum to minimum capacity ratio of the condensers of differing values of capacity these respective bands can be covered. Yet each condenser need not have as great a maximum to minimum ratio as 2 to 1 to cover these bands.

Many receivers may have a selection of as many as 10, 12 or even 18 stations by push-button control in this way. Usually the condensers will be arranged in groups of 2, 3 or 4 to

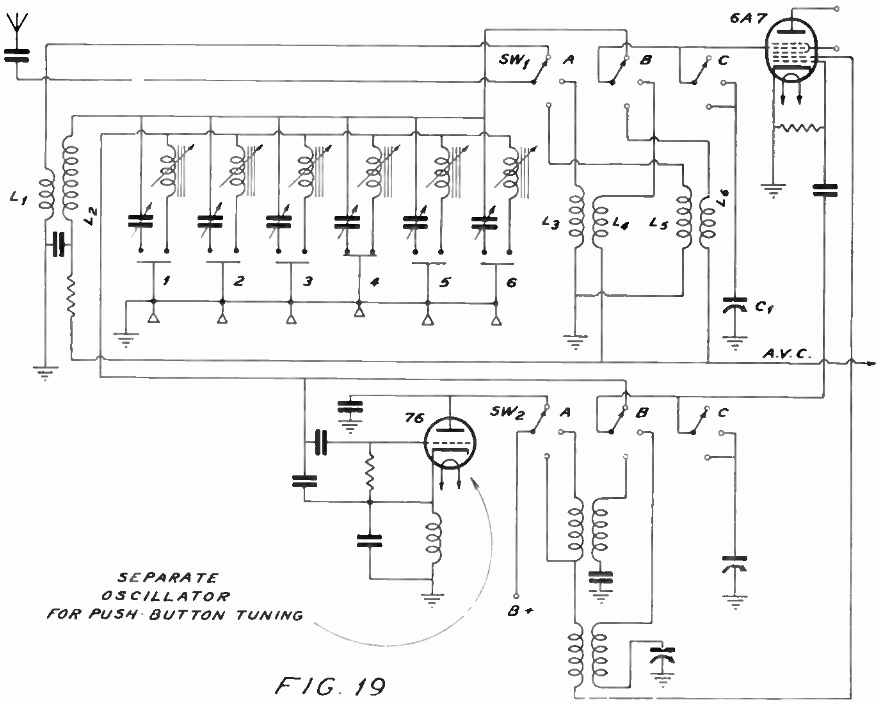


FIG. 19

cover specified sections of the broadcast band. Note carefully that push-buttons are used only for broadcast reception—this method being impractical for higher frequency reception.

Now as to whether the circuit substitution is made by means of condensers or coils, there is essentially no distinction made in the push-button circuit. Substitution coils may be used for either one or both of the circuits, that is, detectors or oscillators. Of course, as you may expect, where a condenser substitution is made, the circuit makes use of the same coil used for regular manual or continuous tuning. On the other hand, where a coil substitution is used, certain fixed condensers already associated with the circuits are used, while the coils used for manual or continuous tuning are switched out of the circuit.

This method of using coils for the oscillator circuit and condensers for the first detector tuner is shown in Fig. 19 as used in the Automatic Radio Co. designs. Here a separate oscillator is used for push-button tuning although this is not generally done.

It was soon realized that instead of having separate and additional positions of the wave band switch for changing from continuous tuning to push-button tuning, this switching

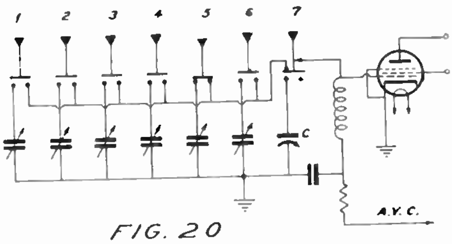


FIG. 20

could be done with simply an additional button. Figure 20 shows how this is done for an RF stage in simplified form. Buttons 1 through 6 control only the actual tuning by push-buttons while button 7 when depressed, disconnects all of the other push-button circuits from the tuning system and connects the main condenser (C) of the tuning gang for this part of the circuit. Similar connections are used for the oscillator and any RF stages. When any other button is pressed in, such as No. 5 as shown in Fig. 20, button No. 7 is released disconnecting the main tuning condenser and connecting the push-button system.

A practical application of this system of using a push-button for changing from manual to automatic tuning is shown in the General Electric touch tuning system as in Fig. 21. This system even disconnects the RF stage by skipping it for push-button tuning when the manual tuning button is released. A three gang condenser is

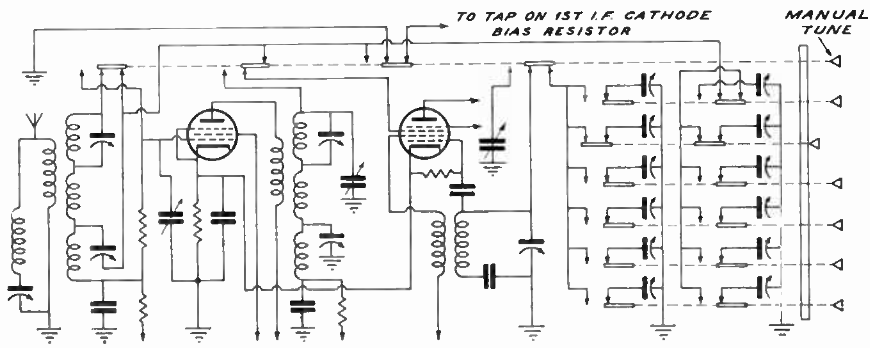


FIG. 21

used for manual tuning and for other bands but only the first detector and oscillator circuits are automatically tuned.

Sometimes another push-button is used to turn off the entire receiver. The receiver is turned on simply by pressing any other button which releases the *off* button.

In most of the push-button mechanism more than one button will remain depressed if they are depressed at the same time. To avoid false tuning, due to this possibility, most of the condenser substitution types are of the series type—that is, one button on being depressed disconnects all of the circuits following it in the sequence and yet remains itself in contact with the preceding circuits. Figure 22 is typical of this type of circuit. Such a connection for push-buttons is vitally needed in motor tuned circuits so that the motor will stop at the required place. Otherwise, the motor might continue to draw power and hum and not rotate at all.

Servicing Push-Button Systems

Within the push-button mechanism all of the contacts are of the sliding type which are always self cleaning and require little or no attention because of conductivity. The face plate on the panel and any guiding members must be mounted so that the button can be pushed all the way to its back stop without *sticking* in the depressed position by wedge action. The units are generally made of metal and insulating stampings clamped together, making it impracticable to dissemble, to replace buttons, springs, contacts, etc. There are generally no adjustments in these units and they will be found the cause of trouble only on the most rare occasions. Spreading solder and broken lugs will be the chief cause of trouble when found in these units.

The trimmer condensers are of the mica-compression type using from two to several plates and must be adjusted with an insulating screw driver or wrench. They are sometimes mounted on the push-button assembly in which case they are accessible from the top or bottom—front of the receiver. At any rate, they will be near the push-button assembly because of the advantages of short leads to the condensers.

Push-button assemblies have been and are used for wave band switching as well as for the other things mentioned. Each band is identified by a button; the broadcast band button being used for manual tuning as for the others, while the regular station buttons automatically choose the desired stations and switch all other operations out of use. The receiver is turned off by pressing one of the buttons. Any of the other buttons will release the off button turning the receiver on and giving the desired selection at the same time.

Remote Control of the Receiver

The essential elements of a tuned circuit must be closely related to perform properly and hence it is not

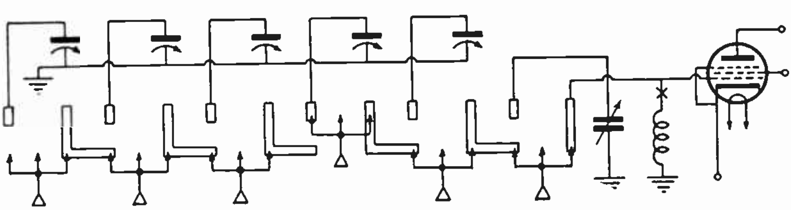


FIG. 22

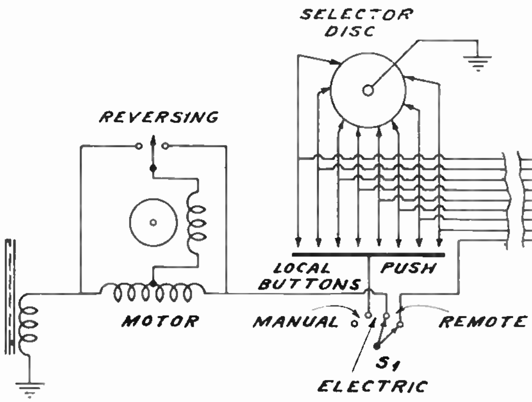


FIG. 23

practical to connect tuning condensers or coils through a long cable for remote control. Therefore, the cable type of remote control can only be used in practice with the motor driven type of automatic tuning.

A cable type of remote control using push-buttons is shown in Fig. 23 as used by RCA. A cable consisting of 9 wires, one attached between each corresponding station push-button in both the local and remote units and an additional return circuit wire is used. Part of the three position two pole switch used to change from manual, to electric, to remote tuning is shown at S1.

The cable carries only the 60 cycle supply current of the tuning motor and can be quite long without having sufficient resistance to alter the operation in any way. This particular system does not automatically select the direction of the tuning motor but when the motor drives the tuning condenser to the end of its scale a lever actuates a reversing switch so that the motor reverses. In this way the motor scans the entire dial reversing at either end until the disc set for the station button depressed opens its circuit. No matter what other button is pressed after this, the motor continues in the same direction to the end of the dial if the desired station is not between this point and the end and scans in the reverse direction until the proper disc opens its circuit. Obviously, a separate disc is used for each station to be set.

The same general idea is employed in the Midwest receiver already described in this lesson. Any suitable socket and plug or terminal strip method may be used for attachment to the remote control unit. Adjustments are, of course, the same for the remote buttons as for the *local* electric tuning buttons.

Philco Mystery Control

One type of trimmer remote control requiring no cable connection has been used by Philco. The circuit represents a rather revolutionary departure from conventional radio circuits in use today.

The receiver is a usual broadcast band receiver having a switch to change from manual to remote tuning, there being no automatic tuning at the location of the receiver. For the automatic tuning of eight stations, iron core filled coils adjustable in inductance are substituted in the oscillator circuit while trimmer condensers are substituted in the first detector grid

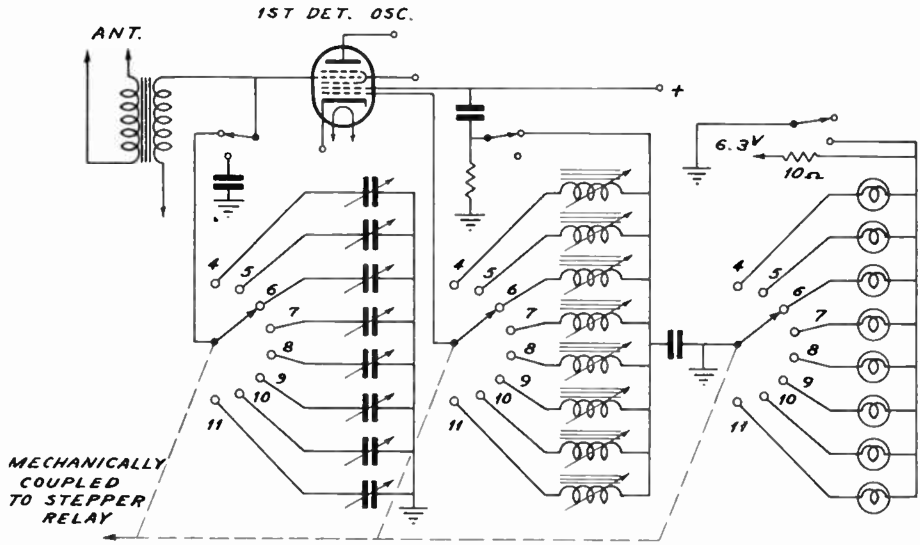


FIG. 24

circuit. With these two switches is a third which energizes a pilot light behind a window wherein is indicated the station which is being tuned.

This much of the automatic tuning system is shown in Fig. 24. The method of operating these switches is the unusual part of the circuit. Now consider the circuit of the remote control unit. It is shown in Fig. 25. It is simply a triode oscillator battery operated and keyed with the dial switch. As soon as the dial is moved clockwise by one contact, the switch arm closes the filament circuit and plate circuit. The oscillator is thus automatically energized and produces a frequency adjustable from 350 to 400 KC by means of the adjustable padder (126) in the plate tuned circuit.

Now assume the dial is moved 8 contacts to the right with the finger just as an automatic telephone dial is operated. the switch will return by governor control and make the oscillator radiate eight pulses of energy at the frequency to which it is set. Since the remote unit has eleven contacts, it may be made to radiate from one to eleven pulses.

The oscillator coil in the remote control unit is a large loop and a corresponding loop is mounted in the receiver which supplies energy to an *impulse amplifier*, very much like the IF amplifier in the receiver. Its circuit is shown in Fig. 26. From two points rather close together on the pick up loop (93) the signal impulses are fed through the low impedance line to the input transformer (90) whose secondary is tuned to the frequency of

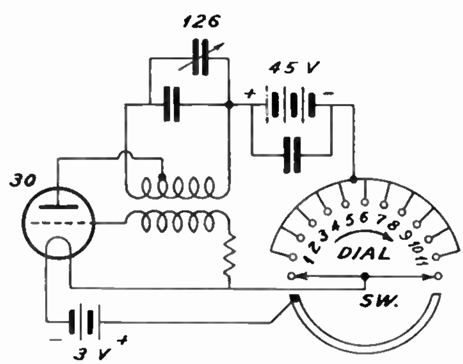


FIG. 25

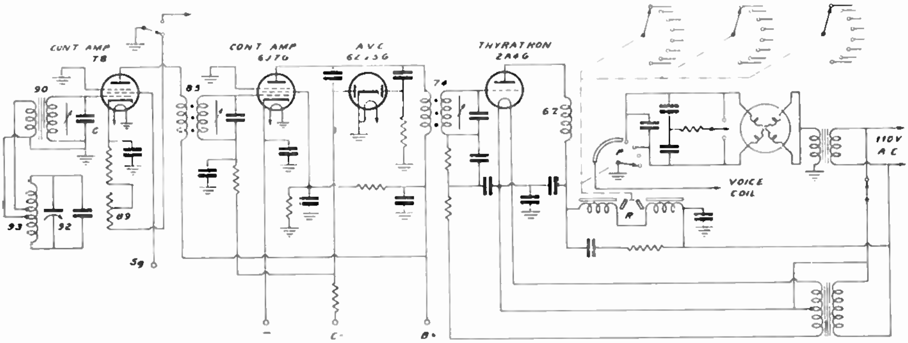


FIG. 26

the remote control unit by an adjustable core.

This first type 78 amplifier with cathode sensitivity control (89) feeds into a 6J7G amplifier, which in turn, feeds two diode plates by capacity coupling and the grid of a 2A4G *thyratron* tube by inductive coupling. The first of the diode sections of the 6ZY5G tube supplies conventional AVC action for the impulse amplifier while the second section acts as a signal peak limiter, similar to many of the automatic tone controls in principle of operation.

In the plate circuit of the 2A4G thyratron is an RF choke (67) and a relay (R) supplied from the AC line. This relay is a complicated mechanical unit, having a *holding* unit and two *stepper* units. The function of the holding unit is to lock the stepper unit on each operation so that it does not fall back to its original position at the end of each impulse. The primary stepper relay moves up on contact (in a circular direction) at each impulse. It comes in mechanical contact with the secondary stepper section on the fourth impulse and continues to the eleventh. The primary section falls back to the start position at the expiration of the action, leaving the secondary stepper section on the desired contact.

The primary stepper (P) carries a switch point over one blank contact, two volume control contacts and then slides over a single arc contact shorting out the speaker voice coil from contacts four to eleven inclusive of the secondary stepper unit. In this range of its motion it picks up the secondary contacts consisting of a triple pole, eight throw switch as diagrammed in Fig. 24.

The thyratron (2A4G) carries a large current through the relay when an impulse is fed to its grid, lessening its bias for an instant. The pulses of energy are timed so that the relay will move the switch contacts one contact per pulse. The fourth pulse serves to release all secondary contacts so that the secondary immediately springs back to position four, ready to stop here or be carried forward by additional pulses by steps.

The volume control and power switch are operated by a motor. Two impulses will stop the primary stepper relay on a motor contact only when followed by a continuous signal from the remote control, which is accomplished by a button on the unit. For an increase in volume, two pulses are dialed and by continuing the signal, the relay is locked in the second position from the stop until the motor has driven the volume control through a

Automatic tuning systems are not confined to the home type receiver. The above view shows one arrangement for an automobile receiver as made by Motorola. The receiver is a separately contained unit and the control system for the receiver is mounted on a separate panel which is to be attached to the dashboard of the automobile. Connecting cables are used between the control unit and the receiver, the latter usually being mounted on the bulkhead of the automobile.

gear train to the required volume level. For reducing volume, three pulses are transmitted and a continuous signal is transmitted. This steps the primary relay to the third position, reversing the motor direction and reducing volume. When the volume reaches the required level, the remote control button is released. If continued the volume will be reduced to zero and the main power switch will be turned off. In the volume control is a clutch to prevent jamming if the remote button is held down after the control has reached its maximum position.

Adjustment of Mystery Control Circuits

The mystery control circuits must be set up first so that through its use stations can be dialed and set up in the automatic position of the receiver.

Both the remote unit and mystery control amplifier can be adjusted anywhere in the band from 350 to 400 KC. Complete units (receiver and remote control units) are shipped with adjustments already made and identified as follows:

Code 5	355 KC
Code 6	367 KC
Code 7	375 KC
Code 8	383 KC
Code 9	395 KC

These frequencies should be retained where two receivers are spaced by more than 100 feet. If two receivers are used in adjacent houses or apartments however, it would be well to choose codes not adjacent. Codes 5 and 7 for example, or 6 and 8, or 9 may be operated in the same room without one remote unit dialing the wrong receiver. On adjustment, of course, any other frequencies in the band 350 to 400 KC may be used. To alter or adjust the frequency of the mystery control circuit, start with the receiver section proceeding in accordance with the following points:

1. Place a 12 inch coil (4 or 5 turns) near the pick-up coil of the mystery control amplifier and connect a signal generator to it, with one end to the high output and the other to ground.
2. Adjust signal generator to desired control frequency and then adjust core trimmers in transformers 90, 85, and 74 of Fig. 26 for maximum output indicated by the intensity of blue glow of the 2A4G thyratron tube. Reduce the signal generator output or remove the loop from the receiver to a minimum blue glow and readjust for a critical maximum.
3. Adjust the sensitivity control 89, Fig. 26. Reduce sensitivity for average glow of the thyratron with minimum signal from the signal generator.
4. Reduce the signal further by placing the signal generator loop farther away from the receiver and adjust padder 92, Fig. 26, for maximum signal.

The next step is to adjust the mystery control remote unit. For its adjustment, proceed as follows:

1. Dial any button and as the dial is released from the stop, press the stop down and hold it in this position.
2. Bring the remote unit close to the receiver and turn the padder 126, Fig. 25 located on the bottom of the unit until the 2A4G thyratron in the receiver glows at full brilliance of the thyratron and then turn the remote unit padder 126 again for maximum brilliance of the thyratron.

Automatic tuning systems are not confined to receiving circuits alone. They are used in many forms as transmitter controls. This view shows the control panel of a modern broadcast station employing several types of automatic controls which work in connection with relays.

You are now ready to set up stations on the remote unit. This is accomplished through the following steps:

1. Select eight desired local or powerful stations or less and arrange according to ascending frequency starting with the lowest frequency.
2. Tune in one of these stations (manually) at the receiver between 540 and 1030 KC. The range switch is set to broadcast. Connect a signal generator (modulated signal) to the antenna and tune to zero beat with the station.
3. Place the tab marked *loud* in the right-hand or full clockwise dial window and insert the tab marked *soft,* inserting the celluloid. Next place the tab marked with the call letters of the station selected between 540 and 1030 KC.
4. Turn the range selector disc of the receiver to *automatic* and dial the station mentioned. Adjust the 540—1030 KC oscillator padder (bottom row of

holes at rear of chassis) for maximum signal by ear or preferably by an output meter.

5. Next adjust the antenna padder (540—1030 KC, top row of holes) for maximum signal. Detune the signal generator and readjust both oscillator and antenna padders to maximum signal.
6. Dial other stations in order of increasing frequency and make corresponding adjustments and insert station call tabs.

Permeability Tuning System

A later design in push-button tuners is permeability tuning. It is very similar to the trimmer condenser type tuning system but variable induction takes the place of the trimmer condensers. With these systems, the entire tuning circuit of the receiver is replaced with each button. That is, for each button a separate tuned stage is used which is tuned to the frequency of the station wanted.

The induction (coils) used with this system are of a special design consisting of a *coil with a variable iron core*. This iron core which consists of finely divided iron powder is evenly distributed in an insulated mold, such that every particle of iron is insulated. The insulating material is molded into the shape necessary for the coil involved. The tuning is accomplished by varying the position of this core in the coil—thus changing the inductance of the coil tuning the circuit.

The accuracy of tuning by this method makes it possible to synchronize the detector and oscillator tuning so that only one tuning adjustment is necessary.

The stability of this type of substitution tuning is much better than the trimmer method. For this reason it has become very popular, and is used on a large number of receivers.

Figure 27 shows a diagram of such a tuning system. Note the variable core adjustments.

To make the adjustments for setting the push-buttons with this system is very simple, as with the trimmer system, each coil is made to cover a certain band of frequencies. The band to which each coil will tune is marked clearly on the receiver proper near

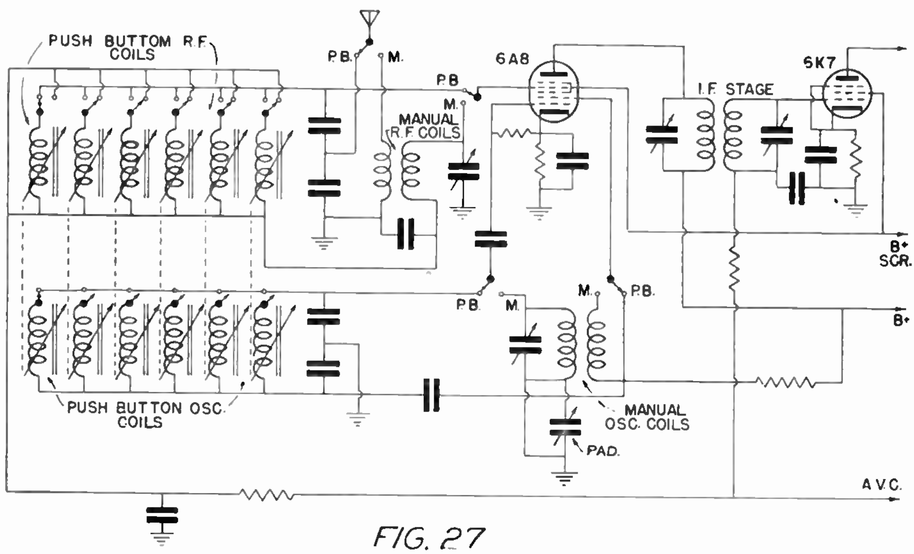


FIG. 27

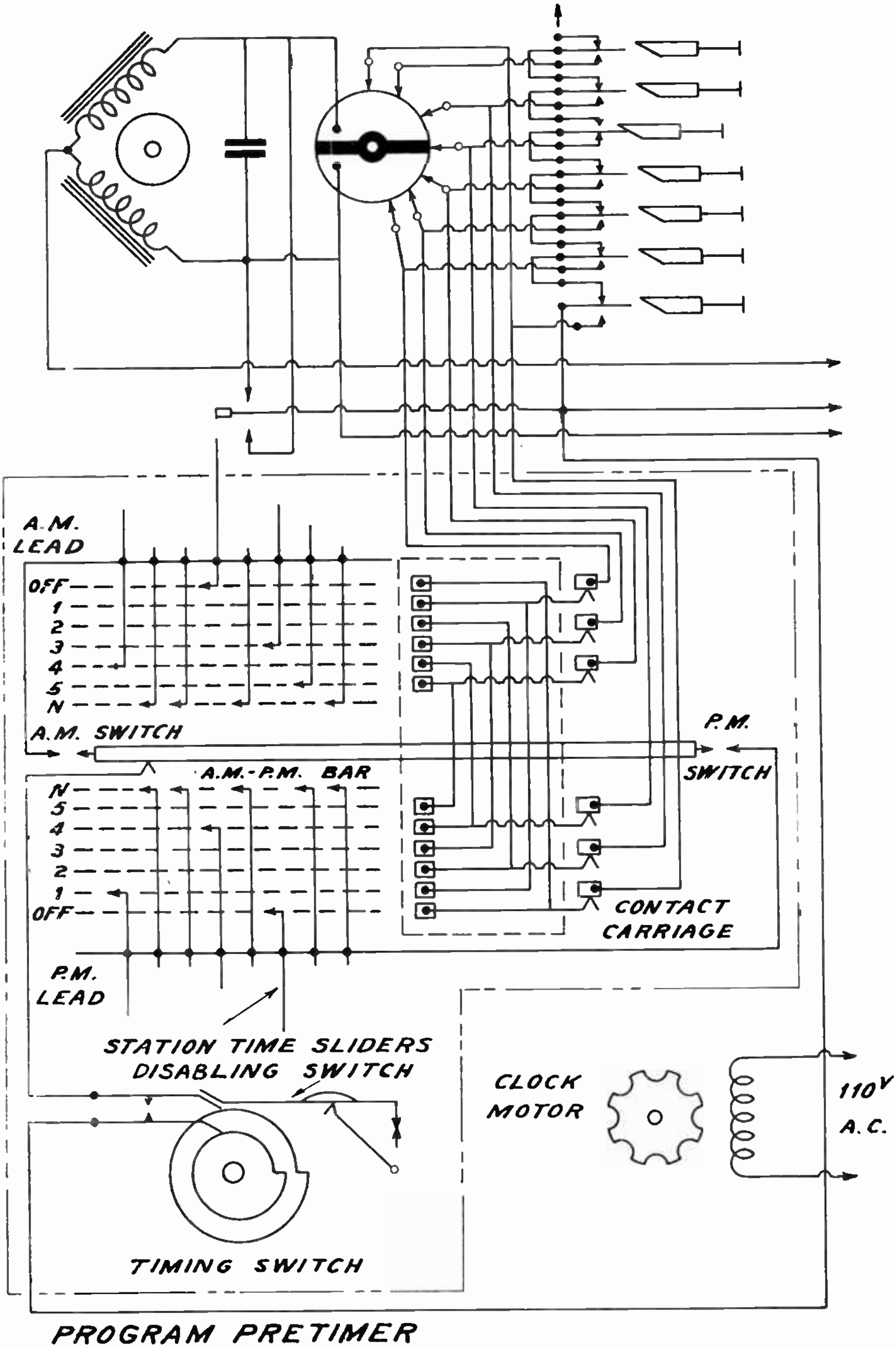

A.M. LEAD
OFF
1
2
3
4
5
N
A.M. SWITCH
A.M.-P.M. BAR
P.M.
SWITCH
N
5
4
3
2
1
OFF
CONTACT CARRIAGE
P.M. LEAD
STATION TIME SLIDERS DISABLING SWITCH
CLOCK MOTOR
110V A.C.
TIMING SWITCH
PROGRAM PRETIMER

FIG. 28

the adjustment for each button. To set up the buttons all that is necessary is to switch the receiver to automatic tuning and adjust the position of the iron core with the screw provided for this adjustment until the station to which you wish this button to tune is tuned in properly.

It is convenient when making this adjustment to tune the desired station in with manual tuning and then switch to automatic tuning for making the adjustment. This will aid in identifying the station you wish the button to tune.

Switching back and forth you can soon identify the station. When the volume of the station does not change when switching from one position to the other, the button adjustment is correct.

Many receivers use a combination of permeability and trimmer tuning for their push button system. The detector is tuned with the usual trimmer condenser arrangement and the oscillator which requires more stability is tuned with the more stable permeability tuned inductors. Making the push-button adjustments on these systems is the same as for the trimmer system. There are two adjustments for each stage of RF and two for the oscillator.

Program Pre-Timer

Among the automatic tuning apparatus which has made its appearance lately has come the automatic program pre-timer. To the selector disc contacts of the General Electric receivers using time tuning, such as in models G-105 and G-106, are attached additional leads just as for remote tuning by cable. Instead of this, however, the leads go to a special frame type switch, having a great number of movable contacts and adjustable switch levers as in Fig. 28.

A synchronous motor clock drives a moulded carriage with sliders on it and the selector disc terminals go to timing contacts. Projections on the timing contacts engage sliders on the carriage corresponding to the wanted station.

The same set of contacts are used for the AM and PM hours, but a switch driven by the contact carriage switches only the correct set in use at the correct time. Dimensions of these contacts are so small that accurate timing is not practicable, so an accurate timing switch is placed in series with the common return lead for each set of contacts which makes any tuning changes for which the apparatus is set every 15 minutes throughout the day and night.

While there are no adjustments to be made by the serviceman for this apparatus, stations are set by simply moving the switch blades to the correct numbered row of contacts at the correct time on the control board for the station corresponding to that number on the keyboard push-button assembly.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 Are all automatic tuning systems using the main gang condenser motor operated?

No. 2 Why is a floating vane used on many of the dial operated automatic tuning systems?

No. 3 What are the two main types of induction motors used for motor tuning?

No. 4 In Fig. 10, will the disc D always turn in the same direction if a given button is pressed?

No. 5 What additional function has the motor in Fig. 11 besides driving the condenser gang?

No. 6 What determines the direction in which the Stewart-Warner tuning motor will turn?

No. 7 For what purpose is the second diode D2 in Fig. 17 and its associated circuit used?

No. 8 Are trimmers T1, T2 and T3 of Fig. 18 adjusted with the push-button trimmers or with the main tuning gang?

No. 9 Name two other uses for push-buttons besides actually tuning in stations.

No. 10 How is peak resonance of the stepper relay amplifier of the Philco mystery control in Fig. 26 indicated?

HOW TO REPAIR AUTOMATIC CONTROL CIRCUITS

LESSON TV-10

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

BUILD AND ACCUMULATE EXPERIENCE

Probably you have already learned the lesson of letting one experience prepare you to handle the same thing in a more efficient manner the next time you encounter it. Experience plus knowledge are the most useful "tools" that a serviceman has.

For example, by the time you have replaced two or three pilot lights (connected across pins 2 and 3 of a 35Z5 rectifier tube) and they immediately "burn out" you soon learn to test the rectifier tube filament section between pins 2 and 3 for an open before replacing the pilot light even one time. The defect here, of course, being an open between pins 2 and 3, the pilot light being connected between pins 2 and 3 cannot carry the full filament current and thus burns out. Thus, this is an example of how you learn by experience and usually you do not make the same mistake twice.

All of this simply points up the very valuable fact that you must profit by knowledge and experience on every job you do.

In other words, don't be content just to find a strange or elusive defect in a receiver by simply correcting and forgetting it. The first consideration, of course, is to find and correct the defect. Having done this, the next thing for you to do is to review the entire job in your own mind and then try to profit from your experiences with it.

With some men, this mental process is automatic because they have learned over a period of years that this is a profitable thing to do.

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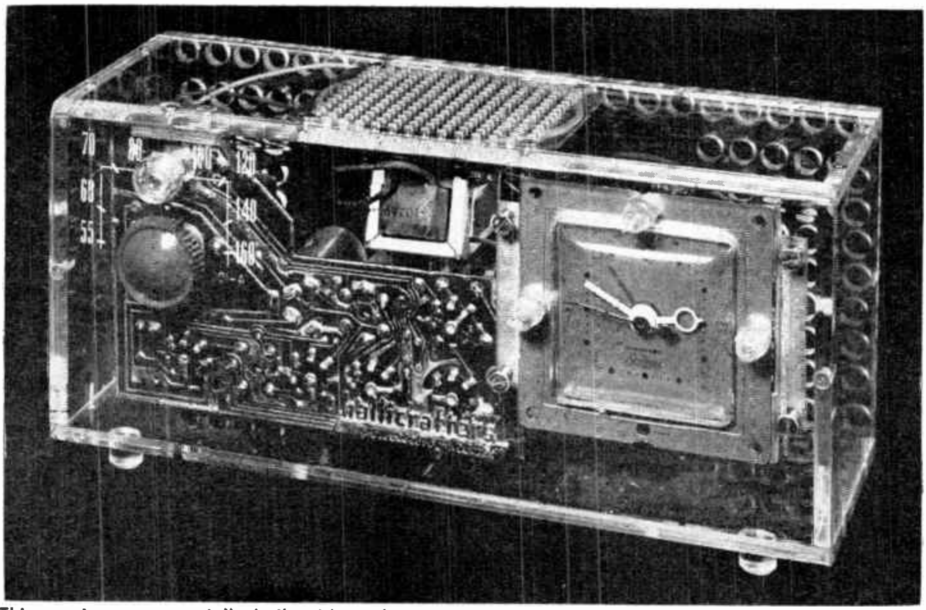


This receiver was specially built with a plastic cabinet to show the printed circuit board and other miniature components. It also contains an electric clock which can be used as an automatic timer or control

Courtesy Hallicrafters Co.

HOW TO REPAIR AUTOMATIC CONTROL CIRCUITS

Lesson TV-10

There is much for you to learn from observing and repairing automatic control circuits. Principally these are automatic volume control, automatic frequency control, in-between-station noise control, etc. Such circuits are very precise in regard to part values and where defects exist there are usually certain characteristic sounds or actions of the receiver which give you a definite clue to the nature of the defect as pointed out in several places in this lesson. For instance you will soon learn to associate AVC defects with certain sounds from the receiver just as you will associate AFC defects with other actions of the receiver. When you do get experience with jobs of this kind try to learn all you can from them and be on the look out for certain characteristic sounds and actions of the receiver. In other words try to accumulate AVC and AFC experiences in your mind so that you can put these things to good use next time you have a need for them. It will be well for you to keep in mind that FM and television receivers make use of these same basic principles of automatic control and thus the more experience you get with AVC and AFC on AM receivers the better prepared you will be to handle similar problems on FM and television receivers.

These special circuits may seem complicated to those not familiar with their operation. However, with an explanation of the operation of these circuits, along with considerable servicing information, should simplify these circuits, making their operation clear to you.

Many servicemen, because they lack a knowledge of the fundamental operation of complex receiver circuits are unable to repair them. In your SAR course an endeavor is made to acquaint you with the operation of all of the important types of circuits found in receivers and to give you a firm foundation of the principles of operation of these circuits as well as actual methods of correcting defects that may occur. In this way you will be prepared to cope with any of the more complex circuits.

AVC Circuits

Almost every receiver in operation today uses some type of automatic volume control, although each receiver may use a slightly different method of securing this control. They all in effect control the sensitivity of the receiver according to the strength of the signal received. By doing this, the volume of the receiver is controlled and made uniform. Because of this action the name *automatic volume control* (AVC) is given to circuits of this type.

These AVC systems being an intricate part of the receiver and also in some instances rather complicated, it is well worth your time to give these circuits *special consideration.* There are so many systems in use that we could not begin to explain each one in detail. However, we will explain the principles under which most of the circuits work. After studying these principles, you will not have any difficulty in understanding other systems when you come across them. In this connection, if you find a certain system difficult to understand, we recommend that *you make a drawing of the AVC circuit only.* Thus you will not be confused with other parts of the circuit, and can trace out the new circuit easily.

First of all, you want to get a clear picture of what an AVC system really does. An AVC system is nothing more *than a sensitivity control.* Its action is such as to increase the receiver sensitivity when tuned to a relatively weak signal. (For instance, a signal from a station several hundred miles away). Also the AVC system is supposed to decrease the sensitivity when the receiver is tuned to a strong or local signal. In other words, a good AVC system will maintain the speaker sound level at a fairly even value for varying strengths of incoming signals. Thus the system should give the same sound level for any given setting of the *manual volume control* provided the signal is not too strong or too weak. For instance, you cannot expect an AVC system to bring up the level of a very weak signal to that of a moderately strong signal. It does, however, tend to do this. The reason the sound does not come up to the expected level is because there is not enough natural amplification incorporated in the receiver to accomplish this without too much noise.

In other words, an AVC action is not obtained on very weak signals. Before the AVC tube can start to function, a certain predetermined AC signal voltage (the designer of the receiver usually sets this value by incorporating certain values of parts in the circuit) must be developed by the normal amplifying action of the receiver. Unless this amplified signal is brought up to what may be termed the starting voltage (threshold level) for the AVC tube, the effect is the same as if no AVC system were incorporated in the receiver.

In the opposite case of a very strong

signal, the AVC action is such as to almost reduce the sensitivity of the receiver to zero. Under this condition, it is often necessary to reduce the volume by means of the *manual volume control* before comfortable room volume is obtained.

The way the AVC system functions to increase and decrease the receiver sensitivity is to increase and decrease the control grid bias of the RF and IF stages. When the control grid voltage is decreased to the 3 volt minimum (or other minimum value), *the sensitivity is at a maximum.*

There is one important point to remember in connection with AVC controlled tubes. That is, the normal negative bias is in most cases applied to the grids of the tubes—thus the effective grid voltage is equal to the normal bias *plus* whatever AVC voltage is developed. This is true for conditions of maximum and minimum sensitivity. Another point to remember in connection with a normal negative bias in an AVC controlled system is that you cannot measure it with an ordinary voltmeter. This is due to the high resistance which is in series with the control grid circuit. The AVC voltage action that is developed by a double-diode tube like the 6H6 is easy to understand. Therefore, this type of circuit will be considered first. Figure 1 shows the circuit. Diode plate (P1) is connected so as to rectify the signal voltage in the usual way. Part of the AC signal voltage is also passed on to diode plate No. 2 through the .0001 mfd. condenser C2. On the negative half of the cycle, the signal voltage is not rectified, since this is a half-wave rectifier circuit.

On the positive half of the cycle current will flow from the cathodes to their respective diode plates, and in the process the signal voltage is rectified—leaving a pulsating direct current to flow. Thus on this half cycle there is two complete paths for the rectified current. One is from K1 to P1 and the other is from K2 to P2. The P1 to K1 (or K1 to P1) path feeds the AF signal to the grid of the

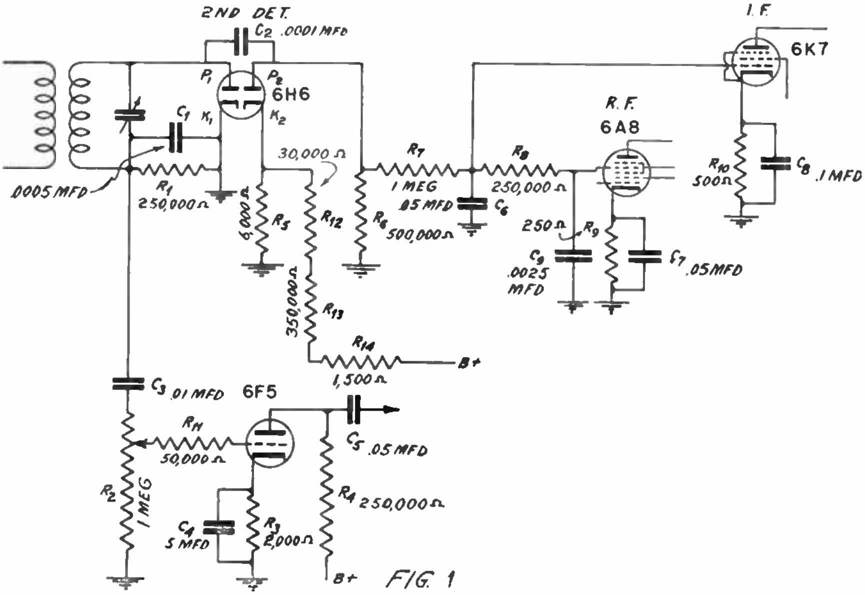


FIG. 1

AF tube by way of C3, R2, and R11. This is the usual diode detector circuit and needs no further explanation.

Part of the RF signal voltage reaches P2-K2 by the way of C2. The rectified voltage developed by the action of P2-K2 is the AVC voltage of the receiver. (Note for an AC signal either direction of current flow may be assumed that is from plate to cathode or from cathode to plate for the exact same results are obtained in either case. The student should remember, however, that electron or current flow is always from negative to positive).

When P2 is made positive K2 is made negative and current flows in the diode circuit. This causes current to flow through R5 and R6. Since current flows through R5 and R6, it is natural that a *voltage drop* occurs across them. The voltage drop across R6 is utilized as the AVC voltage. This voltage must, of course, be *negative* with respect to the cathodes of the controlled tubes in order to act as an AVC voltage.

Resistor R5 of Fig. 1 has a very definite purpose. The purpose of it is to place a *negative bias on plate P2* by making the cathode slightly positive. This prevents the start of AVC action until a definite signal level (equal to this bias) is reached. Suppose that R5 (due to bleeder current flowing through it) will place a 3 volt negative bias on P2. This means a signal voltage greater than 3 volts must be applied through C2 to P2 before the AVC starts to act on the grids of the RF and IF tubes. This is known as a *delayed AVC circuit.*

First, you will want to get a clear conception in Fig. 1 of the normal bias for the 6A8 and 6K7 tubes—these being the tubes which are controlled by the AVC action. The bias for the 6A8 tube is developed across R9 and is applied to the grid of the tube through R6, R7, and R8 (the grid coil being left out to simplify the diagrams). The bias for the 6K7 tube is developed across R10 and is applied through R6 and R7. This negative bias voltage is being maintained all of the time and is present whether or not the AVC is acting.

Now suppose a strong signal is tuned in starting a voltage drop to occur across R6. The rectified current will flow through R5, K2, P2, and R6. This makes P2 positive with respect to K2. It also makes K2 positive with respect to the grounded end of R5 which is the same thing as saying that K2 is positive with respect to the grounded end of R6. The cathodes of the 6A8 and 6K7 tubes are also positive with respect to ground. Therefore, *all voltages* applied to R6 by way of P2 or at the top are *negative.* Thus the AVC voltage and the bias voltages from R9 and R10 *add at R6* where together they are applied to the grids of the 6A8 and 6K7 tubes as already explained.

The fact that different bias voltages are developed across R9 and R10 makes no difference as to the AVC controlling action. Suppose *at one instant* the net AVC voltage is -39.5 volts. The bias across R9 and R10 for normal operation will be -3 volts. Thus the effective control grid voltage on the 6A8 and 6K7 tubes is $-3 + (-39.5)$ or -42.5 volts. The reason that this is possible is because the control grid voltage for each tube is considered as that voltage which exists between the control grid and cathode of *each tube.* Now you will see how the sensitivity of the receiver can be controlled by the AVC action. When no signal is received, no rectified current flows through either R5 or R6. Therefore, normal bias voltages are applied to the grids of the 6A8 and 6K7 tubes—thus their plate currents are at normal values and the receiver is in its most sensitive condition.

When a sufficiently strong signal is received, a *new voltage* appears across R6 due to the rectified current flow. This new or AVC voltage adds to the normal bias of the 6A8 and 6K7 tubes.

The stronger the signal, the higher the voltage drop across R6 and the more voltage is applied to the control grids. This, of course, decreases the amplification of the tubes which in turn means that the sensitivity has been decreased. Thus an AVC action is obtained which is controlled solely by the strength of the received signal. No matter how other practical AVC circuits may be arranged, they all work on this principle.

In explaining the AVC action it was not mentioned that the rectified signal was a pulsating DC whereas for bias purposes, a near pure DC is required. Referring to Fig. 1 again, you can readily see that R5 and R6 represent the load on one diode rectifier. Therefore, the rectified signal exists across both of these resistors. Now this signal voltage is not a pure DC voltage. It is a varying voltage, representing the audio variations that were placed on the carrier. Or considered another way, the voltage across R5 and R6 is an audio frequency voltage which has been separated from the IF frequency in the process of rectification. Condenser C6 of Fig. 1 is for the purpose of by-passing any of the IF frequencies that may appear across R6 and R7.

On the other side of the diode circuit there is an audio voltage across R1 and C1. This voltage will pass through the large condenser C3 and be applied to the triode grid of the 6F5 tube, and from there be passed on to the output stage. Resistor R2 is the *manual volume control* resistor, which determines the amount of the audio voltage that is applied to the triode grid of the AF tube. From this it is clear that it is not desired to remove the AF voltage from one side of the diode circuit. However, it is essential to remove it in the AVC circuit in order that a pure DC may be made available. If you will trace the negative voltage paths from R6 to the grids of the controlled tubes you will find that there are two resistors in the circuit (R7 and R8), each one by-passed with a condenser. One function of these resistors and condensers is to smooth out the varying audio voltages in the same way that chokes and condensers smooth out rectified voltages in the filter circuit of an AC power unit. Thus the remaining voltage that is applied to the controlled grids is an almost pure DC voltage. Another function of the resistors and condensers is to prevent regeneration or degeneration coupling effects between RF and IF stages.

Figure 2 shows a circuit of a diode detector and automatic volume control stage. It is often convenient as in this circuit to use the second detector for developing an AVC voltage as well as for detection. How this is done is as follows: The voltage from the IF transformer secondary is applied to the diode plates which are

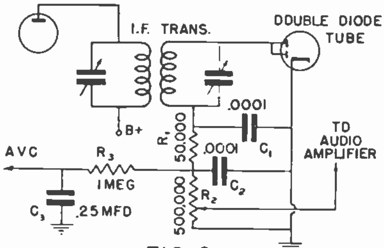


FIG. 2

connected in parallel (they form one element) as indicated by the diagram. This signal voltage causes a current to flow through the tube when the diode plates are made positive. The complete path of the current through the diode caused by the signal voltage being applied to the plates of the diode is through resistors R1 and R2. Thus. a voltage is developed across R2. This voltage, due to the rectifying action of the tube and the filtering action of R1, C1, and C2 is made up of a direct current component and an audio frequency component. These voltages are affected by the signal voltage. The audio voltage is dependent upon the percent of modulation and the signal strength of the station. Whereas the DC component or AVC voltage is more or less proportional to the signal strength of the RF carrier. By properly filtering the AF component the DC component is left to act as a controlling voltage which is proportional to the signal strength of the station to which the receiver is tuned. It is this DC component that is used for an AVC voltage. The filter action of R3 and C3 in Fig. 2 serves as the filter for removing the audio component.

The size of these two parts must be chosen in such a way that the *time constant* is just right for best action. As you know the time constant of a resistor and condenser is equal to their product (RC). This time constant must be large enough to filter out the audio component but small enough to allow a smooth acting AVC. Figure

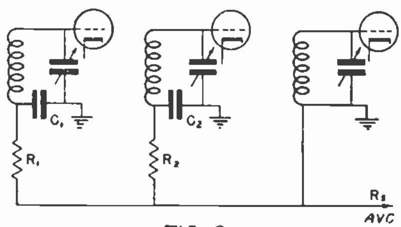
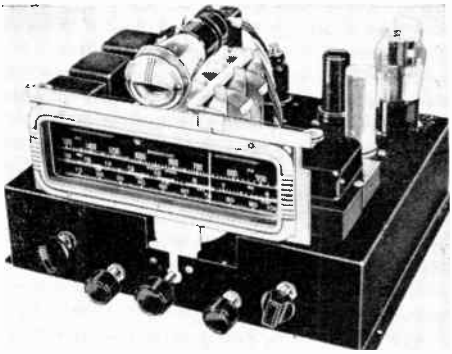


FIG. 3



Above is shown the chassis of the receiver, making use of a tuning eye tube, automatic volume control, and automatic frequency control. Such receivers as this one makes use of the basic principles as set forth in this lesson.

3 shows how the control voltage is utilized in controlling the gain of the RF and IF tubes. The AVC voltage from the second detector is fed to the grid returns of all the preceding RF and IF tubes. The more tubes it is made to control the better is the AVC action. There is no current drawn by these tubes from the AVC circuit because the voltage is impressed upon the grids of the tubes. For tubes which are already biased it just adds more bias as the signal voltage becomes stronger.

Resistors R1 and R2 in Fig. 3 in combination with condensers C1 and C2 act as decoupling filters to isolate the RF and IF stages from each other. This is done to avoid unnecessary coupling between stages.

The 6H6 diode type tube was originally designed for the second detector and AVC functions for the superheterodyne type receiver. However, due to the loss in gain through the use of a diode, more efficient tubes have been developed. These tubes consist of a diode or a double diode section (for use as detectors and AVC) along with a triode, or a high mu triode, or a

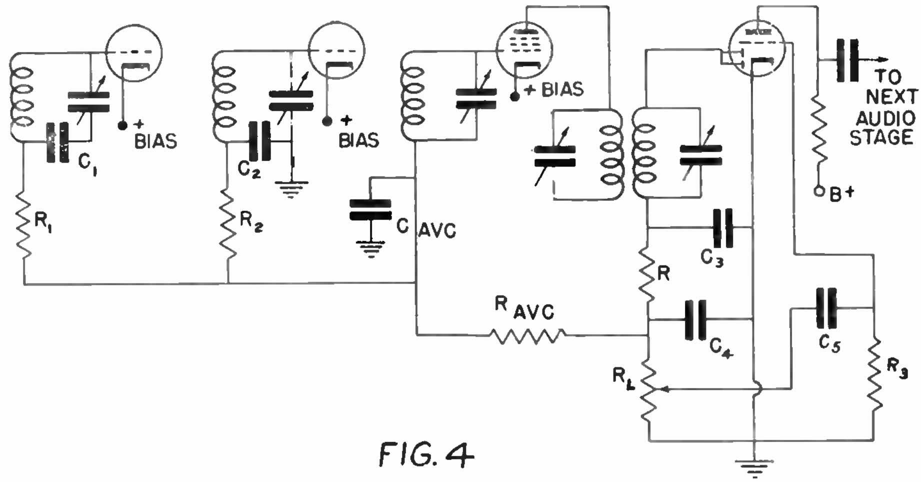


FIG. 4

pentode, and in some cases both a pentode and a triode are all in one envelope. Some of these types are the 55, 75, 85, 7A6, 6B7, 6C7, 6Q7, 6SQ7, 1H5, 12SQ7, 6T7G, 3A8GT, etc. Some of these tubes may be new to you and looking over a complete circuit you may find it difficult to understand just how the AVC voltage is obtained. However, if you will draw the circuit of the complete second detector and AVC separate, you will find that you can get a clear mental picture of just how the AVC voltage is developed.

A circuit using a double-diode-triode tube is shown in Fig. 4. The complete AVC circuit is shown. The receiver parts which are not a part of the AVC circuit are, however, left out in order to simplify the circuit. The AVC circuit is the same as for Fig. 2. The audio frequency signal is fed to the triode section of the tube

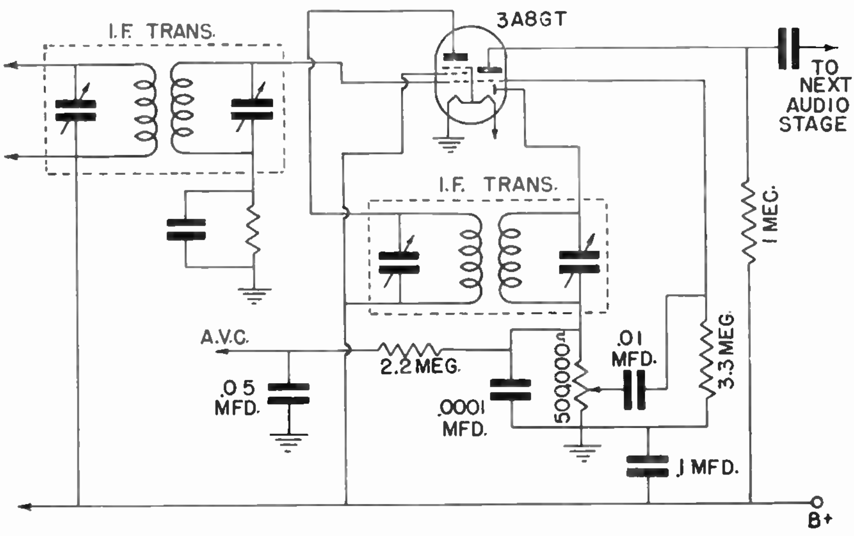


FIG. 5

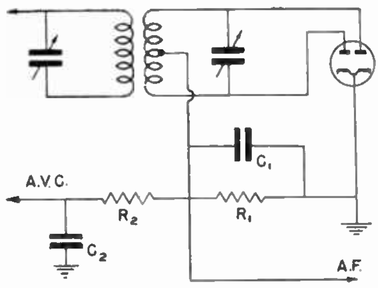


FIG. 6

through C5. In this way it is amplified.

In some of the smaller receivers, only one more stage after the detector is used when a tube of this type is employed. With the more complex type tubes such as the 3A8GT, mentioned previously, the circuit of the second detector and AVC can become somewhat more complex. To illustrate this a diagram of the IF and second detector stage of a Motorola Model 41H is shown in Fig. 5. As the 3A8GT tube is a triple tube containing a pentode, triode, and diode section, three operations can be performed with this one tube. Figure 5 shows how this one tube can be used as an IF amplifier, second detector, and audio amplifier. Although this diagram may seem complex on first sight, upon following the circuit through you will find nothing really complicated. The pentode section of the 3A8GT tube is used as an IF amplifier which is similar to any other IF amplifier. The diode section is a conventional second detector circuit with the AVC voltage taken from the voltage developed across the 500,000 volume control. The triode section of the tube is used as an audio amplifier.

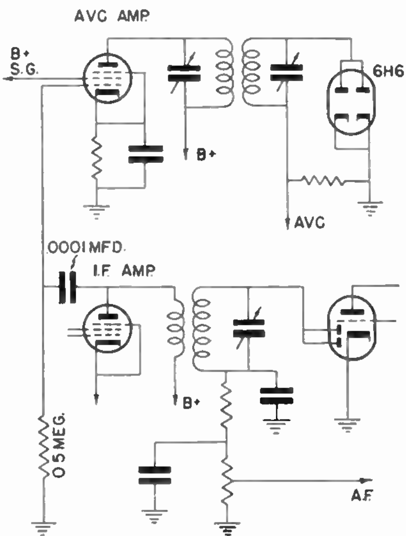


FIG. 7

Figure 6 shows another 2nd detector AVC circuit where a double diode is utilized giving full wave rectification of the signal. The AVC is taken off at the same point as the audio and the AC component is filtered out by resistor R2 and condenser C2.

In larger more elaborate type receivers and in communication receivers, it sometimes becomes advantageous to amplify the AVC through a separate amplifier. Figure 7 shows a circuit of an AVC amplifier system. The signal from the last IF amplifier grid is fed to a separate AVC amplifier tube, amplified, and then rectified by a diode tube which is separate from the second detector tube. In this way the AVC action is much more effective due to the higher AVC voltage obtainable from the AVC amplifier.

Quiet Control or Q Circuits

When an ordinary AVC controlled receiver is tuned between stations, the receiver is at its maximum state of sensitivity because there is no AVC voltage developed and the minimum bias is placed on the control grids of the RF and IF tubes. As a consequence, the receiver amplifies all the noise and static ordinarily encountered

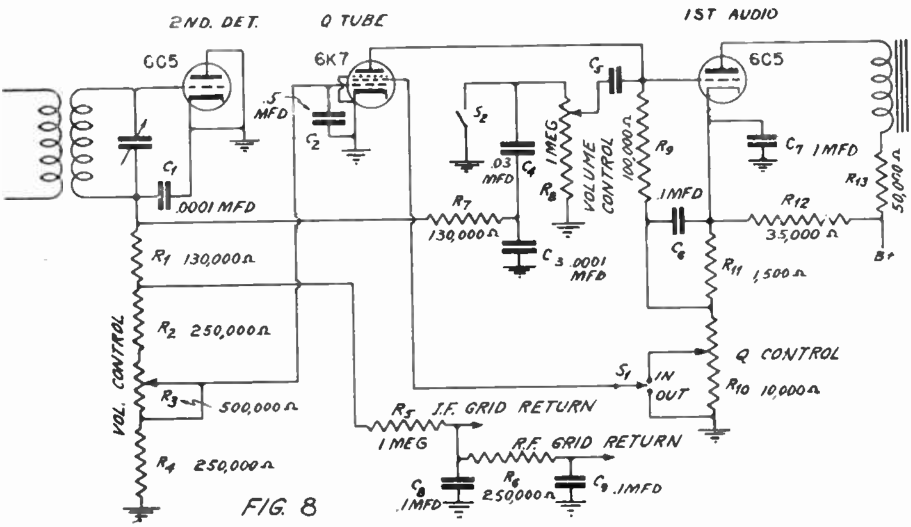


FIG. 8

between stations. To remedy this undesirable condition, design engineers have developed various methods of suppressing the between station noise. One very popular method is to arrange an extra tube to apply a very high negative bias to the grid of the first audio tube. *This high bias cuts off the plate current to the audio tube and*, of course, under such circumstances there will *not be any AF amplification*. As a result of this action there will not be any *in-between-station noise*. Tubes which are employed for this purpose are called *Quiet, Quelch* or simply *Q* tubes.

A 2nd detector, AVC, and Q circuit is shown in Fig. 8. This is the same system that is employed in the Fada RC receiver, and is typical of those which you will find in other receivers.

The 2nd detector employs a diode circuit (6C5 connected as diode). The diode load is represented by R1, R2, R3, and R4—these being in parallel with C1. The AVC voltage is developed by the voltage drop across R2, R3, and R4 and is fed to the grid returns of the controlled tubes through R5 and R6. Condensers C8 and C9 remove the audio or varying voltage, leaving a substantially pure DC to be applied to the grids of the tubes.

The voltage drop across R4 serves as a bias voltage for the control grid of the 6K7 Q tube. It is important to realize that this bias voltage is only present *when a signal is received*. No voltage drop can occur when no signal is received because in this case there is no current flow through the diode load. *Therefore, with no signal, the grid of the Q tube is at zero potential.* Next consider how the rectified signal is fed to the 1st audio tube. Its path of travel is through R7, C4, R8 and C5 where it is then applied to the grid of the 6C5 tube.

Resistor R11, by virtue of the combined flow of plate and bleeder current (through R12) through it, provides a normal bias for the grid of the 1st AF tube. The same current that flows through R11 also flows through R10. Therefore, there is a voltage drop across this resistor which is applied to the screen grid of the 6K7 Q tube. The position of the variable element of R10 determines the value of voltage which is applied to the screen grid of the 6K7 tube. Any voltage above ground along R10 is positive with respect to ground. This establishes that the screen grid of the 6K7 tube is at a positive potential.

While the plate of the Q tube and the grid of the 1st AF tube are connected together, they really are at different potentials and of different polarities *with respect to their cathodes.* Only the voltage drop across R11 is applied to the grid of the 1st AF tube, because this is the only voltage between grid and cathode of this tube. The situation is different with respect to the plate of the Q tube. In this case, you can easily see that R10, R11 and R12 form the usual voltage divider and that the plate circuit of the Q tube is connected between R10 and R11. Actually all of the voltage existing across R10 is utilized as the plate voltage of the Q tube and is positive for the same reason that the screen grid of the tube is positive—that is, the voltage between R10 and R11 is positive with respect to ground. Thus it is easy to see that a positive voltage is applied to the plate of the Q tube and the cathode is, of course, zero due to the ground connection.

Now you will see how the Q tube acts to control the in-between-station noise. When a signal is received, a relatively large voltage drop occurs across R4. This is applied to the grid of the 6K7 Q tube—thus stopping the flow of its plate current. The audio is then fed to the grid of the 1st AF tube as already explained. Thus the entire receiver *acts in a normal manner.*

When the receiver is tuned to the in-between-station position or to a point where no signal is received, the voltage drop across R4 reduces to zero and, of course, the grid of the Q tube reduces to a zero potential. This allows the plate of the Q tube to *draw current* (which it could not do before). Once the plate of the Q tube draws current it causes a *voltage drop* across R9. This *adds to the regular grid bias voltage developed across R11,* thus forcing the grid of the 1st AF tube to the plate current cut-off point. This means that no signal can get through the 1st AF tube. Thus loud static crashes and the usual in-between-station noises cannot cause the speaker to reproduce them. Usual reception of signals is restored when a signal is tuned in. for this blocks the grid of the Q tube—it cannot then draw plate current. Consequently the bias on the grid of the 1st AF tube is normal.

It is interesting to note in a circuit like Fig. 8 that the signal controls not only the AVC action, but also the Q circuit action. In fact, the signal level has a direct control on the action of the RF, IF, 2nd detector, Q circuit and 1st AF stage.

Nearly all receivers that employ a Q tube operate on the principle explained for Fig. 8. Naturally there will be variations of this circuit. However, if you will use the principle of Fig. 8 as a basis, you will not find it difficult to understand other systems. In a circuit like Fig. 8, the Q action is optional. Thus, if an automatic *silencing action is not wanted,* S1 may be turned to the *out position.* This stops the action of the Q tube by reducing its screen grid voltage to zero.

A manual Q circuit action may be obtained by closing switch S2 of Fig. 8. Thus, if you did not want an automatic Q action, S2 would be turned to out and then when tuning from station to station, S2 could be closed to silence the receiver. Switch S2 also may be used to silence the receiver

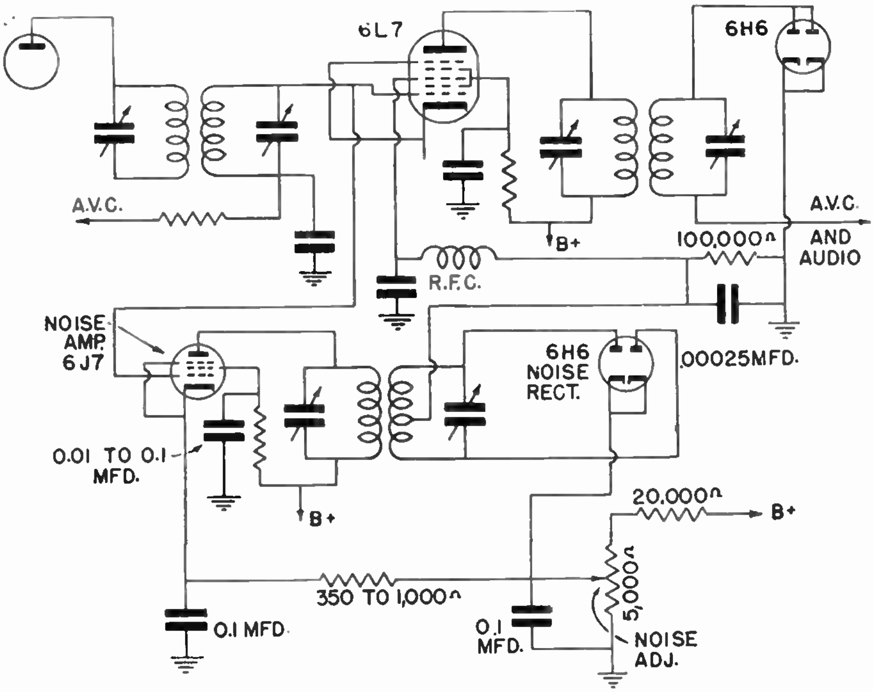


FIG. 9

when the phone is being used or when talking to someone. Thus the heaters of the tubes are kept hot and the receiver can immediately be turned on again at the original volume level by opening S2.

The circuit of Fig. 8 has two manual volume controls which operate from the same shaft. These are R3 and R8. The setting of these determines the volume level and the setting of R10 determines at what noise level the Q tube starts to act on the 1st AF tube. All of these various parts increases the serviceman's difficulty when anything goes wrong with a circuit of this type.

There are circuits employed in the better home type receivers and in communication receivers that tend to limit noise in the receiver caused by static and local interference. These circuits are similar in many respects to the quiet or quelch circuit used to eliminate static between stations.

Figures 9 and 10 show typical circuits of noise limiters. They are generally referred to as automatic noise limiters (ANL). The operation of these circuits is similar to the operation of some of the circuits previously described.

The circuit of Fig. 9 operates as follows: The AVC controlled IF amplifier tube is a 6L7 double control grid tube. Any signal impressed upon the first control grid of the 6L7 is simultaneously impressed upon the grid of the noise amplifier as the grid of the noise amplifier is directly connected to the controlled tube grid. The noise and the signals are amplified through the noise amplifier and fed to the noise rectifier. The noise rectifier, as you can see from the diagram, is of the full-wave rectifier type.

There is a positive voltage fed to the cathodes of this noise rectifier. This makes the rectifier non-conducting. It will not come into action as a rectifier unless a signal of higher amplitude than the positive cathode voltage is applied to the rectifier plates of the noise rectifier. Remember a diode tube will not conduct current unless the plate is made positive with respect to the cathode; and if the cathode has a positive voltage applied to it before the tube starts to conduct, the voltage applied to the plate must exceed that applied to the cathode before current can flow. The rectified current from the noise rectifier tube develops a voltage across the 100,000 resistor which is connected to the center tap of the input to the noise rectifier tube; and in turn this voltage, being negative with respect to ground, is applied to the second control grid of the 6L7 controlled tube by way of the RFC in Fig. 9.

When high amplitude noises such as static are received, the voltage applied to the plates of the noise rectifier exceeds the positive voltage applied to the cathode and the rectifier conducts, placing a negative voltage on the controlled IF tube, thus blocking the tube for the duration of the static pulses. As the length of these pulses are usually of the order of 3 or 4 microseconds, there is no noticeable break in the received signal, but the noise is missing.

The theory for such a limiter is

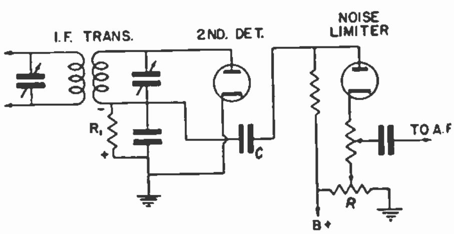


FIG. 10

that these interfering noises are of short duration and high in amplitude. Thus if the cathode voltage in Fig. 9 is adjusted by the 5000 ohm resistor to the signal voltage being received, any high amplitude signals will cause the controlled IF tube to be blocked eliminating the static or interfering pulses which are high in amplitude.

Figure 10 shows a much simpler noise limiter circuit. The second detector is effectively in series with a second diode tube which acts as the noise limiter. A positive voltage is placed upon the plate of this noise rectifier causing it to be conductive. A negative voltage will be developed across R1 due to the rectifying action of the detector tube; and as this voltage is proportional to the received signal, by coupling it through condenser C1 to the plate of the noise rectifier tube, the conductivity of the noise rectifier will be controlled by the applied signal. Thus, the current flowing through this tube will follow the modulated envelope of the received signal unless the amplitude of the signal increases above the applied DC on the plate of the noise limiting rectifier. When this occurs, the rectifier is made non-conducting. Thus any signal of higher amplitude than that of the applied voltage, will be eliminated before it reaches the audio amplifier. The resistor R in Fig. 10 is adjusted so that the DC plate voltage applied to the noise rectifier is equal to the signal voltage. Then any interference of higher amplitude than the signal will be eliminated from reaching the output of the receiver.

Automatic Frequency Control

During the development of the superheterodyne type of receiver, considerable trouble was experienced with the oscillator part of the circuit. Nearly all of them have a tendency to drift in frequency. The drift in frequency does not need to be much to cause serious trouble. For instance, if the IF is adjusted to 465 KC and the oscillator drifts in frequency as little as plus or minus 2 KC, then the beat note will be 463 KC or 467 KC. This causes side band cutting resulting in poor tone quality. A system to overcome frequency drift is called automatic frequency control (AFC). This AFC, in order to correct for frequency drift of the local oscillator, must be able to constantly keep the oscillator frequency above the received frequency by an amount equal to the value of the IF. For instance if the received signal is 900 KC and the IF is 456 KC, the oscillator must operate at 900 + 456 or at 1356 KC. For other received frequencies, the same frequency difference must be maintained by the oscillator.

To accomplish this an AFC system must be devised that will automatically control the oscillator frequency of the receiver in such a way that any deviation from the correct frequency will be automatically corrected. Figure 11 shows the circuit details of one such system (used in the GE-E106 receiver).

Note how the 6J7 AFC tube is connected to the 6A8 oscillator tube (full details of the 6A8 tube are not shown in Fig. 11 since it is a conventional circuit). This AFC tube *acts in effect as a shunted inductance* across

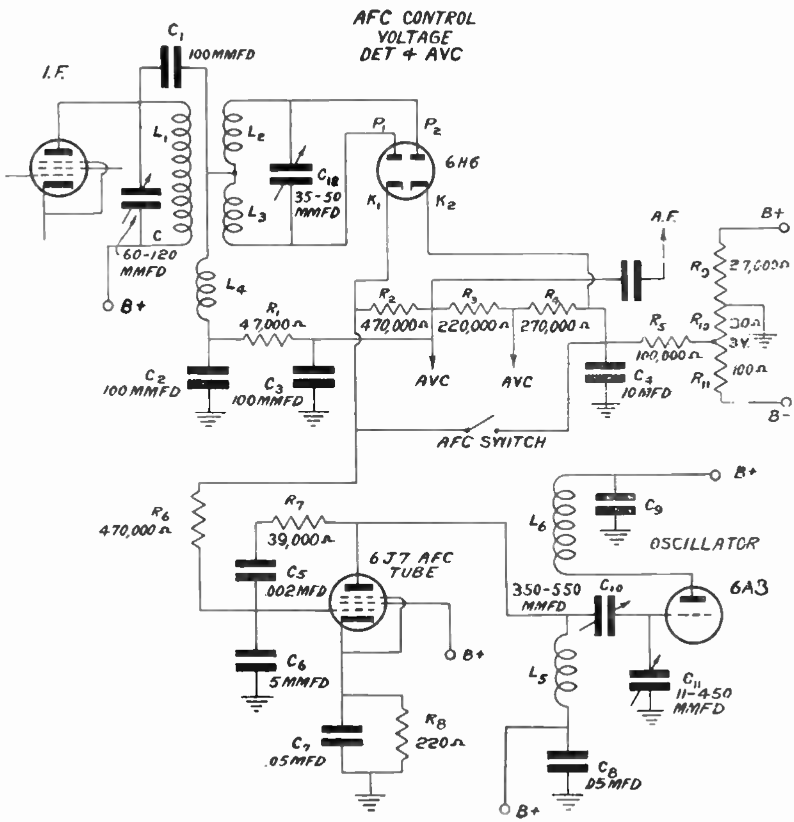


FIG. 11

the tuned grid coil of the oscillator. The amount or value of the effective *shunted inductance* is determined by the grid voltage of the 6J7 AFC tube. If the grid voltage on this tube is controlled by the IF amplifier of the receiver in such a way that it will change the effective inductance (reactance) of the tube, it may be made to correct for any frequency drift or detuning of the oscillator—thus the receiver will automatically be returned to the correct resonant point.

The grid voltage fed to this AFC control tube (6J7) is developed in a special detector circuit as shown in Figure 11. This circuit is called a Foster-Seeley *discriminator,* the operation of which is the same as a discriminator in an FM receiver.

The operation of this discriminator relies upon the fact that there is a 90° phase difference between the primary and secondary voltages of a double tuned, loosely coupled transformer when the resonant frequency is applied; and the *phase angle* varies as the applied frequency varies from resonance.

Thus if the primary and secondary voltages are added *vectorially*, the absolute magnitude of the resultant vector will be greater on one side of resonance than on the other. The side of the resonant frequency on which the greater voltage will appear depends upon the relationship between the two coils L1-L2 or L1-L3 in Figure 11—in one case the maximum voltage will be above resonance and in the other below resonance.

By magnetically and capacitively coupling the primary (L1) voltage to a center tapped secondary, both conditions can be realized and at the resonant frequency the voltage in each half of the secondary will be equal. By connecting the secondary winding of this transformer to the plates of separate diode detectors and by capacity coupling the primary to the center tap of the secondary which in turn is connected to a resistance network between the cathode of the two diodes, a voltage will be developed across this network which will be proportional to the frequency deviation.

The circuit of Fig. 11 is connected in this manner. The diodes are the plates and cathodes of the 6H6 tube. The resistance network between the cathodes consists of resistors R2, R3, and R4. The coupling from the primary to the center tapped secondary is through condenser C1, the value of which is so chosen that its reactance over the frequency range it is to operate is very small. The inductance of L4 along with condensers C2 and C3 and resistor R1 act as an RF and also as a DC *path* for the diodes.

The resistance network R2, R3 and R4 is arranged in such a way that the differential voltage due to an off resonant frequency is produced across this network giving the correct polarity above or below resonance. This is made possible because of the voltage applied to the plates of the diodes. When the frequency is above the resonant frequency of the tuned IF transformer, the voltage from the primary through condenser C1 combining with the voltage in L2 produces a higher voltage at the diode plate P2. Thus more current is drawn through this section of the tube. The current flowing through the network (R3 and R4) produces a negative voltage on the grid of the AFC *reactance* tube causing it to act as a larger inductance (as explained further on), thus reducing the frequency of the oscillator until the correct IF is produced. When the correct intermediate

Many automatic circuits as used in the modern receiver require the use of almost perfect tubes for proper functioning. This view shows a Hickok mutual conductance tube tester which is one of the best types of tube testers to use in selecting tubes for automatic control functions.

frequency is formed the voltage upon diode plates P1 and P2 will be the same. Thus the currents through the network will be equal and in opposite directions, cancelling each other and no net voltage will be developed across the network. The resistor R2 is the *diode load* for diode P1-K1 and R3 + R4 is the *diode load* for diode P2-K2.

The diode load of P2-K2 is slightly larger than the diode load of P1-K1. This is due to the fact that a negative voltage of 3 volts is already applied to the cathode of K2 through R5 from the voltage divider R9, R10 and R11 and the added resistance in the P2-K2 diode circuit just balances this negative voltage. Thus, this negative 3 volts has no effect upon the AFC voltage. It is used in the circuit to supply a bias voltage of the RF and IF tubes through the AVC circuit as indicated in the diagram. Now when the frequency applied to the discriminator becomes lower than the IF, the voltage at P1 becomes greater causing the diode P1-K1 to draw more current. This in turn develops a positive voltage across the resistance network making the grid of the AFC control tube positive, causing it to act as a smaller inductance as will be explained. Thus the oscillator frequency is made to increase to the correct value.

It may seem confusing to the student as to *how a tube can act as a variable inductance*. The following will explain this principle. The plate current in a vacuum tube follows the applied grid voltage. Now if a voltage is fed to the plate of a tube at a certain frequency *and this same voltage is fed to the grid* but made to lag the voltage on the plate by 90°, the plate current and the plate voltage of the tube will be 90° out of phase and the plate voltage will lead the plate current by 90°. The current relationship in an inductance is 90° out of phase and lagging the applied voltage. *Thus the tube acting in this same manner will effectively act as inductance.* The smaller the current through the tube, the greater the equivalent inductance and vice versa because the larger an inductance, the greater the reactance and the smaller the current for a given applied voltage.

Referring again to the circuit of Fig. 11, it is then easy to see how this 6J7 AFC tube acts as an inductance. An RF voltage from the 6A8 oscillator tube is fed to the plate of the 6J7 tube from the grid circuit of the oscillator. This voltage in turn is fed through a voltage dividing network R7, C5, and C6 to the grid of the same tube. The voltage developed across C6 is equal to the reactance of the condenser times the current through it and as the voltage is 90° lagging the current, the voltage applied to the grid of the tube will be 90° lagging the voltage on the plate. The tube circuit, then, simulates an inductance. The amount of the apparent inductance is determined by the DC bias upon the tube grid. This bias is fed to the tube from the discriminator through R6 and as the tube is connected across the oscillator coil, any variation in the equivalent inductance of the tube must have its effect on the tuning of the oscillator.

The oscillator grid circuit, as can be seen from Fig. 11, is connected so that the grid coil is connected to the grid through coupling condensers in order to allow the coil to feed the plate voltage to the 6J7 AFC tube. The oscillator other than this is just a conventional feed-back oscillator.

The AFC action is stopped by closing the AFC switch. This switch shorts the AFC resistance network, stopping its action. The AF and AVC voltages however are not interfered with as the circuit acts as a full wave rectifier when the switch is closed.

The diode load of P2-K2 is split into two resistors so that a separate AVC voltage can be fed to the IF and RF tubes.

This system will compensate for all frequency drifting due to temperature changes in the oscillator circuit or tube, and for small signals as well as for large signals. The degree of frequency control for small signals is, of course, less.

The AVC in the receiver must make the proper adjustments more rapidly than the automatic frequency control to permit the latter from reacting on the former.

The original oscillator adjustment is made by ear with the AFC grid shorted—the receiver being tuned away from resonance about 3 to 5 KC. The AFC is then turned on and the oscillator trimmer is tuned to apparent resonance. The AFC tube should again be shorted and the receiver again tuned away from resonance, but in the opposite direction from which it was tuned off resonance before. With this done, the AFC short should now be removed. The oscillator trimmer should again be adjusted to apparent resonance. It may be necessary to repeat this adjustment several times before accurate alignment of the oscillator stage is obtained.

Various types of AFC will be found in use. Some of these may require special connections before correct alignment can be made. For this reason it is desirable to carry out the manufacturer's specific instructions when aligning the tuning circuits.

You should always be very careful in the selection of AVC, Q and AFC tubes. These tubes should have a minimum of gas content and should be normal in every other respect. Remember you can get the best control action only by selecting *the one best tube in a lot of several.*

Since these tubes operate on very low voltage, and since nearly every circuit will have high series resistances, the ordinary DC voltmeter is not of much help in determining the condition of these special circuits. Where you have trouble with this type of circuit, use a good accurate ohmmeter. In regard to the condensers, these can be tested under a fairly high voltage. It is best to use non-inductive condensers and make sure that replacement condensers are of the correct value because it is absolutely necessary to have the correct time constant in control circuits.

HOW TO CORRECT AVC DEFECTS

Defects which develop in AVC, Q circuits (noise control circuits) and AFC (automatic frequency control circuits) are, in nearly all cases, traced to defective tubes, resistors, condensers or inductances.

One of the first things to do where an AVC, Q or AFC circuit is known to be causing trouble is to change tubes. This means that you might have to try several tubes. A tube may work fine as an IF or RF amplifier, yet the slightest defect in the tube may cause improper AVC or AFC action. Also, if the tube is the least bit gassy it may prove to be a poor automatic control tube. Therefore, don't be satisfied with merely changing tubes. You can often correct improper control circuit action by merely trying several tubes in the stage in question until you find the defective tube.

A leaky by-pass condenser or a defective resistor can also be the cause of considerable trouble in special control circuits. You must remember that these circuits function by virtue of voltage drops across resistors and that the by-pass condenser units (in conjunction with resistors) regulate the *time constant* (product of R and C in seconds) of a circuit and also filter out any varying voltage in the circuit. You can readily see that even a slight defect in the resistor or by-pass condenser units can seriously affect the normal operation of several circuits.

Aside from seeing that *good tubes* are always in the circuit, you must be able to determine very accurately the condition of the resistors and condensers. How can you do this? There are two generally accepted methods. One is to use accurate electrical measuring instruments (ohmmeter and condenser tester or their equivalent) and the other is by the substitution method.

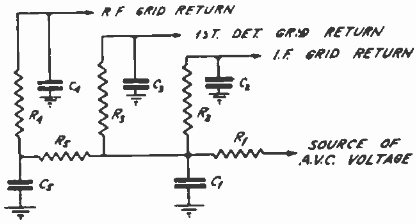


FIG. 12

In the latter method, you may find it necessary to substitute for every part in the control circuit before you find the defective unit. This may appear difficult but may have to be done if you don't have a modern vacuum tube voltmeter. The reason for this is that it is difficult to measure high resistances *accurately* with an ordinary low sensitivity meter (1000 to 5000 ohms per volt). Resistor values for control circuits may run up to as high as 10 megohms. Not all servicemen have the facilities for testing such high value units but the VTVM is coming into wide use for this purpose.

Exact values are not always necessary when testing for defects by means of the substitution method. For instance, a 500,000 ohm load resistor for a diode detector tube may *become open*. You may not have that particular value in your stock of resistors. If the resistor is open, there will be no reception. However, if you connect a 100,000 ohm unit in place of the 500,000 ohm unit you will at least hear a signal or get a slight AVC action. The fact that you now get operation proves that the 500,000 ohm unit was defective. You have established this even though you did not have the proper value for substitution. Once you determine what part is defective you can order the proper value if you don't have it in stock. The same sort of test applies to the by-pass or filter condensers associated with the AVC resistors.

Figure 12 shows a typical AVC filter circuit. If C1, C2, C3, C4, or C5 should become *shorted*, the AVC voltage will be directed to ground instead of to the grids (via the grid return circuit). Should one of these condensers become shorted, you can easily determine it without testing any part by the following method.

If the receiver employs a tuning meter, there will not be an increase in the reading (actually this means a decrease in the plate current) as the station is tuned in. Another way to determine whether the AVC circuit is working is to tune in several local stations. These stations will blast in with varying degrees of volume, depending on the setting of the *manual volume control*. If the AVC circuit is working, all the local stations will be received at about the same volume. Still another way to check the AVC circuit is to insert a milliammeter in series with the plate or cathode circuit of one of the *controlled* tubes. When this is done, tune in a station or a signal from a test oscillator. When the receiver is tuned to exact resonance, the milliammeter reading will decrease provided the AVC is working properly. If it is not working, there will be no appreciable change in the reading as the station is tuned in.

Defects in AVC filter circuits do not always produce effects that are readily recognizable. For instance, you would not have much trouble in recognizing (by ear) that a bias resistor was open or shorted. Yet it may be difficult to recognize (by listening to the receiver) an AVC defect. For instance, if any of the AVC filter condensers should short, you would still be able to get signals. The same thing holds true in regard to the resistors.

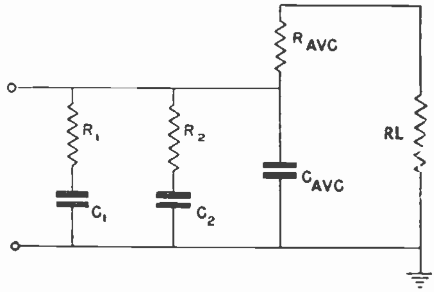


FIG. 13

These may become shorted or open, and signals may still be received.

As a rule, signal reproduction under such conditions would be distorted, and you could not tune stations in clearly. If you have ever listened to a normal receiver with AVC when it was not tuned to resonance (suppose the station received was a local, operating on a frequency of 800 KC, and the dial was set to 805 KC—in which case, the receiver *would not be tuned to resonance*) you have a good idea how a receiver sounds with a defective AVC system.

It is well to bear in mind that the filter units in many AVC systems are not so likely to develop defects as other parts in the receiver. The reason for this is that the filter units are not often subjected to high values of voltage. Therefore, as a rule these parts only become defective due to poor materials or when their natural life ends. Of course, other parts may become defective, and by such a defect, subject the AVC units to a rather high voltage. In this case, these would possibly become defective as the component parts in low voltage AVC circuits are not always made to withstand high voltage.

It is important that the exact replacement value be used for the final repair. Many times servicemen make the mistake of substituting other values in an AVC system and the customer complains that the receiver doesn't sound the same since it was repaired. The reason for this is brought out in Fig. 13. This figure is a rearrangement of Figure 4. RL is the volume control through which the audio amplifier is fed. The AVC network is connected across this resistor and, of course, shunts the audio signal as indicated in Fig. 13.

In the original design of the receiver the values were so chosen that they will have but little shunting effect upon the audio frequencies. However, if these values are changed, this no longer holds true. The effect is more noticeable upon the high frequencies than the low frequencies because of the reactance of the condensers. The reactance of a condenser varies inversely with the frequency. Thus the higher the frequency the lower the reactance. From the diagram of Fig. 13 it is seen that the combination of R1-C1, R2-C2, and C_{AVC} are all in parallel and these in turn are in series with R_{AVC}. This network of resistors and condensers is then shunted across the resistor RL which is part of the diode detector load in Fig. 4. Aside from the fact that this network shunts the high audio frequencies, reducing their amplitude, it also affects the diode load resistance. The resistor RL of Fig. 4 constitutes the diode load without the AVC filter connected. The RF filter consisting of resistor R, condensers C3 and C4 is also part of this load. Condenser C3 and C4 of this RF filter are of the RF type, having very small capacities. Thus they have little effect upon the audio frequencies. The ratings of these two condensers and resistor R, as well as the value of the AVC parts, must be exact original values if they are to be replaced.

As the diode load is designed for maximum undistorted output from the detector any change upon this load will cause a reduction in the signal and an increase in the percent of distortion fed to the audio amplifier from the detector.

If a 1 megohm resistor is shunted across a 500,000 ohm diode load, the distortion will increase from 5% to 20% at a signal frequency of 400 cycles. It is obvious then that if the AVC circuit is changed that the receiver output will be affected—not only because the AVC action is changed but also due to a change in the diode load and the shunting effect of the high audio frequencies.

You have, no doubt, realized by now that it is absolutely necessary for all parts in an AVC circuit to be of correct value and in good condition. The serviceman often comes across a resistance which, although it may show continuity, may be of incorrect value. That is, resistances sometimes change in value, *and if the change is great enough, there is likely to be serious trouble.* The AVC action may be seriously retarded or the voltage drop across the resistance may be too great, resulting in too much voltage being applied to the grids. Of course, when this happens the *sensitivity of the entire receiver is greatly reduced.* For these reasons we recommend that the substitution test be made when trying to correct AVC trouble. If you suspect one resistor, try another one in its place. You may get much better results.

In some receivers it may seem to you that the sensitivity *is not great enough for the particular locality.* There is a way of increasing the sensitivity. All you have to do is to lower the value of the resistor or resistors across which the AVC voltage is developed. The lower the value, the more sensitive the receiver will be down to a certain point. Of course, you must be careful not to destroy the AVC action altogether. This could be done by using a resistance of too low a value. If you want to decrease the sensitivity (and therefore the noise level) all you have to do is to increase the value of the resistance across which the AVC voltage is developed.

When replacing AVC filter condensers, obtain the non-inductive type. Leaky and inductive condensers can sometimes cause untold trouble in AVC filter circuits which is very difficult to overcome except by the substitution of good condensers.

One defect that servicemen sometimes have in AVC controlled receivers is that of fluttering or motorboating. This, in nearly all cases is due to the *grid return filter resistors* being too high—caused by a change in value. The defect can be corrected in many cases by using resistors of correct value in the grid return circuit.

Receivers employing several tuning bands often use different methods of obtaining the AVC on the short-wave bands and in many cases use no AVC at all on the short wave bands. The more elaborate types of receivers designed to operate mainly as a short wave receiver, have a switch with which the AVC action can be made inoperative. When receiving CW (continuous wave, in the form of International Morse code) it is much better to use the receiver without AVC. Thus receivers of the communication type have a control for eliminating the AVC action while the receiver is used for copying code. Most of the receivers used by amateur radio operators are of this type. The ANL circuits discussed in this lesson are also more common in receivers of this type.

There are, as mentioned in a previous lesson, many new types of test equipment in a comparatively low price range that can be purchased for making measurements and tests upon these sensitive control circuits. It isn't, as mentioned, always necessary to use expensive test equipment for servicing these units, but in many cases such instruments are time savers and where a considerable number of receivers are being serviced, these instruments will prove valuable in locating defects in automatic control circuits. Meters of the high sensitivity type such as vacuum tube voltmeters and ohmmeters are the most common instruments for making tests upon AVC, Q and AFC circuits.

The object of this lesson up to this point is to give you a general picture of the common AVC, Q and AFC circuits along with the most common defects that occur in these circuits—also methods of locating and correcting these defects. Now that you have been given a general picture of these control systems a more specific case will be considered in order to acquaint you with the actual problems as they occur within a receiver of a typical design. Bear in mind that there are many receivers employing circuits that are considerably different from those given here. However, if you follow the instructions as outlined any circuit can be analyzed and tested as described.

In the following example an actual circuit of a receiver will be used to demonstrate a test procedure to follow when testing a receiver which has a faulty AVC system. The symptoms of the receiver action, possible cause for this action, and the cure will be given.

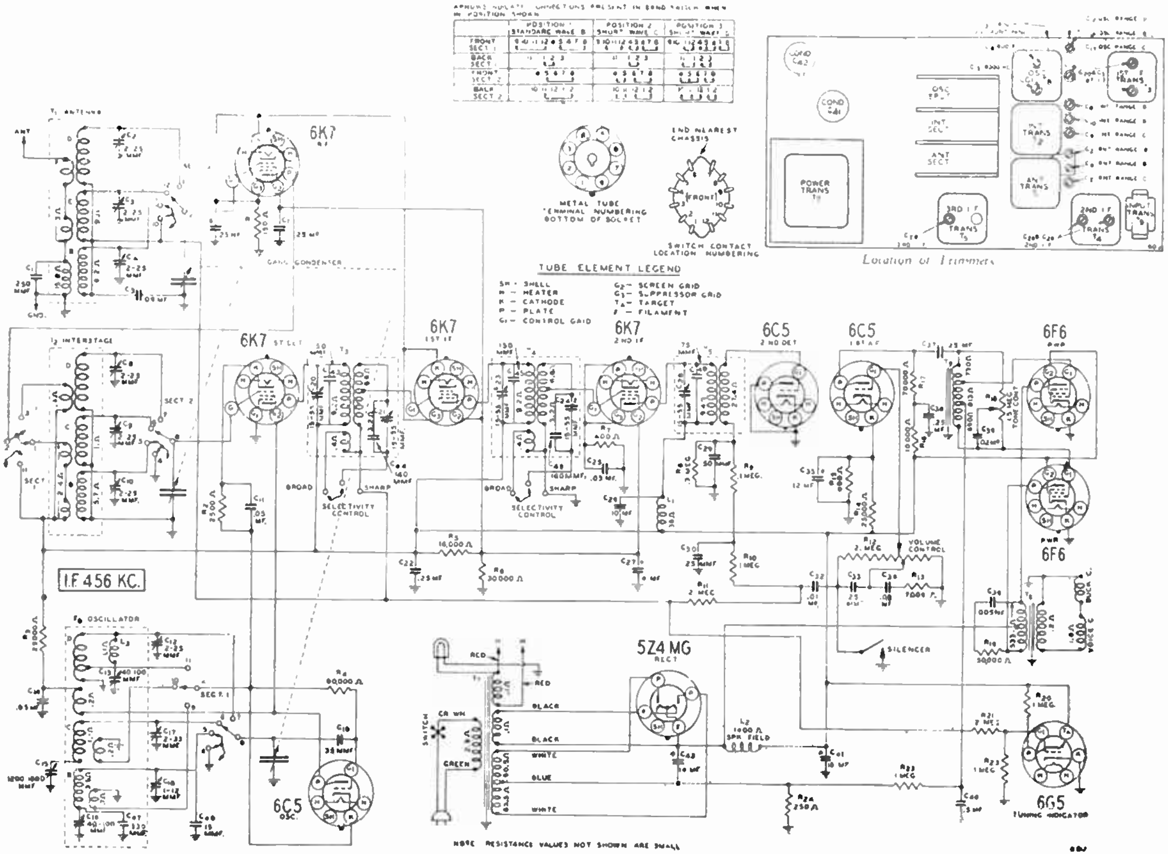

6K7
6K7
6K7
6K7
6C5
6C5
6F6
6F6
5Z4 MG
6C5
6G5
I.F. 456 KC.
TUBE ELEMENT LEGEND
SELECTIVITY CONTROL
VOLUME CONTROL
SILENCER
Location of Trimmers
POWER TRANS
NOTE RESISTANCE VALUES NOT SHOWN ARE SMALL

FIG. 14

The receiver of Fig. 14 is a Montgomery-Ward Model 62-271. This receiver has 11 tubes and two of these tubes are controlled by the AVC action of the receiver. The first step in the analysis will be to isolate the AVC. By doing this the complexities of Fig. 14 are simplified, allowing an analysis of the AVC system without the numerous circuit component parts of the receiver, that do not affect the AVC system, from interfering with the analysis of the AVC action. Figure 15 shows the complete AVC system of the circuit of Fig. 14. Each part is labelled in the same manner as it appears in Fig. 15. This is done to allow a quick reference from either diagram, making the identity of the circuit components from either diagram possible.

It is well to learn the important features of the receiver of Fig. 14 so that an intelligent analysis of the circuit under discussion can be made. This receiver is a three band high fidelity receiver with a selectivity control which allows broad or sharp tuning. There is one stage of RF and two stages of IF. The 6C5 oscillator tube in this receiver is a separate triode tube. The second detector is a 6C5 connected as a diode with the plate grounded and the grid acting as the diode plate. (Using tubes for a different purpose than for which they were originally designed is done quite often in modern receivers). The AVC and audio voltages are secured from the secondary of the 2nd IF stage transformer T5. The second 6C5 tube is the first audio which drives a pair of 6F6 tubes. A tapped choke is used instead of an audio transformer for driving the grids of the 6F6 output tubes.

The 6G5 electric eye tube is the tuning indicator which is controlled by the AVC voltage. The power supply consists of a 5Z4 rectifier with a typical filtering system. The telephone dial type push button tuning system has a silencer which grounds the audio signal while tuning, thus reducing noise between stations.

The AVC voltage is produced across R8 and fed to the 1st RF, 1st IF and tuning indicator tubes through

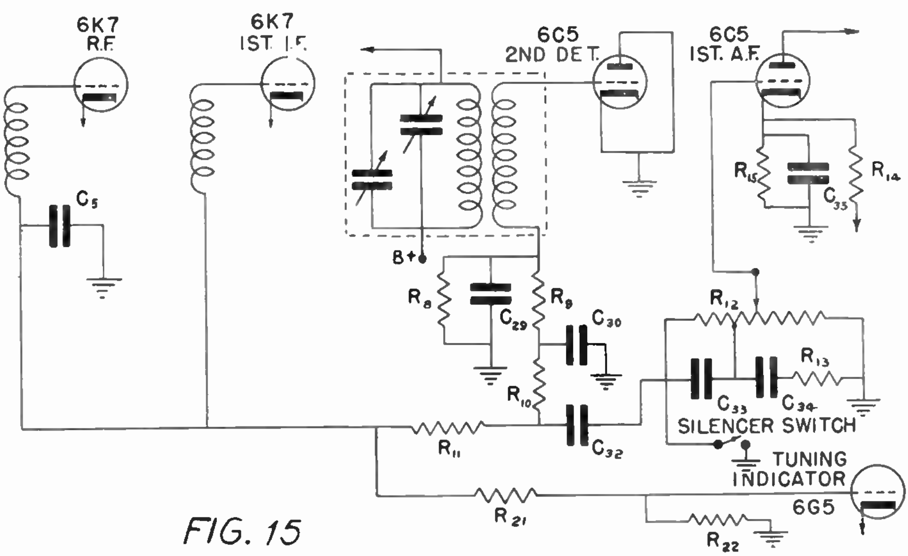


FIG. 15

resistors R9, R10 which in conjunction with C29 and C30 act as the RF filter.

The audio is fed to the 1st AF tube through the volume control resistor R12 which is a special tone compensated type control. Condensers C33 and C34 along with resistor R13 connected to the tap on the volume control make up a special tone compensator, giving an automatic tone control to accommodate for the characteristics of the human ear as the volume of the receiver is reduced.

The AVC system may seem complicated and confusing in the main circuit diagram of Fig. 14. However, looking at the AVC circuit redrawn in Fig. 15 without the other receiver components, it is considerably simplified. If any of the parts within the circuit of Fig. 15 become defective the AVC action will be affected. The symptoms which will identify AVC defects are not always obvious. Some of the symptoms which may be due to AVC defective action are poor sensitivity, mushy distorted signals, low volume, noise and oscillation which cause audio howls and squeals, fading and a completely inoperative receiver. As most of these symptoms are also associated with other receiver defects which are not connected with the AVC system, it becomes necessary to make a few tests to determine the source of the abnormal receiver operation.

Taking these symptoms in the order listed, a test procedure which, in most cases, will definitely identify the AVC circuit as the source of the defect will be given.

Poor sensitivity is often caused by a fault in the AVC system, but more often caused by some other defect remote from the AVC system. Thus it is important to know just how to determine which is causing the faulty operation. Resistor R8 and condenser C29 of the circuit of Fig. 14 should be checked. A considerable change in the value of R8 or a faulty condenser can cause an abnormal AVC voltage which in turn may cause the receiver to be insensitive due to a possible high bias placed upon the controlled tubes.

An open grid return lead from the grids of the controlled tubes back to the diode load resistor can also cause low sensitivity. The operation of the tuning eye tube is a clue to such defects. If the eye tube closes too soon and a blurry pattern occurs upon the fluorescent screen of the tube, it indicates an abnormal AVC voltage unless the tuning eye tube is defective.

Where there is no tuning eye tube in a receiver a vacuum tube voltmeter can be used to measure the AVC voltage. Remember that there is no AVC voltage unless a signal is being applied to the AVC tube. When no means of actually measuring the AVC voltage is available, the continuity method of locating the defect in the AVC system will have to be used. Every component in the AVC circuit should be measured accurately, if this system is suspected of being faulty.

Mushy distorted signals can be caused by an open circuit in the AVC grid return circuit. Resistors such as R11 in Fig. 15 or an open AVC feed line between the 1st RF tube and R11 is likely to cause such trouble. The best check for a symptom of this type is to make a quick continuity check of the grid circuits involved. In Fig. 14 check continuity between the grids of the RF and 1st IF tubes to ground. There should be as you can see from the diagrams of Figs. 14 and 15 a resistance of approximately 1.36 megohms. This value of resistance is calculated from the series parallel combination of R21 plus R22 in parallel with R11 plus R10 plus R9 and R8.

In some circuits where the AVC is developed separate from the AF system, open AVC resistors can cause distortion. Low volume is usually associated with poor sensitivity, but may be due to a defect in the audio portion of the AVC network caused by shorted or open condensers or resistors.

An open condenser such as C32 in Fig. 14 or shorted condenser C33 or C34 could cause a weak output although these condensers are not part of the AVC circuit. They are connected to the AVC circuit. Many times in circuits where the AVC voltage is developed across the volume control, the volume control becomes defective and causes a low volume output. Usually the volume control is noisy in operation if it is causing the trouble. A quick check of this control while the receiver is in operation should soon reveal such difficulty.

More than normal noise is often caused by open grid circuits or too low an AVC voltage allowing the receiver to be too sensitive. Oscillation may occur in the IF or RF stages of a receiver which, if of the proper frequency, may cause audio howls if the AVC feed line between each RF and IF stage is not filtered properly. In the receiver shown in Fig. 14 condenser C5 acts as the filter between the RF and IF stage. If it becomes open, feed back between these two stages can develop, causing oscillation which will either cause howls, weak reception, or excess noise.

The best check for symptoms to indicate this defect is to measure with a VTVM the RF voltage upon the tube elements of the IF and RF tubes and if a high RF voltage is present, it indicates the tube is oscillating. The cause of oscillation may be due to the AVC filtering system between stages. A separate test of the grid return bypass condensers will give a positive check on the operation of the AVC filter.

Fading can be a condition due to the received signal. This sometimes causes one to suspect there is something wrong with the AVC of the receiver when actually it is due to the condition of the signal. The signal strength of stations at a considerable distance away from the receiver will often drop below the normal operating signal necessary for the AVC action of the receiver to take place, and the signal will appear to fade out. This condition is usually easy to identify as there will be considerable noise because the receiver is made to operate at full sensitivity when the field strength of the signal reduces too much. A quick check to make sure it is caused by the signal strength is to tune the receiver to several other stations noting if the fading continues to occur. Fading is often due to improper AVC action and open resistors or a faulty volume control which the AVC voltage is taken from, or in many cases fading can be caused by an open grid return by-pass condenser such as C5, or an open resistor in the AVC feed line such as R11 in Fig. 14. If the grid return resistors are open, the AFC action is inoperative and any change in the signal strength of the station will cause fading because the AVC is not operating.

When a receiver becomes entirely inoperative the repair is usually much easier because some part has completely failed and it is usually an easy matter to locate a faulty part that has completely deteriorated. However, in some instances it becomes a difficult task to locate a defect in an inopera-

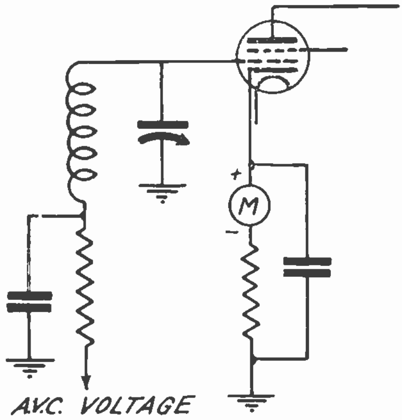


FIG. 16

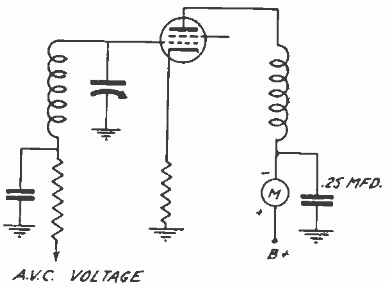


FIG. 17

tive receiver. The method to use for actually determining which stage is inoperative is discussed thoroughly in other SAR lessons. After the defective stage is located, means by which the actual defect is found may vary—usually the continuity method of locating the defective part is used.

The type of AVC system incorporated in other receivers may be considerably different from the circuit of Fig. 14. However, the same testing procedure as outlined here should be followed in each case. The symptoms listed here are of a general nature and regardless of the AVC system used in a receiver, these same symptoms will indicate a faulty AVC system.

Every AVC controlled receiver should incorporate a tuning meter or other device to *indicate resonance.* There are thousands of AVC controlled receivers in use which do not at present employ a tuning meter. Every time you come across one of them you should recommend to the owner that he have a tuning meter or electric eye (6E5 or 6G5 tube) installed. Explain to him that it is very difficult to tune an AVC controlled receiver to exact resonance without aid of a tuning device. We suggest that you stress the point that with the aid of a resonance indicator it is easy to realize the best tone quality from the receiver. Such a receiver is often tuned to one side of the resonance point, and whenever this happens, the tone quality is below par.

It is not at all difficult to install a tuning meter. One of these meters may be connected in series with the plate or cathode circuits of the controlled tubes. However, if one is connected in a cathode circuit, its resistance has to be considered. Also the leads must be kept as short as possible to prevent interaction between circuits. The meter has resistance, and, therefore, when in a cathode circuit, the voltage drop across it is applied as a negative voltage to the control grid. For instance, the regular cathode bias resistor may have a value of 500 ohms. Tuning meters usually have a resistance of about 300 ohms. Therefore, to use the tuning meter in the cathode circuit, the original 500 ohm resistor should be removed and a 200 ohm unit used in its place. This resistance plus the meter resistance equals 500 ohms which is the total required resistance for the circuit. Fig. 16 shows how the meter should be connected in the cathode circuit.

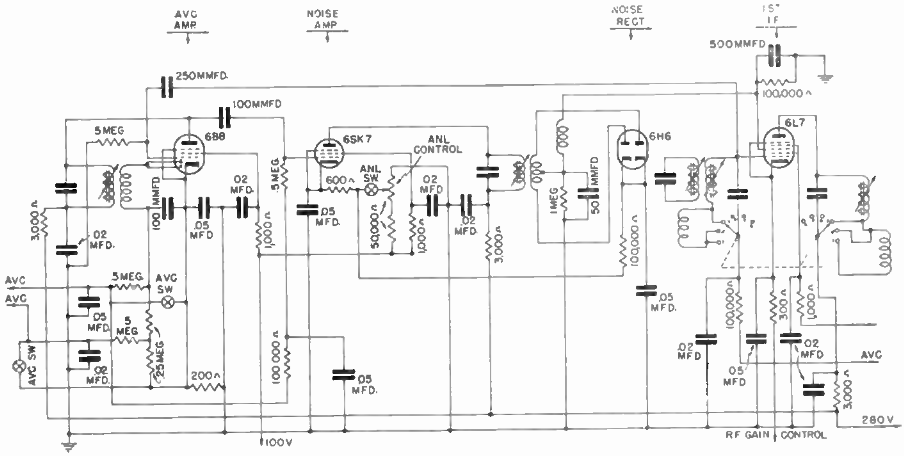


FIG. 18

The plate circuit is usually considered the best position for the tuning meter, for in this position, long leads can be used provided the meter is connected below the plate load and *not above it* (that is, it should not be connected between the plate load and the plate terminal at the tube socket). Fig. 17 shows the connection for the meter in the plate circuit. Note the meter polarity for both Figs. 16 and 17.

To most radio men the greatest problem of installing a tuning meter is getting it mounted. However, this need not be such a problem if the work is done right. You will need a sharp 1/2 inch wood chisel and a brace and bit. First decide where you want to mount the meter. Choose this position with reference to the cabinet thickness (you don't want to cut through a relatively large thickness unless you have to) and the place where the shortest leads can be used. Then place the meter over the spot where it is to be mounted and trace the outline of it with a pencil.

The next step is the most important. The modern receiver cabinet is made of veneer (strips of wood glued together.) These are very thin, and rough handling will cause these strips to split. Therefore, you must be careful when first starting to cut the hole for the meter. After you have made the outline with the pencil, place the cutting point of the chisel on the pencil mark and tap it lightly. Continue tapping the chisel until you have cut through the first ply or strip. Then with your brace and bit bore a hole in the center of your outline, and then begin cutting all the way through the cabinet wall. This time you can use heavier blows with the hammer. Be sure to hold your chisel in such a way that if it slips it will fall toward the hole you have bored in the center. A sharp pocket knife can be used to smooth off any ragged edges. This can also be used to enlarge the hole if you find it necessary.

Some tuning meters come equipped with pilot lights and others do not. If the one you use is equipped with a pilot light, then all you have to do is to connect its leads to a suitable filament circuit. If you don't get a pilot light with the tuning meter, then you will have to obtain one separate. It should be mounted on a bracket so

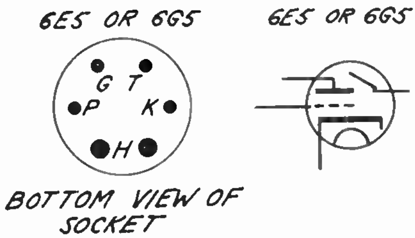


FIG. 19

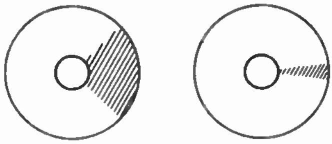


FIG. 20

that the light from it falls on the rear of the tuning scale.

SERVICING ANL CIRCUITS

Figure 18 shows the ANL circuit used with the Hallicrafter's SX28 communication type receiver. The signal from the grid of the first IF tube is fed to the grid of the 6B8 tube which has the dual purpose of an AVC amplifier and a noise amplifier. The signal from the 6B8 is then fed to the diode plates of the 6B8 for the AVC action and to the grid of the 6SK7 for the noise limiter. The 6SK7 further amplifies the signal and feeds it to the 6H6 noise rectifier. The action of this noise limiter is identical to the action of the circuit in Fig. 9. However, it has an added feature in that the rectified voltage from the 6H6 diode is filtered through a special low pass filter before reaching the controlled tube.

This filter eliminates the low audio frequencies but does not attenuate the high audio frequencies and as the greater portion of the noise consists of

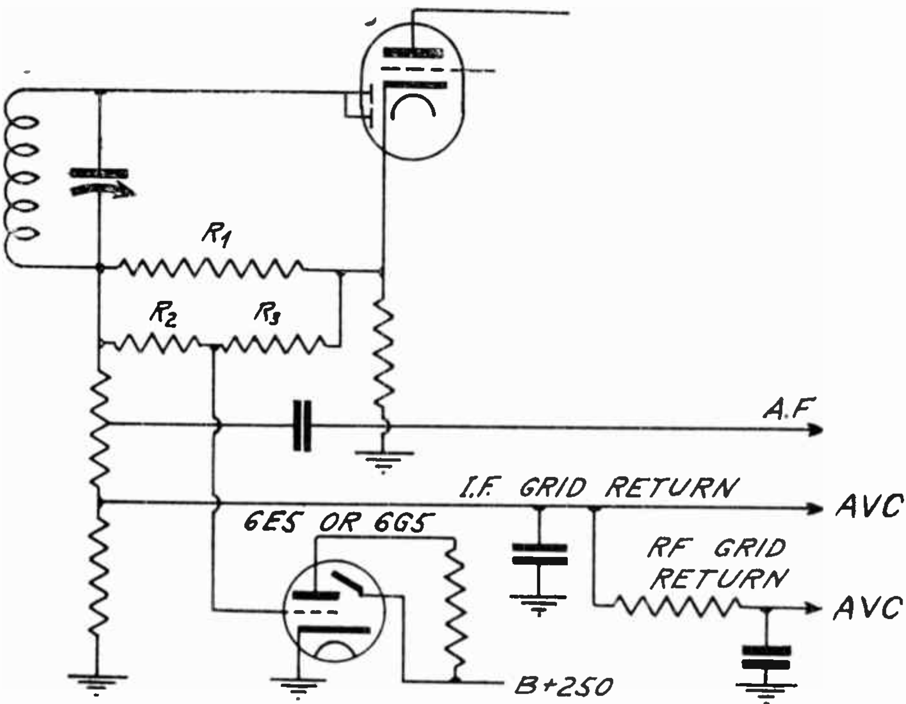


FIG. 21

high audio frequencies by allowing these frequencies to bias, the IF tube will reduce the amplification of these high frequency noises—thus increasing the effectiveness of the limiter at the high audio frequencies causing the noise component of the signal to be reduced.

The servicing of such a circuit is very much the same as for an AVC circuit. All parts replaced must be identical to those originally used in the circuit. To test the effectiveness of a limiter remove the noise rectifier when the limiter switch is turned on and the receiver is tuned to a weak signal, notice any change in the noise level. If the noise level increases when the tube is pulled out, the limiter is operating. If it remains the same, the limiter is out of adjustment or isn't working properly. The two AVC switches are used to make the AVC action inoperative when using the receiver to pick-up code signals of the CW (continuous wave) type. The ANL switch is used to stop the limiter action when it isn't needed.

The Electric Eye

A tube commonly called the *electric eye* or *magic eye* is being used in many receivers as a resonance indicator. It may be used for the same purpose on any AVC controlled receiver. The 6E5 or 6G5 is a small cathode-ray tube which incorporates a triode in the same envelope. Figure 19 shows the bottom view of the socket for this tube. The various elements are also shown.

The tube is so arranged that under normal conditions (no signal-zero grid bias) a fluorescent pattern equal to about 100 degrees appears on the end or screen of the tube. This is similar to the glow seen on the screen of a cathode-ray tube in an oscilloscope. This effect is shown in Fig. 20. This can be so connected that as the AVC voltage begins to take effect (representing an approach of resonance) the width of the shaded area on the screen of the tube will decrease. The more narrow the width of the shaded area, the nearer the point of resonance—provided the part values of the circuit have been chosen correctly. It is possible for the pattern to close up entirely or blur, and this, of course, is undesirable. This action may be prevented by limiting the negative voltage applied to the grid of the 6E5 tube. Resistors R1, R2 and R3 of Fig. 21 controls the value of the negative grid voltage applied to the tube.

Figure 21 shows the 6E5 tube connected to an ordinary diode circuit. The plate and target of the 6E5 should be connected together by means of a 1 megohm resistor. The target terminal should then be connected to approximately 250 volts positive. The cathode of the 6E5 should connect to the cathode of the diode tube or to ground.

Resistor R1 may be a load resistor for any diode type of circuit. It is to be shunted by R2 and R3. These two resistors should be chosen with two purposes in view. First to have a high enough value so that the parallel effect across R1 will not be noticeable. This means that from 3 to 6 megohms total are required. Second, R3 should be so chosen that when the receiver is tuned to the strongest local signal, the pattern on the 6E5 will not close or blur. Due to different designs, individual receivers will require R3 to have any value between 200,000 ohms and 1 megohm. Start with 200,000 ohms and increase the value of R3 until you get the desired effect.

These tubes must be horizontally mounted so that the end of the tube shows through the cabinet wall. Regular kits with the tube escutcheons may be obtained from a number of firms. When making a hole in the cabinet wall for the end of the tube, the same precautions should be observed as for tuning meters. Keep all leads to the tube as short as possible.

If a 6U5/6G5 tube is used, R2 and R3 will not be needed as the grid of the tube may be connected almost at any point along the AVC circuit. The reason for this is that the 6G5 tube will allow a much large swing of grid voltage before the pattern begins to blur or close.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 From what part of a superheterodyne circuit is the voltage for automatic volume control obtained?

No. 2 Why is it usually unsatisfactory to measure AVC voltage directly at the grids on which the AVC voltage is impressed?

No. 3 If the signal at the 2nd detector is only 2 volts peak when applied to P2 through C2 of Fig. 1, what value of AVC voltage will be developed?

No. 4 Is the AVC voltage proportional to the signal carrier or is it proportional to the modulation?

No. 5 What type of voltmeter is best suited for AVC voltage measurements?

No. 6 Which has the highest peak voltage in Fig. 8, the audio signal fed to R7 or the AVC voltage fed to R5?

No. 7. If a given signal is being received in Fig. 8 and the movable element of R3 is moved down (towards ground) will this make the grid of the 6C5 1st AF tube more negative or more positive?

No. 8 What is the purpose of a tuning meter in a receiver circuit employing AVC?

No. 9 Would a 2nd detector plate circuit meter or a diode plate circuit meter serve as a tuning indicator?

No. 10 Why cannot the grid of the 6E5 tube of Fig. 21 be connected directly to the left end of R1 omitting R2 and R3 entirely?

PRACTICAL METHODS OF CONDENSER TESTING

LESSON NO. TV-11

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K2562M

PRACTICAL METHODS OF CONDENSER TESTING

LESSON TV-11

The radio-TV repairman in general is interested in only three tests for condensers. The first is a test for a shorted or leakage condition, the second is a test for an open and the third is a test for capacity. The first two tests are most important. Rarely will it be necessary for the repairman to determine the capacity of a condenser unless it is just to satisfy his own curiosity. The majority of receivers that he is called upon to service are manufactured, and therefore, assuming good design all the parts including the condensers are of the proper value. The electrolytic condenser is perhaps the only type which changes appreciably in capacity value. When this happens, there is usually present an excessive leakage current, and if this current is measured it will be sufficient to show if the condenser is defective—and that is what you want to know.

There are times when the serviceman will want to know the capacity value of a paper condenser, as for instance, when several *unmarked* condensers are at hand. For this reason directions will be given further on in this lesson for determining the capacity value of a condenser.

Two methods are in common use in determining the condition of condensers. One is the substitution method and the other method is to subject the suspected condenser to some kind of an electrical test.

There are many different methods of placing the condenser under test, but first the substitution method will be considered. This method is best fitted for the shop. The best way to use the substitution method is to make up a unit of from 600 to 1000 volt fixed condensers in an adjustable bank. Figure 1 shows the circuit. Condensers rated at from 600 to 1000 volts are recommended because you can never tell when you are going to need to repair power units which employ high voltages.

The circuit of Fig. 1 consists of a seven terminal selector switch and seven condensers, rated as follows: .01, .05, .1, .25, .5, 2 and 8 mfd. The last, or the 8 mfd. condenser, may be an electrolytic, although a paper condenser will give best results, because the electrolytic must be correctly polarized and it is likely to give trouble since it will not be in constant use (the correct film will not be formed on the plates all the time).

You will be able to handle a great many substitutions with only three

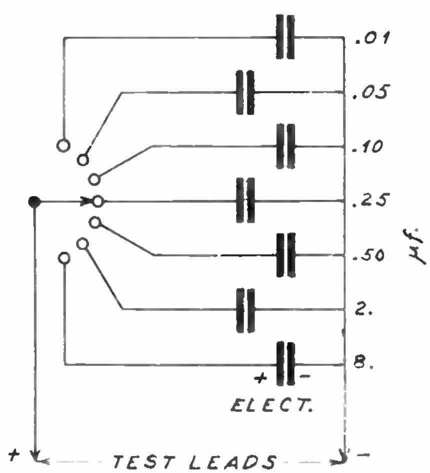


FIG. 1

or four of these values, such as .01, .25, 2 and 8 mfd., but the others are shown for completeness. The most common values are given and, of course, you can use as many as you like.

In order that you fully understand the use of a circuit like Fig. 1, it will be explained. Suppose you have a receiver on the work bench, and you suspect it of having several open or shorted condensers. For example, if you get a clicking sound with oscillation or motorboating or both, you would probably suspect the plate or screen grid RF by-pass condensers. Disconnect the first condenser you suspect. Then connect the two test leads from Fig. 1 to the receiver in place of the condenser you have disconnected. Now turn on the power to the receiver. The switch of Fig. 1 should be set to the capacity value corresponding nearest to the value of the condenser you have disconnected. Capacity values are not as a rule critical in by-pass and filter circuits. If this restores normal operation of the receiver, the original condenser is defective. You would then permanently connect a new condenser of the proper capacity and voltage rating in the receiver circuit. This same procedure would be followed when substituting for any condenser in the receiver. No matter how the condensers in the receiver are connected, you can always substitute other units temporarily with a circuit like Fig. 1, because this circuit has two separate independent leads—neither of which are grounded. All you have to do is to connect the leads properly. *For quick connections, two spring clips are recommended for the test leads.*

Of course, you don't have to build a circuit like Fig. 1 in order to practice the substitution method. You can always connect individual condensers in place of those which you suspect of being defective. However, this requires that you waste a lot of time hunting up the correct condenser, then you must solder leads to it, etc. A unit like Fig. 1. but with ten capacitors is constructed as a part of the SAR Multitester. A capacity substitution tester is a very useful piece of test equipment. Such a unit is particularly valuable when you wish to test a filter circuit to find out just how much capacity is required to reduce hum to a low level. As you work with a unit like this. you will find more and more uses for it.

Ohmmeter Test for a Shorted or Leakage Condition

A lesson on condenser testing would not be complete without a description of how to use the ohmmeter for determining the condition of a condenser. This method has been in use for a long time, and is still practiced by most servicemen. However, it has one serious drawback. A partial short or high resistance leakage can exist, and in many cases, the ohmmeter will not show up this condition unless the ohmmeter is very sensitive. The main reason for this is that the ohmmeter operating voltage is not high enough to cause the condenser to break down. In other words, the leakage resistance measured across the condenser is not always constant in a defective condenser. At a fairly high voltage it may be very low, while it may be so high at low voltage that it cannot be measured with an ordinary 1000 ohms-per-volt ohmmeter meter movement.

It is interesting to tear apart a condenser which has developed a high resistance leakage. To do this, care-

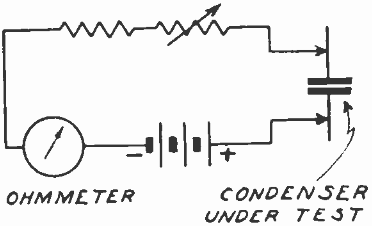


FIG. 2

fully remove the outside covering of a defective condenser and unwrap the foil. As you do this, examine the surface of the paper between the layers of the metal foil. More than likely you will find what appears to be a *tiny pin hole.* This is the short or source of leakage. By doing this, you can get a much clearer picture of what happens to cause a short or leakage of this type.

After you have done this, tear apart a condenser which shows a full short. This time you are likely to find several layers of foil burned all the way through from one to the other. This type of short has negligible resistance. When this occurs to a power unit filter condenser, the effect is the same as if you had connected a wire from the positive to the negative of the power unit. If you have ever done this, you know that hot sparks are produced. This same action is what causes a shorted filter condenser to show *burned spots* on the foil and paper.

Now to return to testing with the ohmmeter—the ohmmeter and condenser are connected in series just as for a resistor under test. See Fig. 2. You should, of course, understand that this test is applied only to paper or mica condensers—not to electrolytics. If the condenser is in good condition, there will be no reading on the ohmmeter except when first connecting to the condenser. The reason for this initial slight reading is because of the condenser charging current. When voltage is first applied, the condenser takes a charge. After this initial charge, there should be no further reading on the meter. However, if there should be a reading, you will know the condenser is defective and will need replacing.

To perform properly in some circuits, such as audio coupling circuits and AVC filter circuits, the leakage resistance of a condenser must usually be well above 100 megohms.

The condenser may have a high internal resistance of from 25 to 50 megohms and the average ohmmeter may not show it—such a condenser would not be suitable for operation in critical circuits. Therefore, to be absolutely certain about the condenser, a high voltage test is recommended. The high voltage can be obtained from the power unit of the receiver in which the condenser is used. First turn off the receiver power. Next disconnect the suspected condenser from the receiver. Then connect your *high range DC voltmeter* (the voltmeter must be capable of measuring the highest voltage of the power unit) and condenser across the positive (highest positive point of the power unit) and negative terminals of the power unit. See Fig. 3. Now turn on the receiver power. If there is high resistance leakage, the meter will show a steady reading. Remember if the condenser is in good condition, there will only be the initial charging voltage reading on the voltmeter.

There is another condenser test

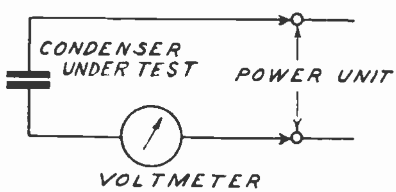


FIG. 3

widely used by servicemen. This test determines whether the condenser is open, shorted or if it has high resistance leakage. The test is simple, but requires a little time, and applies best to large condensers—.1 mfd. and above in value.

The condenser is first disconnected from the circuit. Its two terminals are then connected to a high voltage source (300 volts or more). The condenser is next disconnected (being careful not to let the terminals touch) from the high voltage source. A screw driver with an insulated handle is then used to short the condenser terminals. If a large spark is produced, it proves that the condenser is not fully shorted, and that it is not open.

To test for high resistance leakage, connect the condenser to a high voltage source, then disconnect and lay it aside for from five to thirty minutes. After this time has elapsed, short the condenser terminals as already mentioned. If a spark is produced, it proves the condenser does not have high resistance leakage. A paper dielectric type of condenser that will not produce a spark after having been charged is a defective condenser. Likewise, when applying the ohmmeter or continuity test, if there is no initial charging reading, the condenser is open. If there is a full reading on the meter, it is a sure sign that the condenser is shorted.

This test called the *spark test*, showing that the condenser can hold a charge for sometime cannot be relied upon for accuracy in determining either the condenser value or leakage resistance. The rate at which a condenser will discharge depends on its capacity and its leakage resistance. Also to be able to produce a spark after a given time, its voltage at full charge must be known.

While you can specify all of these things exactly, you cannot make the proper measurements in practice to determine the condition of the condenser. If a .5 to 16 mfd. paper type condenser will spark immediately or within three or four seconds after a full charge at 250 to 300 volts, it will usually be found suitable for use. This at least shows that it is not shorted, that it has some capacity and can withstand a voltage equal to that applied.

In the foregoing, it has been assumed that the condenser was not less than .1 mfd. in capacity. If the condenser is smaller than .1 mfd., the charging or spark method of testing is not recommended. On these small condensers it is much better to use the high voltage continuity test or the bridge method as will be explained.

The ordinary headphone unit can also be used to test condensers. This method is particularly good for small condensers, having a value down to .001 mfd. The procedure is to charge the condenser by connecting it to a high voltage (around 300 volts) source. Then carefully remove it, but be sure the condenser terminals do not have a chance to become shorted. Next place the headphones to your ears, then touch the headphone tips to the charged condenser terminals. In doing this, do not touch the metal phone tips with your fingers. Instead hold the cord with your hands and let the tips rest on the condenser terminals. If there is a loud click in the headphones when this is done, it indicates the condenser is in good condition and will hold a charge.

Because of *contact potentials* and the very rapid rate of discharge of small condensers, this method is by no means conclusive, and has no value whatever in the vicinity of values around .0025 mfd. or smaller. Such a condenser can discharge almost completely in about 1/40th second even though the discharge current flows in a leakage path of 100 megohms resistance. This provides no time in which to make any test connections.

Ammeter and Voltmeter Capacity Testing of Condensers

The amount of alternating current which a condenser will carry is proportional to its capacity—that is, as its capacity is increased its current will increase by the same number of times or by the same factor. Naturally, it is assumed here that the test voltage remains constant. On the basis of this fact, you can connect an AC ammeter or milliammeter in series with the condenser under test and place the line AC voltage across the two and measure the current flow. *The value of this current will then be a measure of the capacity.*

In determining the capacity from the current reading you can use a table of values, a chart or you can mark capacity values directly on the meter

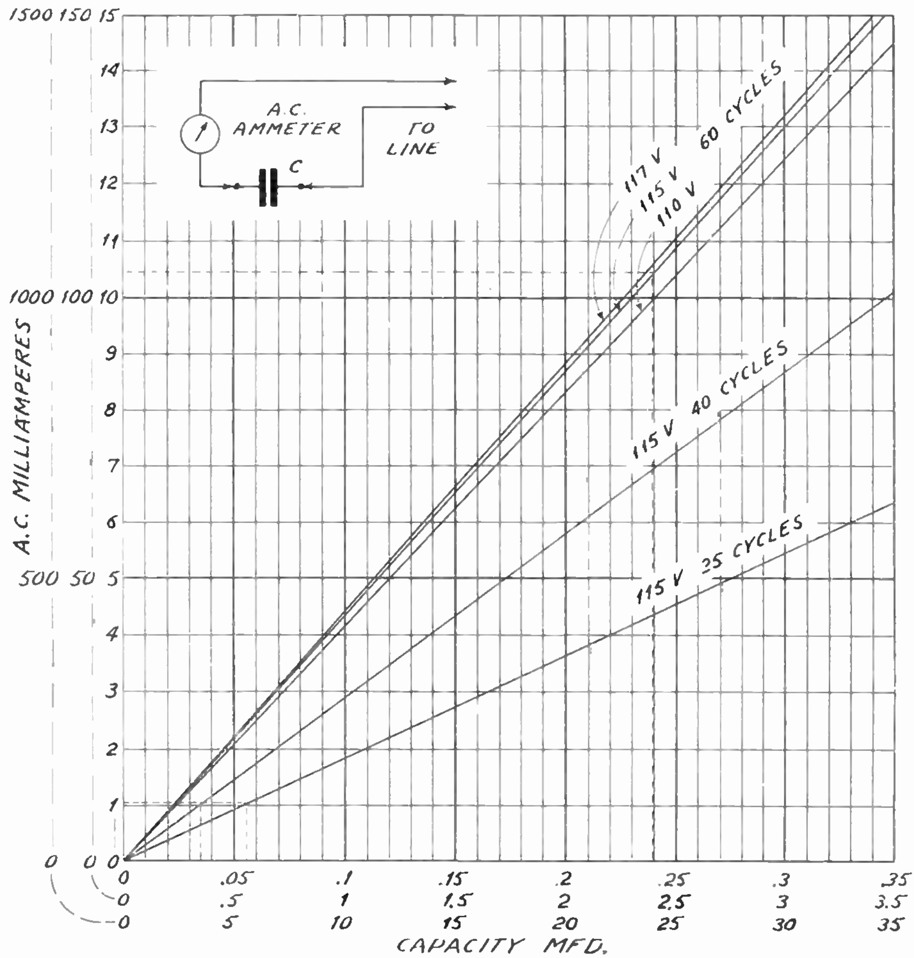


FIG. 4

scale. The first method is slow, and, therefore, little used. The last method is impractical but the second method, using a chart, is by far the best for this purpose.

A chart for this purpose is given in Fig. 4. It permits the measurement of capacities from .05 mfd. to 35 mfd. with an accuracy of better than 5%. In this case, the accuracy is only a matter of the accuracy of the meter and the accuracy of reading the chart.

Reference lines are given for 117 volts at 60 cycles, 115 volts at 60 cycles, 110 volts at 60 cycles, 115 volts at 40 cycles and 115 volts at 25 cycles. For all frequencies, make certain that the meter is designed to read equally accurate for all frequencies in this group. Note in Fig. 4 each of the current ranges of the meter has a corresponding capacity range.

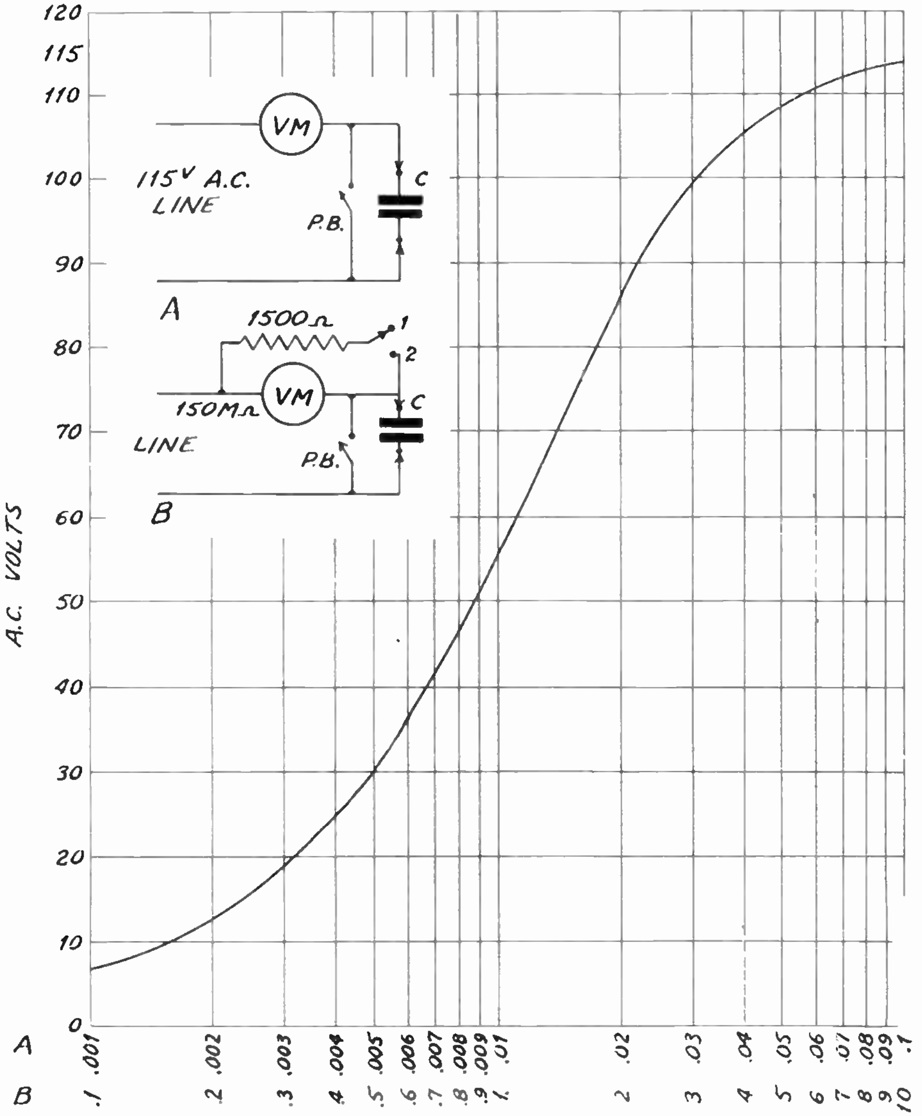
Suppose you connect an unknown condenser (C) as shown in Fig. 4 and the meter reads 10.4 milliamperes. If your test makes use of a 115 volt AC line of 60 cycles frequency, the capacity value will be .24 mfd. If you get this reading using a 40 cycle line at 115 volts, obviously the 40 cycle line is just out of range of the chart for this setting of the meter. However, if you will refer to the 10.4 milliampere point on the 0-150 milliampere scale, you will find that the capacity reading is now approximately .35 mfd. Similarly for 25 cycles, a reading of 10.4 milliamperes would indicate a capacity of about .56 mfd.

For the use of this chart it does not matter what ranges the meter has as long as they cover the scope shown on the chart. For example, an 0-25 or an 0-20 or 0-50 AC milliammeter may be used as well as the 0-15 and 0-150 ranges for making measurements within the meter ranges indicated.

Care must be taken in setting up this equipment to avoid shock from the power line and burning out of the meter, due to a shorted condenser. A resistor can be placed in series with the circuit to limit the current to that which the meter can handle for a preliminary test, and this resistor can be shorted out once the reading indicates that the condenser is not shorted. Another way to accomplish this is to test the condenser first with an ohmmeter to determine if it has a short. This test method is suitable only for paper dielectric condensers and cannot be used with electrolytic condensers. Mica condensers have values generally too small to be applicable to this test.

For condenser values lower than .05 mfd., but greater than .001 mfd., the series voltmeter method of testing is very convenient. Its circuit is shown in Fig. 5, together with a graph for interpretation of AC voltage values in terms of capacity values. The range of capacity values for which this circuit is suitable is from .001 mfd. to .1 mfd. For use of this graph, the details of the meter must be more definitely specified. The graph is based on a 1000 ohm-per-volt voltmeter adjusted to a range of 150 volts or any AC voltmeter having 150,000 ohms resistance with a scale reading up to 115 volts AC or beyond. Since the points on the graph depend on these values, they may not be altered if this graph is to be used. This chart is intended only for operation with 110 volts at 60 cycles, as this is by far the most common power supply found. Note carefully that in order to get a large number of values in the space, a logarithmic arrangement of the capacity values has been employed.

For range B, the sensitivity of the meter circuit is reduced to 10 ohms-per-volt approximately by means of a



CAPACITY MFD.

FIG. 5

shunt resistor (1500 ohms). The push-button (PB in the diagram part of Fig. 5) which shorts the condenser when depressed in both circuits of Fig. 5 may be included to measure the line voltage just before the test and to distinguish between a shorted condenser and a good one when readings are made very near the high capacity end of the range. If the meter needle does not move when the button is pressed, the condenser is probably shorted or, at any rate, of such value as to be out of range of this circuit.

The Condenser Bridge Type Tester

The bridge method of condenser testing like any bridge method of testing or measurement is essentially a means of *comparing unknown values with known values.* Theoretically a correct condenser bridge would consist of 4 condensers, but in practice, the reactance of the variable unit in a convenient size would be so high at audio or power line frequencies that resistors are used instead of two of the condensers. The basic bridge circuit is shown in Fig. 6.

From some AC voltage source G, such as a signal generator, or a power transformer filament winding (5 or 6.3 volts), energy is supplied to two series circuits R1-C1 and R2-C2. The current flow in each circuit will depend on its impedance and when the product of the current through R1 and the resistance value of R1 equals the product of the current through R2 and the resistance value of R2, the AC voltage will have the same value at both terminals across the bridge or at B.

To produce this condition, the ratio of R1 to the reactance of C1 must be the same as the ratio of R2 to the reactance of C2. One of these condensers, C1 for example is a standard value while the other C2, is the unknown value under test.

Provided the condensers are both of good quality, the angle of voltage lag for both impedances (R1-C1) and R2-C2 will be the same, and hence the two voltages at B will not only be of the same value but of the same phase as well, when the ratio $R1/X_1$ is equal to $R2/X_2$. There will be no voltage *difference* between the two points at B when the bridge is balanced and hence no current will flow through the headphones or other indicating device.

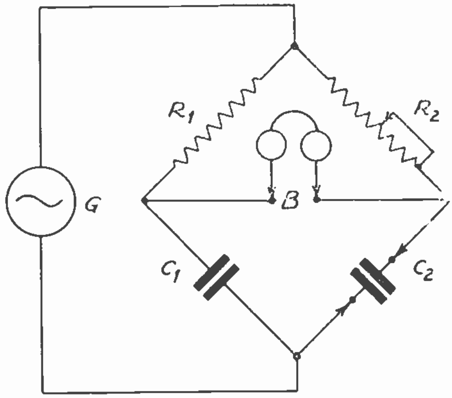


FIG. 6

As a means of measurement of the unknown condenser value when the bridge is balanced and $R1/X_1 = R2/X_2$ the value of R2 must be adjusted to make this relationship possible. The value of R2 from this relationship must be—

$$R2 = \frac{R1 \quad X_2}{X_1}$$

and if you choose *known values* for R1 and X_1, you can write values of R2 directly in terms of X_2. Thus, if you use a value of 10,000 ohms for R1, with a 1 mfd. condenser at C1 which would have a reactance of approximately 2650 ohms at 60 cycles, you can see at once by substitution that—

$$R2 = \frac{10{,}0000 \quad X_2}{2650}$$

$$R2 = 3.77 \quad X_2$$

Now, you can find the reactance values of a number of condensers for example from .1 mfd. to 10 mfd. at 60 cycles and then by multiplying each of these reactance values by 3.77 you will have the resistance value of R2 *corresponding to that capacity value* in the bridge. The following table shows the results.

Capacity Mfd.	X_2 at 60 Cycles Approximately	X_2 Multiplied by 3.77 Approximate Values of R_2
.1	26500	100000
.2	13250	50000
.3	8840	33300
.4	6630	25000
.5	5300	20000
.6	4420	16660
.7	3790	14300
.8	3310	12500
.9	2941	11100
1.	2650	10000
2.	1325	5000
3.	884	3330
4.	663	2500
5.	530	2000
6.	442	1666
7.	379	1430
8.	331	1250
9.	294	1110
10.	265	1000

From this information you can calibrate potentiometer R2 and *provide it with a dial or index pointer.* Then with an ohmmeter you could adjust its resistance value to the resistance values shown in the table and mark the condenser capacities at the point where the pointer of the index rests at each resistance value. A variable linear 0-100,000 ohm potentiometer of course would be advisable for this example.

These figures are simply to show how a bridge is calibrated and how capacity measurements are determined through the use of a variable resistor (R2 in Fig. 6). An actual circuit of this type would not be practical for several reasons. The resistance calibration for the dial or index corresponding to the range from 1 mfd. to 10 mfd. would all be confined to 1/10 of the entire scale as the figures show, and thus, the capacity readings would be inaccurate for these values. Moreover, the terminals at B in Fig. 6 at which the bridge voltage is compared are free from ground requiring a balanced (or push-pull) type of indicator circuit. In a practical bridge testing circuit it is convenient to place the ground connection at one of the indicator terminals as at B in Fig. 6. This form of connection is used in Figs. 7 and 8.

Note from the table that you can decrease the range of this instrument by using a 10,000 ohm potentiometer instead of a 100,000 ohm unit. Thus a scale can be arranged to read from 1 mfd. to 10 mfd. However, by means of a very simple circuit trick you can make the capacity and resistance readings linear as will be explained further on.

One of the widely used bridge test circuits with these connections is the *Wien Bridge* illustrated in Fig. 7. Note that equal and opposite phased voltages are supplied at the ends of the bridge resistors which have been combined in one unit. The center or adjustment arm of the bridge is grounded and the common output of the standard condenser C1 and the one under test (C2) is coupled to a type 6E5 *eye tube* through condenser C.

The transformer secondary (usually 5 or 6.3 volts) supplies opposite phase voltages at A and B in Fig. 7. Now, if the potentiometer is adjusted so that R2 is for example 4 times as great as R1, naturally the voltage at A will be 4 times as great as that at B. However, if the reactance of C2 is also 4 times as great as that of C1, when the voltages reach the coupling condenser C, they will be equal and of opposite phase and will exactly cancel. There will, therefore, be no voltage at the 6E5 grid and its shadow angle will be 90 degrees. However, if this ratio is disturbed in the bridge

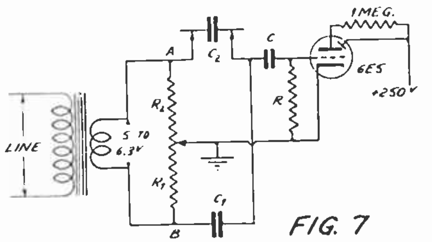


FIG. 7

by using a different condenser value at C2 or by setting the potentiometer at a different point, one voltage A or B will be greater than the other at C and a net voltage equal to their difference will be impressed on the 6E5 grid.

While this voltage will be a 60 cycle AC voltage, it will cause rectification at the 6E5 grid in the manner of any diode detector or grid-leak condenser detector. This will produce an average negative bias on the 6E5 grid which will reduce the shadow angle. The reduction of the shadow angle is a measure of the *degree of unbalance of the bridge.*

A satisfactory adjustment and reading of the R1-R2 scale can be made when R2 is 10 times R1 or when R1 is 10 times R2. If the ratio is very much greater such as 100 to 1, many of the readings would be so crowded at one end that they would not be satisfactory. While you might choose a ratio of R1 to R2 of 15, 20 or even 25 to 1, the 10 to 1 ratio has the great advantage of being a convenient decimal multiplier. Thus, if your standard C1 is 1 mfd. for one range, you can measure capacities ranging from 10 times this value to 1/10th of this value or from .1 to 10 mfd. Then if you replace C1 with a value of .01 mfd., you can span the range of from .001 mfd. to .1 mfd. With this multiplying factor one scale will serve for all capacity ranges. At a point on the scale where you mark the ratio of R1 to R2, for example at .2, you can measure a .2 mfd. condenser at C2 if a 1mfd. condenser is used at C1. Also, you can measure a .002 mfd. value at the same point, using a .01 mfd. condenser at C1 (See Fig. 7).

A coupling capacity C in Fig. 7 of .01 to .1 mfd. may be used and a 6E5 grid resistor of 1 to 5 megohms is advisable. This is a very simple and practical bridge test circuit and can be easily assembled from standard parts. If you wish to avoid use of the 6E5 due to its requirement of plate and filament voltage and mounting facilities, you can use headphones instead as in Fig. 8. Note in Fig. 8 the original standard condenser has been replaced by three standard values with a switch so that one at a time may be used. The same arrangement may be employed for Fig. 7.

Calibrating the Condenser Bridge

The calibration of a bridge test circuit will be described before going into its further refinements. Refer to Fig. 9 as a reference. The voltage source in Fig. 9 is a 6.3 volt high current filament winding. By using such a heavy winding, the voltage of the source will remain constant or very nearly so for all ranges of the meter. The variable resistor is a 10,000 potentiometer. The capacity range of such an instrument is dependent upon the circuit arrangement.

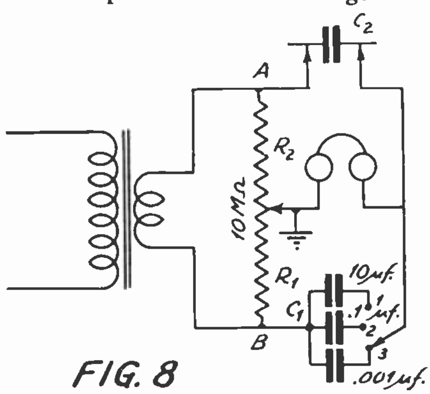


FIG. 8

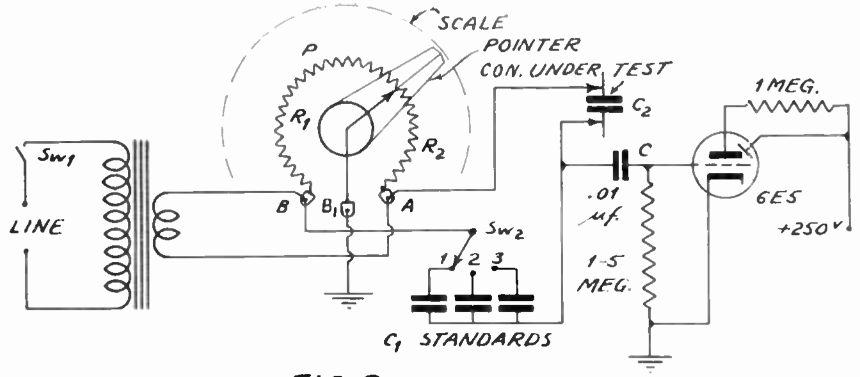


FIG. 9

The low capacity ranges will be affected by the circuit wiring, etc. The higher capacity range is limited by the standard available capacities and the current carrying capacity of the voltage source. The accuracy of balance which determines the percent of error for the unit is determined by the sensitivity of the indicating instrument.

Thus, the more accurate the indicating device the less chance of error. For this reason the electric eye tube is preferred over other type indicators. A convenient capacity range which will be sufficient to measure the most common condenser values is from .0001 mfd. to 100 mfds.

The next step is to divide the capacity range in such a way that the ratio of the largest to the smallest capacity value in each range shall be 100 to 1. This will agree with the previously made observation to confine the limit of one capacity range to 1/10 or 10 times that of each standard chosen. Thus, the following ranges may be arranged.

$\frac{100}{10}$ = 10 mfd. standard for range 1.

$\frac{1}{10}$ = .1 mfd. standard for range 2.

$\frac{.01}{10}$ = .001 mfd. standard for range 3.

With this having been determined you may now arrange a suitable circuit and calibrate a direct reading scale for the bridge type test circuit. See Fig. 9.

The potentiometer (P) is mounted on a large panel, having a clear space of from 3 to 4 inches completely around its shaft. Figure 10 shows the front panel view of the calibrated scale. All leads should be disconnected from terminals B and B1 in Fig. 9 and an ohmmeter should be connected from B to B1—more directions will be given later.

The lowest bridge reading should be at the left, (see Fig. 10) a maximum counter-clockwise position of the potentiometer or when the value of R1 is 1/10th that of R2 in Fig. 9. At a balance of the bridge there is, therefore, 10 times as much voltage across R2 as across R1, and the test capacity C2 under test must have a reactance of 10 times higher than the C1 unit in use so that the bridge may be balanced.

A general method of calibrating any bridge circuit of this kind is given here to help the constructor of this equipment. Even if a bridge circuit type tester is purchased in manufactured form, this information should help greatly in understanding its operation. It is not essential, however, in the use of the bridge in practical testing.

The three relationships necessary in this calibration are as follows:

1. The relation between the resistance and reactance for a balance of the bridge.

2. The total resistance of the potentiometer in ohms which is R and is equal, of course, to the sum of R1 and R2.

3. The actual multiplying factor marked on the bridge scale which is M. This is the ratio sought between the standard condenser (C1) and the condenser being tested (C2).

These three relationships are expressed in a formula as follows:

$$R1 = \frac{R \times M}{R + M}$$

Where R1 is the portion of the potentiometer that is in series with the known capacity values.

R is the total resistance of the potentiometer.

M is the ratio of the standard condenser to the unknown value.

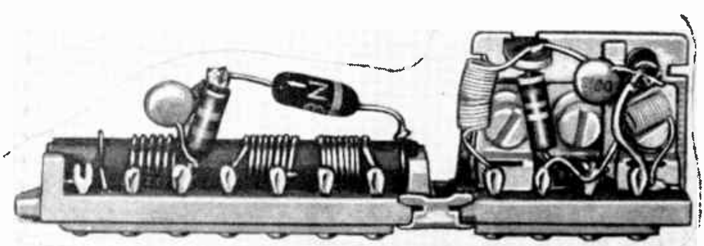
One way to proceed is to simply choose a number of convenient values of the ratio M between .1 and 10 in steps of approximately 10% each, and then find the resistance value of R1 (Fig. 9) corresponding to each of these values.

By using the general calibration formula. for any potentiometer value and any range as described by the values of M. a table similar to this can be compiled.

In Table No. 1. are listed some convenient values of M for a 10,000 ohm potentiometer to represent P in Fig. 9.

The first column of the table gives the values of M used. The second column of the table gives values of the 10.000 ohm potentiometer for every value of M chosen. The third column gives the values of 1 + M for each value of M. Each number in column 2 divided by the corresponding value in column 3 will give the proper value of R1 for each value of M.

With a pointer or dial on the potentiometer of a 3 inch radius or more connect an ohmmeter between terminals B and B1 in Fig. 9 and (all other connections removed) adjust the potentiometer to the values of R1 (as given in the table) and in succession mark the position of the dial or pointer index with the value of M. Thus at 909 ohms mark .1, at 990 ohms mark .11, at 2000 ohms mark .25 and so on as indicated by the table.



The circuit shown is part of a television tuner unit. The small size coils and condensers are used to tune to the high frequencies.

Courtesy Standard Coil Co.

Table No. 1

M	10,000 M	1 + M	R1	M	10,000 M	1 + M	R1
.1	1000	1.1	909	1.	10000	2.	5000
.11	1100	1.11	990	1.1	11000	2.1	5240
.12	1200	1.12	1070	1.2	12000	2.2	5450
.13	1300	1.13	1150	1.3	13000	2.3	5650
.14	1400	1.14	1228	1.4	14000	2.4	5830
.15	1500	1.15	1305	1.5	15000	2.5	6000
.16	1600	1.16	1380	1.6	16000	2.6	6150
.17	1700	1.17	1455	1.7	17000	2.7	6300
.18	1800	1.18	1525	1.8	18000	2.8	6425
.19	1900	1.19	1596	1.9	19000	2.9	6550
.2	2000	1.2	1667	2.	20000	3.	6667
.225	2250	1.225	1837	2.25	22500	3.25	6920
.25	2500	1.25	2000	2.5	25000	3.5	7140
.275	2750	1.275	2155	2.75	27500	3.75	7325
.3	3000	1.3	2303	3.	30000	4.	7500
.35	3500	1.35	2590	3.5	35000	4.5	7770
.4	4000	1.4	2860	4.	40000	5.	8000
.45	4500	1.45	3100	4.5	45000	5.5	8175
.5	5000	1.5	3334	5.	50000	6.	8330
.6	6000	1.6	3750	6.	60000	7.	8570
.7	7000	1.7	4120	7.	70000	8.	8750
.8	8000	1.8	4440	8.	80000	9.	8880
.9	9000	1.9	4735	9.	90000	10.	9000
				10.	100000	11.	9090

Due to contact resistance and to lack of precision of the ohmmeter to read such accurate values as these, it is often more convenient to lay out the bridge scale by angle measurement. If the potentiometer which you choose has a total angle of rotation of 300 degrees (the usual value), the following table (Table 2) shows the angles corresponding to the same values of M as previously given:

Table No. 2

M	Angle	M	Angle
.1	27.3°	.3	69.2°
.11	29.7°	.35	77.7°
.12	32.1°	.4	85.7°
.13	34.5°	.45	93.°
.14	36.8°	.5	100.°
.15	39.2°	.6	112.5°
.16	41.4°	.7	123.7°
.17	43.6°	.8	133.4°
.18	46.75°	.9	142.°
.19	47.8°	1.	150.°
.2	50.°	1.1	157.5°
.225	55.°	1.2	163.5°
.25	60.°	1.3	170.°
.275	64.7°	1.4	175.°

Table No. 2
(Continued from preceding page)

M	Angle	M	Angle
1.5	180.°	3.5	233.°
1.6	184.5°	4.	240.°
1.7	189.°	4.5	245.5°
1.8	192.8°	5.	250.°
1.9	196.5°	6.	257.°
2.	200.°	7.	263.°
2.25	207.5°	8.	267.°
2.5	214.2°	9.	270.°
2.75	220.°	10.	273.°
3.	225.°		

In this way, the layout may be made without an ohmmeter but with an angle protractor. The angle is measured from the point where the potentiometer stops at the left, to the various M values. The layout would look somewhat as in Fig. 10 when completed and will be correct for any total value R of the potentiometer. The resistance values given in Fig. 10 however are correct for a linear 10, 000 ohm potentiometer only. This layout or a copy of it may actually be used for this instrument provided that the potentiometer is linear and covers 300 degrees in its full range.

Obviously, when you use a standard capacity value of 1 mfd. for C1, Fig. 9, these calibrations will be actually the number of *microfarads* measured by the bridge. On using a value of 10 mfd. for C1 a reading such as .5 on the scale (Fig. 10) when the bridge is balanced would be 10 × .5 or 5 mfd. On reading 4, it would be 10 × 4 or 40 mfd. When the .01 mfd. standard is used, each reading is multiplied by .01 and thus a reading of .2 would be .01 × .2 or .002 mfd., etc.

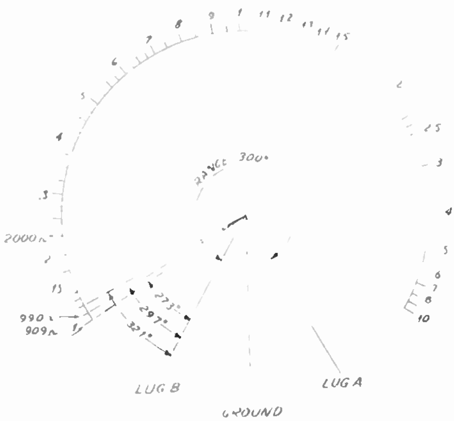


FIG. 10

There are certain *disadvantages* to a bridge scale as in Fig. 10. The accuracy of reading and measurement varies considerably throughout the scale being about 3 times as good at its center as at either end. The scale subdivisions are difficult to layout and in the attempt to cover a large range some accuracy must be sacrificed.

These difficulties are easily overcome simply by making the two resistance sections of the bridge separate units, one of them being of fixed value and the other variable. This is the circuit trick previously referred to in this lesson. The basic circuit of this type of bridge is shown in Fig. 11. Another important thing to note in Fig. 11 is that the condenser under test (C2) is in the alternate bridge branch instead of being adjacent to R1 as in Fig. 6.

As noted in the foregoing the requirements for balancing this bridge

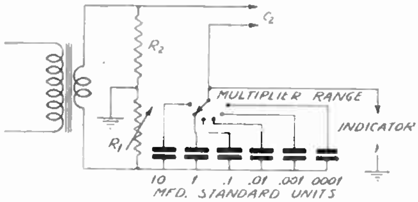


FIG. 11

will be met when the ratio of R1 to X1 is equal to the ratio of R2 to X2. Thus when a balanced condition exists. the value of the unknown capacitor. C2. can be determined. The advantage of the bridge circuit is that the unknown value can be read directly from the scale if it is properly calibrated.

Retaining the value of R1 at 10, 000 ohms maximum, a value of 10, 000 ohms is needed also for R2 if it is desired to compare a condenser under test to the standard condenser without any multiplying factor. Accordingly the values of C2 for Fig. 11 which will be measured for various values of adjustment of R1 are as indicated in Table 3.

The scale for this type of bridge is quite easy to layout and appears in Fig. 12. For a 300° range potentiometer each value is placed 30° from the former one. All values as in Table No. 3 may be placed on concentric circles or only the values of R1/R2 and each value may be read by inspection from the resistance ratio values.

An additional advantage of this type of bridge is that instead of using condensers as multipliers you can just as well use resistance multipliers as in Fig. 13. Each resistor is ten times the value of the one preceding and one-tenth that of the next following. The ranges may be the same as those given in Table No. 3 or other ranges may be chosen if desired.

All of the bridge test instruments for radio servicing use one of these basic circuits. Some have amplifiers preceding the indicator and, of course, there are a number of other variations in the various condenser test instruments.

Electrolytic Condensers

Electrolytic condensers are affected by many more conditions than ordinary condensers. Mention is made of this fact so that the serviceman will be able to account for various observations which he makes in connection with the use of these units.

The first of these conditions is that the capacity of any electrolytic condenser depends upon three factors entirely unrelated to its electrode area or dielectric thickness.

1. TEMPERATURE: The graphs of Figs. 14, 15, and 16 illustrate how temperature affects an electrolytic condenser.

Table No. 3

R1	R1/R2	C2 with C1 = 10mf.	C2 with C1 = 1mf.	C2 with C1 = .1mf.	C2 with C1 = .01mf.	C2 with C1 = .001mf.	C2 with C1 = .0001mf.
1,000	.1	1	.1	.01	.001	.0001	.00001
2,000	.2	2	.2	.02	.002	.0002	.00002
3,000	.3	3	.3	.03	.003	.0003	.00003
4,000	.4	4	.4	.04	.004	.0004	.00004
5,000	.5	5	.5	.05	.005	.0005	.00005
6,000	.6	6	.6	.06	.006	.0006	.00006
7,000	.7	7	.7	.07	.007	.0007	.00007
8,000	.8	8	.8	.08	.008	.0008	.00008
9,000	.9	9	.9	.09	.009	.0009	.00009
10,000	1.	10	1.	.1	.01	.001	.0001

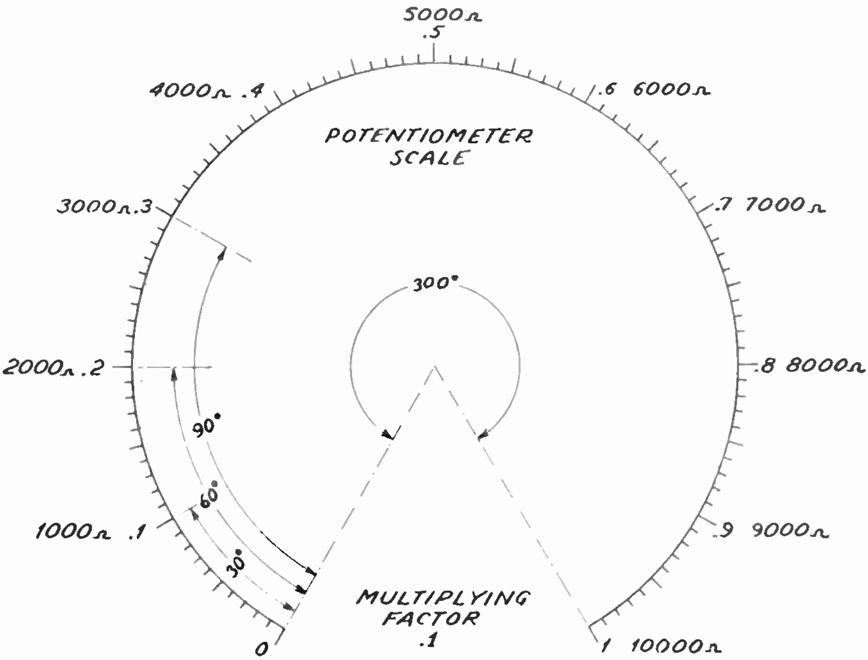


FIG. 12

Figure 14 shows a curve of leakage current plotted against temperature for an 8 mfd. 450 volt polarized wet type electrolytic condenser. The current curve is seen to increase rather slowly up to 130° F and from this point on up to 150° (the last reading measured) the curve on the graph is increasing very rapidly. The curve ends at 150° because any higher temperature than this would prove injurious to the condenser.

Figure 15 shows how the capacity of an electrolytic condenser varies with the temperature for the same condenser as used in plotting the curve of Fig. 14. The capacity is seen to increase as the temperature is raised. The power factor of a condenser is also changed with the temperature as shown in Fig. 16. The power factor of a perfect condenser is zero—thus, the lower percent power factor the better the condenser.

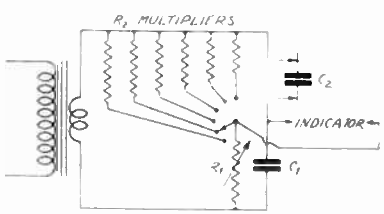


FIG. 13

From the definition of power factor as given elsewhere in the SAR course, it is equal to the true power or the power dissipated in the condenser divided by the apparent power. The apparent power is the power that appears to be in an AC circuit as measured with a voltmeter and an ammeter without taking the phase difference between the voltage and current in consideration. It can easily be seen from the foregoing definition that the smaller the power dissipated by the condenser the better, more efficient the condenser will be and the lower its power factor. More about power factor later on.

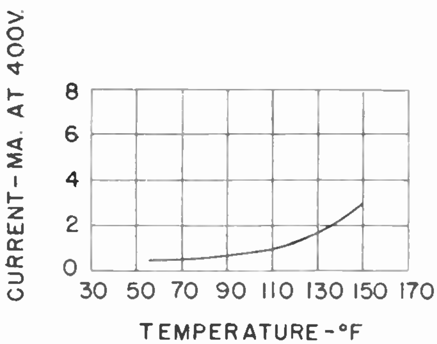


FIG. 14

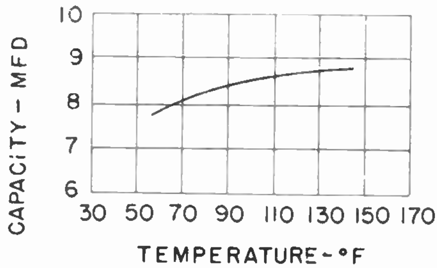


FIG. 15

2. VOLTAGE: Electrolytic condensers have a maximum voltage rating determined by their construction which should not be exceeded. If this voltage either DC or peak AC component is consistently exceeded, the condenser will either immediately become defective or gradually become defective. If occasionally exceeded, the condenser will usually recover. In general, the capacity of an electrolytic condenser will increase if a lower voltage is used on it. This becomes more and more apparent as the hours of operation of the condenser increase. If half the rated voltage is used, for example, the capacity may rise 20 to 25% or more in the course of several thousand hours of operation.

3. OPERATING TIME: An electrolytic condenser will recover from a very long period (a year or so) of non-operation in a few minutes of use. The recovery time is nearly proportional to the capacity, the larger condensers requiring a few minutes total time; a good rule of thumb principle by which to judge an electrolytic condenser. The leakage resistance for an electrolytic condenser decreases with the voltage applied to it but this decrease is so small that it may be considered constant for practical purposes. It varies inversely with approximately the 4th root of the voltage—that is, if the voltage is increased 16 times, the resistance is only reduced in half. Therefore, it may be said that the time constant RC of any electrolytic condenser is nearly proportional to its capacity at any voltage. An 8 mfd. condenser will hold a charge to a satisfactory degree for 2 minutes, a 1 mfd. for one-eighth this time, etc. For example, if a 4 mfd. condenser is charged to 500 volts, its voltage in 1 minute should be about 185 volts which should give a good spark on discharge.

For the reasons outlined an electrolytic condenser should be tested at or near its rated voltage. It should be noted at this point that an AC bridge such as those described cannot be used directly in testing any electrolytic condenser, *because a reverse polarity will be placed on the condenser. This will destroy the condenser if continued and a test of this kind will have no value.*

Thus, a way must be found of applying a high DC voltage on the condenser under test without interfering

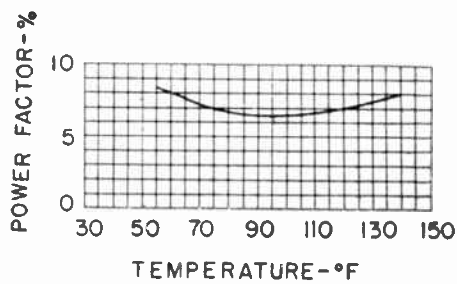


FIG. 16

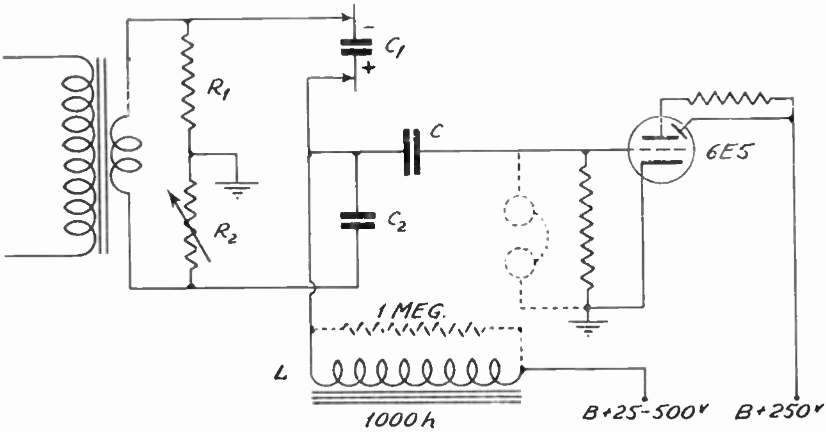


FIG. 17

with the bridge operation. One of the best ways to do this, is illustrated in Fig. 17. This circuit or variations of it are used in most manufactured bridge type condenser testers for electrolytic condensers.

From a voltage source which may be adjusted up to 500 volts or from a fixed 250 or 300 volt source, a series resistor or choke coil connects to the positive of the electrolytic condenser C1 under test. The reactance of the choke or resistance of the resistor, whichever the case may be, is so great as compared to the reactance of C2, that it has negligible influence on the action of the bridge. As the bridge approaches balance even this small effect is eliminated because the high voltage circuit becomes an actual part of the bridge element with the indicating device. Naturally, condenser C2 must be rated at this minimum test voltage, because the voltage is applied to it also.

The choke coil is preferred to the resistance as the DC voltage drop is very small through it and equivalent results may be obtained with a lower voltage applied at the B+ terminal of Fig. 17.

Leakage Resistance Tests

Because of the way in which various condensers are used in circuits, the leakage resistance test is perhaps *the most important test of all.* Naturally, the leakage resistance has much more importance in some circuits than in others.

A partial receiver circuit showing typical uses of condensers is shown in Fig. 18. There are, of course, many other condenser uses, but this circuit will show how to determine or estimate what minimum leakage resistance a condenser may have without having a noticeable effect on the operation of the circuit.

Starting with condenser C1, it is desired to know what minimum leakage resistance it should have without changing the voltage across it more than 5%. Although this voltage may change as much as 10% without noticeably affecting the circuit operation, the lower percentage value will be used to provide a safety factor. Disregarding all other AVC connections not shown, you will see that the voltage at B will equal the applied voltage multiplied by $\frac{R_x}{R_x + R_1}$, when R_x is the leakage resistance (equivalent shunt resistance of C1) and R1 is the 2 megohm resistance shown in Fig. 18.

Now, if the voltage at A in Fig. 18 is to be not less than 5% below the voltage at B, it must be equal to 95 percent of the voltage at B. Thus, to find what value the minimum leakage resistance of condenser C1 should be in Fig. 18 to limit the voltage at A to 95 percent of that at B, the following equation may be stated:

$$\frac{R_x}{R_x + R_1} = .95$$

Since R1 equals 2 megohms it will be found for the equality of the equation to hold true that R_x must equal 38 megohms.

Thus, regardless of the capacity of C1 or its power factor, its leakage resistance must be no less than 38 megohms for this circuit. If the leakage resistance falls below 38 megohms the condenser should be replaced if the 5% voltage variation is to hold true.

Excessive leakage of condenser C2 in Fig. 18 will reduce the total voltage at B because it will form a shunt path to ground from point C. This path, however, is in parallel essentially with R2 and R3. The rectifier diode is in series with this circuit and, therefore, assuming the diode resistance to be 50,000 ohms, the voltage at point C must be not less than 5% lower than it would be with no leakage resistance across C2. The leakage of C2 may be as low as .87 megohm or 870,000 ohms without causing trouble. Practically the same information is also true for C3, although if both C2 and C3 have leakage, their total resistance considered in parallel must be .87 megohm or more. If their leakage resistance is the same value, they must each be greater than 2 ×.87 or 1.74 megohms. If the volume control (R3) has a higher value, for example from 1 to 2 megohms, these leakage figures must be higher by about the same factors—that is, twice or four times as great.

So far it is obvious in Fig. 18 that many times more leakage resistance can be tolerated in C2 or C3 than in C1 without materially changing the circuit operation. It must be observed that this leakage resistance must be of fixed value so as to avoid intermittent reception. More than this, a large

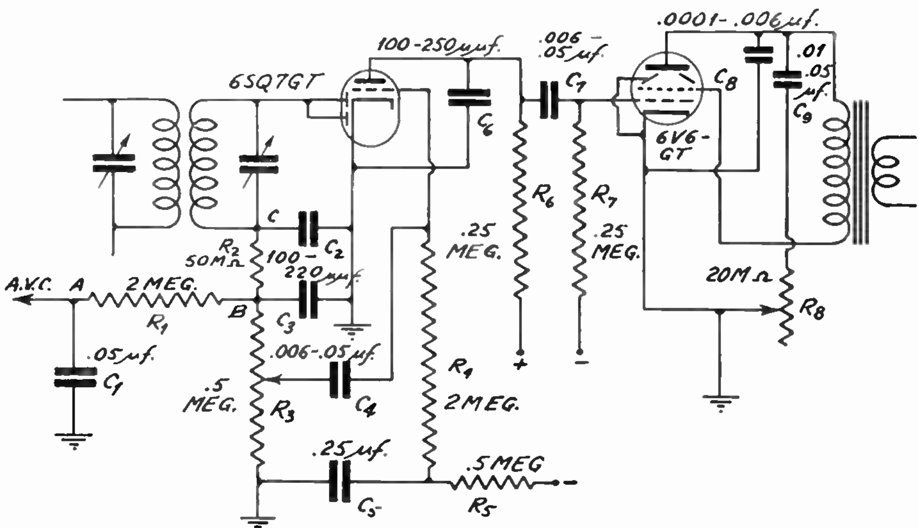


FIG. 18

condenser having more plate area is more susceptible to leakage than a condenser of low capacity. Condenser C1 having about 500 times the capacity of C2 or C3 must be superior in dielectric quality to C2 or C3 by a factor equal to $500 \times \frac{38}{.87}$ or 20,800 times. Per unit capacity, C1 must have 20, 800 times *less* leakage per mfd. than C2 or C3. This figure shows the vast difference in leakage quality for condensers used for different purposes.

Referring to C4, in Fig. 18 you may observe that when the volume control movable element is at B. the DC voltage impressed on C4 may reach a maximum of about 2 volts peak. Perhaps as much as 20 or 25 DC volts may be developed at B but this would form an AF of about 18 to 20 volts peak. Under these conditions you would not move the movable element of R3 past the 2 volt AF peak value. The DC value would be nearly the same as this at the same point. Now this DC if impressed across C4 by reason of any leakage which may exist, must not change the bias of the 6SQ7GT tube more than 5%. Accordingly, R4 must be only 5% of the leakage value of C4, making this 20 times as great as R4 or 40 megohms minimum leakage resistance. In a similar sense, the leakage resistance of C5 must be not less than 20 times the value of R5 or 10 megohms to prevent any greater bias change than 5%.

The plate by-pass condenser C6 in Fig. 18 must not cause the applied plate voltage to drop more than 5% due to leakage and, therefore, you may roughly estimate its effect on the circuit provided that R6 is of a high value. The leakage of C6 must be roughly not less than 10 times the DC plate resistance of the 6SQ7GT tube which would be about 200,000 ohms. A leakage resistance as low as 2 megohms may, therefore, be tolerated for C6.

The condenser C7 in Fig. 18 presents the most difficult leakage problem of all, and this is generally true of *all audio coupling condensers in resistance-condenser coupled stages.* The voltage at the 6SQ7GT plate or an equivalent tube may reach a DC value as high as 150 volts for low plate load resistance values such as R6. The bias voltage for the 6V6GT tube must be −12.5 volts within 5% according to the requirements as mentioned. There is. therefore, a DC voltage pressure of 150 + 12.5 or 162.5 volts across C7, for a perfect condenser.

Any leakage of C7 will tend to make the 6V6GT grid more positive, reducing the bias but you cannot permit this to go beyond $12.5 \times .95$ or about 11.9 volts. This is a maximum difference in voltage across the .25 megohm grid resistor or 12.5 − 11.9 or .6 volt, and would cause a current of .6/250,000 amperes to flow at 162.5 volts. This amount of current could flow through a resistance of 67.6 megohms as shown by the following example.

$$R = \frac{162.5}{.6/250{,}000} = \frac{162.5 \times 250{,}000}{.6} = 67.6 \text{ megohms.}$$

With an output grid resistor R7 of .5 megohm this figure for leakage would be approximately doubled to 135.2 megohms. Thus, it is seen that condenser C7 must have very high minimum leakage resistance for best results. The minimum leakage resistance for C8 and C9 may be compared to that for C6. While C8 and C9 are much larger than C6, they may have

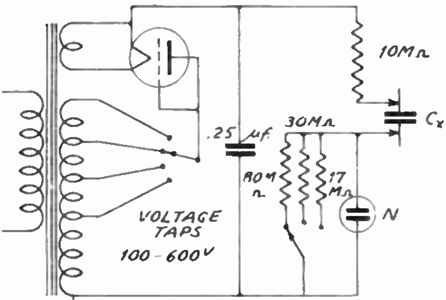


FIG. 19

correspondingly lower leakage resistance without causing trouble.

The leakage resistance which may be tolerated in any condenser in any circuit may be found in the same way similar to the examples given. The importance of measuring the leakage resistance of many condensers in radio circuits cannot be over emphasized as you can see from these examples.

Both for the reason of very high resistance and because the usual ohmmeter uses low voltage, the ordinary ohmmeter test is not at all satisfactory for condenser leakage testing. Of course, if the leakage resistance is very low or the condenser is shorted, the ohmmeter will show this immediately, but the leakage of an AVC or AF coupling condenser might be low enough to be unsatisfactory for use, while the ohmmeter may not have sufficient range or voltage to show this fact. The reason why a condenser of this kind must be tested at operating voltage or at its maximum rated voltage preferably, is that the leakage resistance if any is found will be maximum at the highest voltage. Even if a condenser tests perfect at 3 volts or at some other low ohmmeter voltage, it may not be satisfactory for use at operating voltage.

The commonly accepted methods of testing for leakage in condensers make use of either a neon tube circuit, an electric eye tube circuit or a very sensitive VTVM ohmmeter circuit. The two most prevalent types of neon tube testers are shown in Figs. 19 and 20. Both consist primarily of an adjustable DC voltage source from 25 to about 600 volts, a neon tube and associated resistors. The selection of voltages, of course, is intended for condensers of various voltage ratings.

In series with a resistor, the selected voltage is chosen as the voltage at which the condenser is rated and is thus applied to the condenser under test. The condenser circuit is completed through a neon tube which is shunted with a condenser for paper or mica condenser testing and is shunted with a resistor for electrolytic condenser testing. The neon shunt condenser, however, need not be used.

Assuming some value of leakage resistance through a condenser under test as in Fig. 21, the graph shows the operation of the test circuits of Figs. 19 and 20. On closing the circuit, the positive voltage is instantly applied to both sides of the condenser (until the condenser charges) and the voltage at E for an instant is equal to the positive high voltage. The neon tube instantly flashes and current flows in the condenser under test limited principally by R in series with the neon tube. This resistance must be used to prevent destroying the neon tube with too much current flow. As the condenser charges its negative terminal becomes more and more negative, reducing to 15 to 25 volts in a few microseconds, if the leakage resistance is small and the condenser is small.

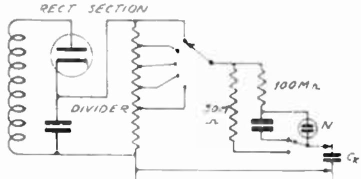


FIG. 20

As soon as the voltage E drops to a value which will no longer maintain ionization of the neon tube N, current flow in the neon tube and R stops. The condenser is then left at full charge at time T. Its charged voltage as observed by the graph in Fig. 21 is nearly equal to that of the high voltage supply. Now, if the condenser has no leakage this charge will remain indefinitely, and the neon tube will not flash any more. This is impossible in practice, because the charge will eventually be dissipated by the surrounding air. If there is excessive leakage present, however, the condenser will discharge through this leakage. This discharge will lower the voltage across the condenser and raise the voltage E across the neon tube. At 60 or 80 volts, depending on the neon tube, ionization will again take place and the condenser will charge to maximum again, producing a flash of the neon tube. Naturally, the less frequently these flashes occur, the better is the quality of the condenser, because this indicates higher leakage resistance. Time interval T2 in Fig. 21 represents a short charging time with frequent flashes and relatively low leakage resistance. Time interval T_0 shows a better condenser while the longer interval T1 shows a very good condenser. Time interval T1 is about 5 seconds in Fig. 21.

However, there is no direct indication of this resistance value as it must be determined by the number of flashes per second of the neon tube or the number of seconds per flash of same. The manufacturers of this type of equipment generally supply charts or descriptions of operation sufficient for practical purposes. There are several variable quantities which makes the finding of the actual leakage resistance value somewhat difficult. However, the following formula will give this value to a high degree of accuracy.

$$R = \frac{T\ (Eo - E_x)}{C\ (Ei - E_x)}$$

When:
T = flash time of N-seconds.
C = capacity under test in mfd.
Eo = total voltage of supply.
Ei = ignition voltage of neon tube.
E_x = extinction voltage of neon tube.

Once you have determined Ei and E_x with a simple power supply or battery and potentiometer with the neon tube, you can substitute these values in the formula and obtain a number for all values except T and C. As an example, if Eo = 500 volts, and E_x = 30 volts, you have:

$$\frac{500 - 30}{80 - 30} = \frac{470}{50} = 9.4$$

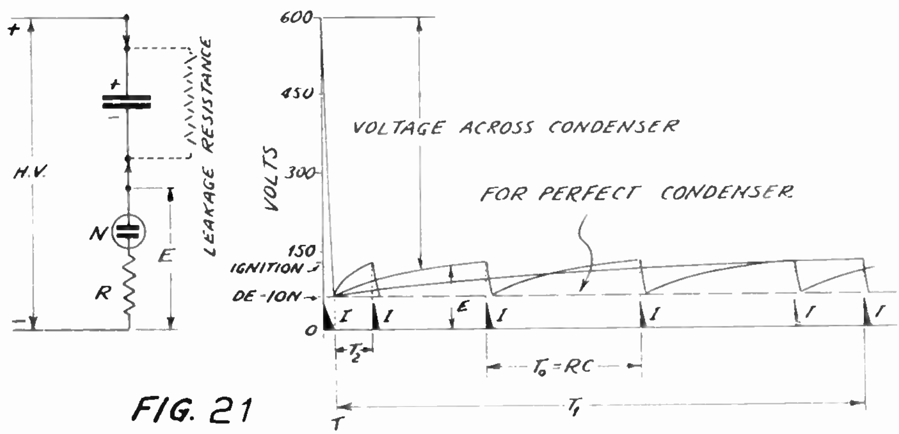


FIG. 21

This should be done for each value of Eo that is used. The resistance is equal to: $R = \frac{T}{C} \times 9.4$, and if you get about one neon flash per second for a .1 mfd. condenser, the leakage resistance in megohms will be equal to:

$$R = \frac{1}{.1} \times 9.4 = 94 \text{ megohms.}$$

Such a condenser would be satisfactory for practically any by-pass circuit but not for AF coupling or for AVC as a rule.

Electrolytic condensers, of course, have a small internal leakage current normally and in a test of this kind, the neon lamp would flash very rapidly or remain on, producing a continuous light of the bulb. Because of this you cannot distinguish a good condenser from a shorted condenser (electrolytic).

In testing electrolytics for leakage, you should use a resistance in parallel with the neon tube so that this leakage current can be carried by the circuit. This parallel resistance is chosen with such a value that when the leakage of the condenser under test drops to its operating minimum, the voltage drop across the parallel resistor and neon tube will be slightly less than the extinction voltage of the neon tube. The voltage will drop below this value in from 1/2 minute or less to 5 minutes, depending on many factors such as time out of service, temperature, age of the condenser, its capacity, its type, dry or wet, etc. If the time required is more than 5 minutes in any case, the condenser is most likely defective. Several parallel resistors for the neon tube are sometimes used as in Fig. 19 to correspond with different capacity ranges. Values given in the circuit are not critical.

Obviously, the neon lamp method of leakage resistance testing of condensers is a very indirect method, and is not accurate in practice unless all factors are known and calculations as mentioned are made. Ohmmeters are available of the VTVM type capable of measurements up to several thousand megohms and would be very good for the testing of condenser leakage. Another type of high range ohmmeter is called a *megger*. These are manufactured by a number of prominent instrument makers. The operating voltage is usually obtained from a small hand driven or motor driven generator.

Even if a condenser is suspected of being defective and is replaced with a new one, there is no assurance that the trouble has been corrected. If your instruments are not adequate for these leakage tests, *you may never know where the trouble lies*. For this reason a megger or VTVM type ohmmeter is highly recommended.

Power Factor

The power factor of a condenser may be expressed in several ways. It is most usually expressed as a percentage. This percentage is the percentage of the total electrical power fed to the condenser (in terms of the product of the voltage across it and the current it carries)—that is, actually wasted in heat losses. It might just as well be called the *loss factor* of the condenser from this understanding. An example will clarify the meaning of power factor from this explanation.

If 100 volts RMS AC is applied to a condenser at such a frequency that 100 milliamperes of current flows, the energy or potential power available to the condenser is $100 \times .1$ or 10 watts. The charged voltage of the condenser, however, will give some of this energy back to the line or source used in charging it. In fact, a perfect condenser will give back *all* of this 10 watts to the line and it will never be

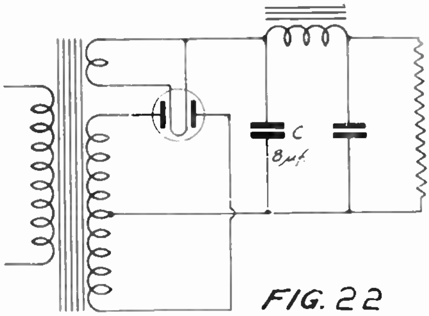


FIG. 22

used. Such a condenser *will draw 100 milliamperes but will consume no power*. It will remain at the temperature of its surrounding objects and a *wattmeter in the power line will not record any power used by the condenser*. Such a condenser would be described as having a *zero power factor or zero percent power factor.*

If, however, the condenser has a sufficient leakage or loss of any kind so that it uses 1 watt of this potential 10 watts, it is said to have a power factor of 10% (1 is 10% of 10). If it uses 3 watts, its power factor is 30% etc. If the available power (condenser voltage times condenser current in amperes) is 50 watts and the condenser only uses 2 watts of this, it would have a power factor of 4% (2 is 4% of 50). The power factor is always between 0 and 1 while the power factor percentage is between 0 and 100 being 100 times the power factor.

Now, you will see what value this term has in connection with various practical problems. First, consider an input filter condenser as C in Fig. 22. Assume that the ripple voltage or the voltage change (RMS) across this condenser is 20 volts. The peak DC voltage may be 400 or 450 volts but you do not consider this at present.

The reactance of an 8 mfd. condenser at 120 cycles (for that is the frequency of the ripple voltage for a full wave rectifier as in Fig. 22) is about 166 ohms. Since the charge and discharge current at 20 volts and 166 ohms would be approximately 20/166 or 120 milliamperes, there would be a potential power supplied to the condenser of 20 × .12 or 2.4 watts, as power is equal to voltage times current. The power factor determines what portion of this available power is wasted in heat.

There is some leakage of electrons through an electrolytic condenser and this leakage path may be *symbolized* as a shunt resistance with the condenser. It is actually part of the characteristics of the condenser but is shown in Fig. 23A as a separate shunt resistor to clarify its relation to the circuit. It represents principally the AC or DC conductivity of the dielectric. For example, an 8 mfd. condenser will allow a flow of DC through it of about 2 milliamperes at 400 volts, indicating a dielectric resistance of 200,000 ohms.

The dielectric and electrolyte use some power in maintaining the chemical arrangement of the condenser and the recovery of the dielectric on discharge is not perfect accounting for some power loss. Since this action does allow actual electron leakage across the dielectric, it may be thought of as an equivalent series resistance. This is shown in Fig. 23B. Both the shunt and series conditions may be represented as in Fig. 23C. It is always simpler to represent the entire

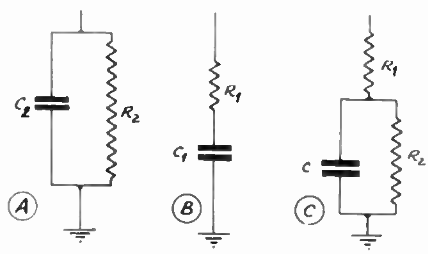


FIG. 23

condenser resistance as a single unit either in series or in parallel with the condenser. In fact, in testing for power factor, you need not actually know what portion of the condenser loss is a series loss and what portion is a shunt loss.

The input filter condenser of a rectifier circuit has by far the greatest AC power loss of any condenser in the usual receiver. If its power factor were 50%, its use as a filtering capacity would be limited.

It should be obvious that the lower the power factor, the better the condenser, and that the power factor of a condenser depends to some extent on the frequency of the voltage with which it is used. Because of the fact that by far the greater part of the condenser loss is created in the dielectric the power factor of a dielectric is often referred to as a separate item. As the power factor is influenced by the frequency, the latter is usually specified.

Usually the losses of a condenser either series or shunt are of such nature that they are nearly proportional to the condenser reactance, and in this case, the frequency need not be considered.

A rough indication would be a power factor of about 15(%) for a condenser rated at 300 or more volts. For one rated at 150 volts a power factor of 20(%) would be satisfactory, and for one rated at about 25 volts, the PF would be about 30(%).

The practical measurement of power factor is always done by means of adding a series resistance in the standard condenser circuit. Whether a condenser under test has a shunt, series or both resistances, its total impedance may be made to exactly match the impedance of a condenser

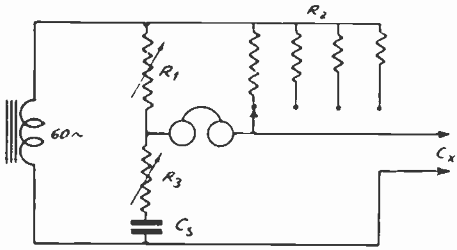


FIG. 24

with a series resistance. The match must be both in total impedance value and phase angle.

For reading a maximum power factor of 50% for example, as in Fig. 24, resistance R3 is used. Its maximum value must make the ratio of its resistance to its total impedance equal to .5 with the standard condenser C_s.

In Fig. 24, the bridge is balanced as near a perfect balance as possible before using the power factor resistance R3. This is then adjusted for a *better bridge balance.* The bridge must also be readjusted again, depending on how large is the real power factor of the condenser. CS in Fig. 24 must be a high quality paper or mica type condenser, having as near zero power factor as possible.

Additional marks in the power factor scale may be found by substituting .4, .3, .2, .1 and any others desired for .5 in the formula given and solving for R. The points where the power factor has these resistance values are marked with corresponding percentages of 40, 30, 20, 10, etc.

For small paper and all mica condensers the power factor will be so low that no reading can be obtained for this small power factor, and it is left set at zero at all such times. For large paper condensers, this should also be true. No electrolytic condenser should be used whose power factor exceeds 20 or 30%.

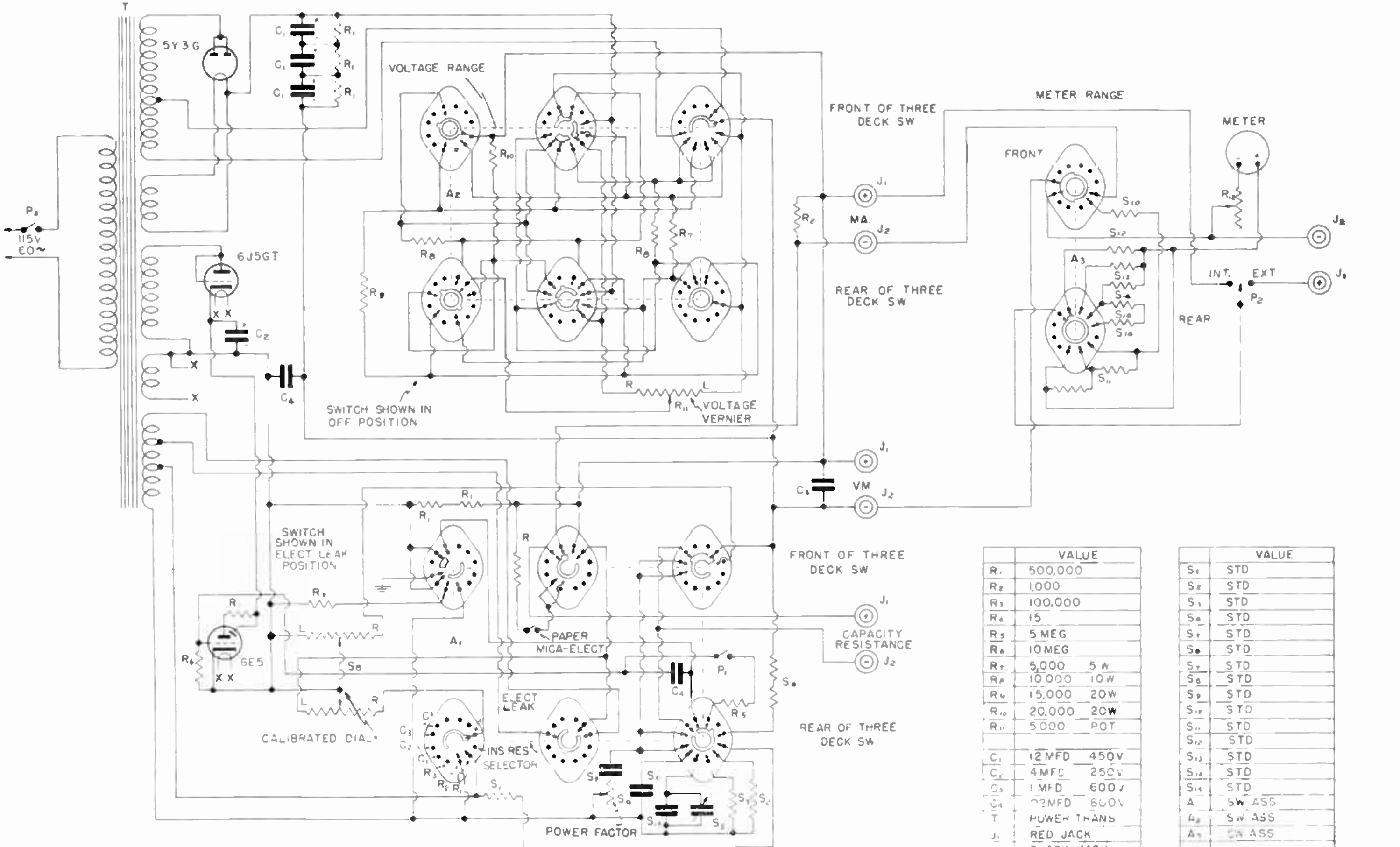


FIG. 25

	VALUE
R_1	500,000
R_2	1,000
R_3	100,000
R_4	15
R_5	5 MEG
R_6	10 MEG
R_7	5,000 5 W
R_8	10 000 10 W
R_9	15,000 20W
R_{10}	20,000 20W
R_{11}	5000 POT
C_1	12 MFD 450V
C_2	4 MFD 250V
C_3	1 MFD 600V
C_4	.02MFD 600V
T	POWER TRANS
J_1	RED JACK
J_2	BLACK JACK
P_1	PUSH BUTTON SW
P_2	SPDT
P_3	SPDT

	VALUE
S_1	STD
S_2	STD
S_3	STD
S_4	STD
S_5	STD
S_6	STD
S_7	STD
S_8	STD
S_9	STD
S_{10}	STD
S_{11}	STD
S_{12}	STD
S_{13}	STD
S_{14}	STD
S_{15}	STD
A	SW ASS
A_2	SW ASS
A_3	SW ASS

Commercial Capacity Testers

As is the case with other types of test equipment, there are certain advantages to using commercial capacity testers. The type of unit and the cost are all factors that must be considered in selecting the tester to be used in the service shop. Testers are available in both kit form and already built. There are several different types in use, but usually these are variations of the bridge circuit which has been discussed, and the pulse generator which is covered in this section of the lesson. One of the big advantages of a commercial unit is that it usually is self contained. That is, it contains its own power supply and also a source of AC or pulse voltage for testing purposes.

Figure 25 shows the circuit diagram of the Sprague Model TO-2 TEL-OHMIKE combination tester. This instrument is a complete bridge type resistance and capacitance analyzer with a built in DC volt-milliammeter.

The condenser tester, is of the bridge type and allows for an accurate test of all types of condensers. The instrument is so arranged that the actual working voltage is impressed upon the condenser during the test, thus simulating the actual operating conditions of the condenser. By doing this, a more satisfactory test is made eliminating any possibility of error that may arise if the condenser is tested with a lower than operating voltage.

This instrument measures capacitance from 10 mmfd. to 2000 mfd. in four direct reading ranges as follows: 10 mmfd. to .005 mfd.; .001 mfd. to .5 mfd; .1 mfd. to 50 mfd; 50 mfd. to 2000 mfd. The power factor of electrolytic capacitors can be measured directly within a range of 0 to 50 percent.

DC resistance can be measured from .5 ohm to 5,000,000 ohms and insulation resistance (dielectric leakage resistance) up to 10,000 *megohms.* The voltmeter range is from 0 to 1500 volts DC and the milliammeter range is from 0 to 50 milliamperes DC.

The circuit diagram, because of the complex switching arrangement necessary for such a versatile instrument may seem rather complicated, but if you follow through the switching system carefully you will find the operation of the condenser bridge similar to those already given in this lesson.

Figure 26 shows a circuit diagram of the Jackson Electrical Instrument Company Model 650A condenser tester. This tester tests condensers for shorted, leaky, open, intermittent, incorrect capacity and bad power factor conditions. It has the convenient feature of push-button operation for changing to the different capacity ranges and a selector switch for applying the correct operating voltage to the condenser under test.

The dial scales are directly calibrated in terms of capacity for easy reading. This tester like most condenser testers, uses the bridge method for measuring the condenser capacity.

One of the newer types of capacity testers is the *pulse,* or *in-circuit* tester. As the name implies, this tester is designed to check the quality of a fixed condenser without having to remove it from the circuit. This type of tester uses a *pulse* of voltage rather than DC or a sine wave of AC. The pulse is of very high value and very short duration. Thus it will not affect the operation of the circuit resistors. Even though a large voltage is applied across them they will not overheat because it is quickly removed. The condenser under test however

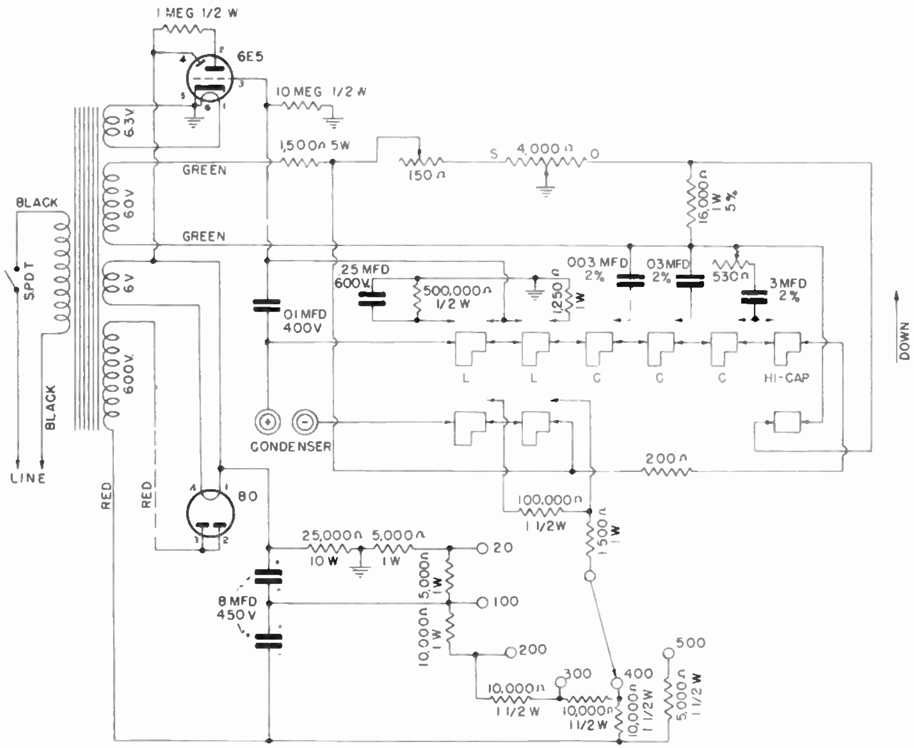


FIG. 26

will charge to the peak value of the voltage pulse almost immediately.

A center reading DC microammeter is used in series with the pulse circuit and a small battery. These components which are in series, make up the tester and are placed across the capacitor under test. The zero center meter is used because it will give a reading even if the resistance decreases when the large pulse of voltage is applied. (This often happens within a capacitor.) The basic circuit is shown in Fig. 27.

The battery E_c is used to provide a 'bias' or operating level of a few volts. The resistor R represents the normal resistance of the capacitor being tested (C), and the resistor R_L represents the leakage resistance. The pulse generator consists of a low impedance source such as a thyratron that will not affect the operation of the circuit. When a capacitor is to be tested. the power of the radio or TV receiver must be turned off. The pulse voltage is applied and an indication is read from the meter. Usually, the meter has a range marked 'GOOD' in the center of the scale and a 'BAD' range extending on either side of center.

It has been found that the dynamic (AC) leakage resistance of a condenser will not be steady but will vary with the applied voltage. Thus when a large pulse is applied, the leakage resistance is very small and so the capacitor is unable to charge to its full value. This of course will cause a deflection of the meter indicating a leaky capacitor. It has also been found that the application of a large voltage may cause the condenser to 'heal' a small defect such as a pin point short. It may acutally correct the defect so that the leakage resistance will again rise to a high value. If this is the case. then the meter will show no variation when the pulse is applied and the needle will remain on the center or 'good' range. The same results will be obtained if a good capacitor is tested. If there is leakage resistance present, the current can flow through it and this will cause the needle of the meter to be deflected rapidly to one side or the other of center. For this reason, the tester should not be left in place across a shorted condenser. There are several companies which make this type of tester and more complete directions are given for each specific unit.

The value of the pulse tester for television receiver circuits and for printed circuit assemblies should be mentioned. Because of the mechanical construction of these circuits it is sometimes difficult to remove a component from the circuit without destroying it. Thus a tester which will operate without having to remove the component is useful. Also, condensers which are constantly subjected to pulse type voltages such as in a TV receiver will fail more readily than those having a steady voltage applied. These condensers can best be tested by use of a pulse rather than a sine wave or DC.

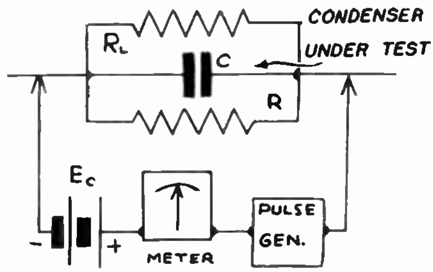


FIG. 27

Questions

No. 1 Why is a high voltage test for condenser leakage more reliable than an ordinary ohmmeter test?

No. 2 Would the spark method of condenser testing be suitable for a .001 mfd. condenser?

No. 3 In measuring the capacity value of a condenser marked .005 mfd. without a bridge circuit, would you consider the series voltmeter or ammeter method more suitable?

No. 4 Could resistors be used as range multipliers in Fig. 11 instead of condensers as shown?

No. 5 What must be added to an ordinary condenser bridge circuit for testing electrolytic condensers?

No. 6 Why is it desirable to test electrolytic condensers at or near their normal or rated DC voltage?

No. 7 Would headphones be satisfactory as an indicator in a bridge circuit used to measure condensers of .0001 mfd. or less?

No. 8 Which two condensers in Fig. 18 must be of the highest quality from the leakage resistance standpoint?

No. 9 What action of a neon tube type leakage condenser tester shows that the condenser is of poor quality—that is, has low leakage resistance?

No. 10 For what types of condensers is the measurement of power factor most important?

HOW TO TEST FOR RESISTOR DEFECTS

LESSON NO. TV-12

Sprayberry Academy of Radio

CHICAGO ILLINOIS

K9542M

The above photo shows a continuity test being made of a circuit in which several resistors are involved. The test leads are plugged into the proper jacks on the meter panel. The other ends of the test leads have clips attached, making it possible to temporarily connect the test leads to any two points of the circuit. Values are read by referring to the meter.

How To Test For Resistor Defects

Lesson No. TV-12

Resistor defects are common in radio receivers and amplifiers. Along with condensers more of these parts have to be replaced than all other parts used in radio circuits. As you know resistance units are used in many forms but regardless of the form of the resistance unit it is subject to an open, it may change in value, it may become intermittent in operation, it may overheat, it may short or become grounded. The most common resistor defect is an *open*. This is a condition where the resistor no longer has continuity or it will not conduct current. The only remedy for this condition is to replace the resistance with one of correct value and power rating.

A change in value can occur in a resistance unit and in general where a change in value takes place the resistance unit should be replaced.

An intermittent condition is one when the resistance unit opens and closes either regularly or irregularly. Regardless of the regularity of the intermittent action the resistance unit should be replaced.

A resistance unit may overheat (be required to dissipate more electrical power than for which it was designed) and not cause undue trouble. If this is continued for a long period of time the unit may become open or may change in value. Where it is a clear case of overloading, the resistance unit should be replaced with correct resistance value and a unit should be chosen which will dissipate the required power. Be sure, however, for this condition that some other unit such as a condenser is not shorted or otherwise defective and thus causing excess current to flow through the resistor. Later on in this lesson more information will be given on power ratings for resistors.

A resistor rarely develops an internal short and where it occurs it is usually confined to the wire wound types. An external short can and often does occur across a resistance unit. An example is where a condenser connected in parallel (in effect) to a resistor develops a short. When such a condenser shorts it also shorts the parallel connected resistor. The remedy, of course, is to replace the condenser which automatically removes the short from across the resistor.

A resistor can become grounded through another part being defective or one of its terminals can be grounded to the metal chassis accidentally. Otherwise a resistor does not ordinarily become grounded. It is well to keep in mind, however, that many resistors are supposed to have at least one terminal connected to ground or to the metal chassis. This, of course, is a proper connection and does not constitute a defect.

The average radio man determines the condition of a resistor by means of an ohmmeter. The two test leads of it are connected across the resistor terminals. This permits the reading of the resistance value and also indicates if the unit is open. This follows the general pattern of *continuity testing* as explained in a previous lesson. Thus, what is to follow in this lesson is based on the use of the ohmmeter. First you will study the ohmmeter (using various type meters), then in order will follow directions for resistor testing, correct use of ohmmeter, heat and power ratings for resistors, testing the variable types, repairing noisy controls, etc.

First it should be remembered that ohmmeter test circuits are of two types. (1) Those employing a *series circuit* and (2) those employing a *shunt circuit*. Both of these types of circuits may be included in one ohmmeter circuit. The shunt type of circuit is usually employed to measure low values of resistances (below 300 ohms). The series type of circuit is usually employed to measure high values of resistance (above 300 ohms). In the series type of circuit the resistance to be tested is connected in series with the test circuit whereas for the shunt or parallel type of test or ohmmeter circuit the resistance to be tested is connected in parallel or shunt to the test circuit. More on these types of circuits will be given later in this lesson.

The measurement of resistance is, of course, an application of ohms law. You know, of course, that the voltage across the resistance and the current through it is a result of the resistance value. Although a voltmeter and milliammeter or ammeter can be used for these measurements, it has been much more practical to combine both measurements in one instrument (commonly known as a multimeter). If you start with a known voltage, you do not have to measure it for each resistance measurement. You can then measure the current accurately which passes through the resistance under test (in series or parallel with another resistance) whose value is known and the current will be an index

This view shows several types of resistors commonly used in radio equipment. The upper resistor is a 50,000 ohm, 50 watt unit. The next unit is of the glass enclosed type for high frequency use. The two lower units show two types of power wire wound resistors. *Courtesy of Sprague.*

of the total resistance. Subtracting this (the known resistance) from the total indicated by the voltage impressed and current flowing, you will have the remaining added resistance. The *ohmmeter* is, of course, such an instrument in which the current values are marked in ohms because each value of current measured by the meter actually is used to represent a definite resistance included in the test circuit.

Because of the added resistance in the ohmmeter circuit and the fact that resistance and current are *inverse*—that is, as resistance increases current reduces—the graduations of the ohmmeter scale have uneven divisions.

Now any milliammeter-voltmeter can be made into an ohmmeter so far as the electrical circuit is concerned, but the dial scale calibration cannot easily be added. The values of resistance for any deflection of the meter needle can be found very accurately but it is still not practicable to mark these values on the meter scale. It would be possible to make a table, or graph or scale in which, for any needle deflection, the proper resistance could be found but a separate table or graph would have to be made for each combination of meter and voltage employed.

For meters which do not have ohm values marked on their scales, a new scale can sometimes be obtained from the manufacturer of the meter. However, most of the present day meters are provided with ohmmeter scales. Later in this lesson a universal ohmmeter scale applicable to any meter and any battery voltage as met in practice will be given.

The following information is given for building an ohmmeter or for checking the design or accuracy of an ohmmeter that you may already have. The circuit of a simple *series type ohmmeter* is shown in Fig. 1. Both as a protection to the meter movement and as a means of adjusting the circuit, two resistors are used in series with the complete instrument. The resistance of the meter itself makes a third value in the circuit. The internal resistance of the cell or battery (E) and of the test leads are neglected since they may be compensated for by means of a zero adjustment to be described later.

In order to measure low resistance values with test leads (P1 and P2) in Fig. 1 the combined value of Rm + Rv + R must be large enough so that the voltage (E) used will not cause more current to flow than that for which the meter is rated. In other words, if the resistance Rx under test is shorted, the only elements in the

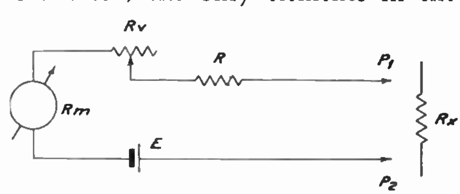


FIG. 1

METER SENSITIVITY-MICROAMPERES-MILLIAMPERES

Volts	40 Micro-amperes	50 Micro-amperes	200 Micro-amperes	400 Micro-amperes	500 Micro-amperes	1 Ma.
	Meter Sensitivity—Ohms Per Volt					
	25,000	20,000	5,000	2,500	2,000	1,000
1.5	37,500	30,000	7,500	3,750	3,000	1,500
3.	75,000	60,000	15,000	7,500	6,000	3,000
4.5	112,500	90,000	22,500	11,250	9,000	4,500
22.5	562,500	450,000	112,500	56,250	45,000	22,500
45.	1,125,000	900,000	225,000	112,500	90,000	45,000

circuit to limit the current are Rm, Rv, and R.

The sum of these is, therefore, determined by the voltage used and the meter sensitivity or its current for maximum scale deflection. The value is found simply by dividing the voltage of the ohmmeter battery by the maximum scale current which the meter will carry. In the foregoing table is given values of resistance for the *total* of Rm, Rv, and R for various commonly used voltages and commonly used meters. The sensitivity of the various meters is expressed both in microamperes or milliamperes and in ohms-per-volt.

From ohms law you know that at a given voltage if the resistance of any circuit is *doubled its current will reduce exactly in half*. Accordingly, if a resistance such as Rx in Fig. 1 is used which will give an exact *half scale* deflection, the needle of the meter must point to the actual value of Rx. Further, since the current is now just half of what it is when the test leads are connected or shorted together (zero resistance on the ohmmeter scale) the resistance Rx under test must be equal to the resistance already in the ohmmeter circuit.

This means that the values in the table immediately preceding are the resistance values which will be read at the *exact center of the meter scale*. Check this value with the voltage and sensitivity of any meter you might have.

Referring again to Fig. 1, when the battery voltage reduces through use, the resistance of the circuit must also be reduced so that maximum scale current can still flow. The use of resistor Rv permits this and is known as the zero resistance adjustment for the ohmmeter. For example, if a 1.5 volt flashlight cell is used in a 1000 ohms-per-volt instrument and the voltage reduces in the course of time to 1.2 volts, 1200 ohms is needed to limit the current to 1 milliampere and hence Rv is reduced until the total of Rm, Rv and R just equals 1200 ohms.

Now, if you place a 1200 ohm resistor at Rx and connect the test leads to it, you will measure 1500 ohms because the meter will still read half scale but will have actually only 1200 ohms external to the meter. The instrument will thus read 25% too much in this case. The importance of replacing the ohmmeter battery is thus made obvious.

It should also be observed that by reducing the resistance of Rv the resistance of the circuit has been changed by 300 ohms or by 20% of the total

Here is shown a view of the Philco No. 7001 circuit tester. Among its many uses, it may be used for resistance measurement and for circuit continuity testing. It has seven resistance ranges up to 1500 megohms and is, of course, of the electronic voltmeter type.

of 1500 ohms. Every reading on the scale will, therefore, be incorrect by at least 25%. Remember also that as the battery voltage reduces, the error in reading is high—that is, the value that the ohmmeter shows is greater than the actual value of the resistance by about the same percentage that the battery voltage has reduced.

For most of its life the voltage of a dry cell holds up fairly well. You should not, however, wait until the *zero adjustment* (for example Rv of Fig. 1) of the instrument is impossible before replacing the battery. The same information applies to the shunt type ohmmeter but, of course, to different degrees, depending on the circuit.

An ohmmeter can be made practically independent of the voltage which operates it if a shunt type of zero resistance adjustment is used. Note in Fig. 1 that resistance Rv provides the zero adjustment. This is known as a series zero adjustor. If the basic circuit of Fig. 2 is used it does not matter how much the battery voltage reduces. It will still be an accurate ohmmeter if a zero adjustment can be obtained by means of Rv. The resistors R1, R2 and R3 are calculated to match the meter used and to provide the necessary range of resistance values. This basic circuit of Fig. 2 is used in most commercial ohmmeters on the market today.

Now, if you have any meter with an ohm scale and wish to make an ohmmeter, carefully note its center scale reading. It will most likely be one of the values in the preceding table. Suppose it is 7,500 ohms. This value appears twice in the table. If the meter has a sensitivity of 400 microamperes (2500 ohms-per-volt) a 3 volt dry cell battery must be used with a fixed resistance of 7,500/1.25 or 6,000 ohms and a variable resistor of 7,500-6,000, or 1,500 ohms wire wound. The resistance of the meter need not be considered because whatever it may be this much resistance can be subtracted from the 1,500 ohm variable unit for exact adjustment.

If the meter in question has a sensitivity of 200 microamperes, the same resistance values are used with a 1.5 volt dry cell. For multiplying the ohmmeter range where a voltage in an exact multiple of 10 is not available, the sensitivity of the meter is reduced for one of the ranges (usually the lowest range) so that the same scale may be used for all readings.

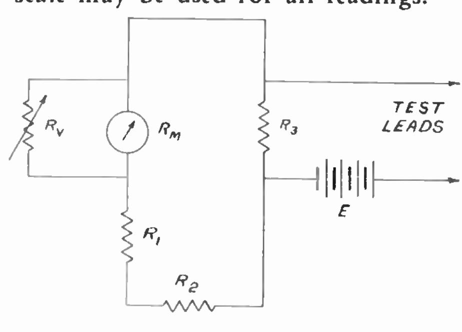


FIG. 2

When using a DC meter as an ohmmeter, the original scale of the meter may be divided into any number of units such as 10, 25, 50, 75, etc. No matter how the scale is marked or divided, it is possible by means of mathematics, to translate the scale divisions into terms of resistance values.

After you calculate the resistance value for each of the divisions on your meter, you do not mark these values on the meter scale—instead you should make up a table which will show the resistance value for each division of the scale. This gives much more accuracy than a printed meter scale, for it allows a value for each scale division.

You first determine the resistance value for the center division on your scale. If you have an accurately calibrated variable resistor, this center value may be determined by adjusting a resistor across the test leads until half scale is obtained. Or you may simply add up all resistances in the external ohmmeter circuit. The total resistance of the external ohmmeter circuit will be the same as the center scale reading.

Once you know the resistance value for the center division of your meter, you can, within a short time, calculate the resistance values for all other divisions on your meter, no matter how many it has.

The procedure to follow in doing this is best explained by the example which will be given later. At this point, remember that these principles do not apply to the one example only. *The same procedure is to be followed for any type of DC meter.*

Suppose you have any DC meter with 10 divisions. Also, suppose for example that the 5th or center division is equal to 100 ohms. To calculate the resistance value for the other scale divisions, you would set up the scale divisions in the following form:

$$(1)\ \frac{9,\ 8,\ 7,\ 6,\ 5,\ 4,\ 3,\ 2,\ 1}{1\quad 2\quad 3\quad 4\quad 5\quad 6\quad 7\quad 8\quad 9}$$

If your meter has 50 divisions, the scale divisions would be laid out as follows:

$$(2)\ \frac{49,\ 48,\ 47,\ 46,\ 45,\ 44,\ 43,\ \text{etc.}}{1\quad 2\quad 3\quad 4\quad 5\quad 6\quad 7}$$

Note that in (1) and (2) when you add the number above the line to the one below the line for any one scale division, the sum is the total number of scale divisions.

This principle holds true for a meter with any number of scale divisions.

For example, in (1), $9 + 1 = 10$, $8 + 2 = 10$, $7 + 3 = 10$ and in (2) $49 + 1 = 50$, $48 + 2 = 50$, $47 + 3 = 50$, etc.

This is brought out so that you may check for errors when laying out the numbers for your particular meter. Before making further calculations, you should go over each set of numbers to see that each set totals the number of scale divisions on your meter.

You will notice that no resistance value will be obtained for the two ends on the scale. That is, full scale deflection and zero deflection. This is correct. The end of the scale to the left for a series type ohmmeter is always equal to *infinity*. Likewise, the end of the scale to the right is always equal to *zero* on any series type ohmmeter. This applies to all ranges of the series type meter. The reverse is true for the shunt type ohmmeter as will be explained later.

Now you are ready to calculate the resistance value of the first division, reading from left to right. To do this, there are three units to work with.

(1) The scale division.

(2) Total number of scale divisions.

(3) The resistance value of the center scale division.

Note that (1) the scale division must be calculated as the number of divisions from the zero resistance or right hand end of the scale.

In the example of a meter with 10 divisions, the three factors to be used to calculate would be as follows:

(1) = 9 (the scale division).

(2) = 10 (total number of scale divisions).

(3) = 100 (resistance at the center division).

The resistance value is then calculated as follows:

$$\frac{9}{10-9} \times 100 \text{ or } \frac{9}{1} \times 100 = 900 \text{ ohms}$$

Likewise, the other values would be calculated as follows:

$$\frac{8}{2} \times 100 = 400 \text{ ohms.}$$

$$\frac{7}{3} \times 100 = 233 \text{ ohms.}$$

$$\frac{6}{4} \times 100 = 150 \text{ ohms.}$$

$$\frac{5}{5} \times 100 = 100 \text{ ohms.}$$

$$\frac{4}{6} \times 100 = 67 \text{ ohms.}$$

$$\frac{3}{7} \times 100 = 43 \text{ ohms.}$$

$$\frac{2}{8} \times 100 = 25 \text{ ohms.}$$

$$\frac{1}{9} \times 100 = 11 \text{ ohms.}$$

For a meter with more or less divisions, the same system is used until a resistance value is obtained for each division. In the foregoing example, there are nine calculations, giving resistance values for nine points on the scale. If the meter scale had 50 divisions, you would have 49 such calculations to give 49 resistance values for 49 points on the scale.

In formula form, this is

$$R = \frac{Y \times Z}{X - Y}$$

Where:

R = resistance value on ohmmeter scale.

Y = scale division you are calculating (this must be taken from the zero resistance or right hand end of scale).

Z = the resistance of the center division.

X = the total number of scale divisions.

Example: A meter has 75 scale divisions. The resistance value of the center division is 3500 ohms. Find the resistance value for the 11th scale division (64th from zero resistance end of scale).

Formula: $R = \frac{Y \times Z}{X - Y}$

Substituting: $R = \frac{64 \times 3500}{75 - 64}$

$$= \frac{224{,}000}{11} = 20{,}363 \text{ ohms.}$$

Or, if the meter had 60 scale divisions and a center resistance of 6500 ohms, find the resistance value of the 39th scale division (21st from the right hand end).

$$R = \frac{21 \times 6500}{60 - 21} = \frac{136{,}500}{39} = 3500 \text{ ohms.}$$

This shows that this formula may be applied to any DC meter with any number of scale divisions and in any circuit for which the resistance value of the center scale division is known.

It should be noted that any ohmmeter may be calibrated if a number of resistors of known value are available. Simply connect the known resistors across the test leads, one at a time, and make a record of the readings. Then refer to your record when testing resistors of unknown value. You should use resistors of the value which you will most commonly test when making your calibration.

This method is useful when you want to use a certain meter occasionally as an ohmmeter, which you do not wish to incorporate in an ohmmeter circuit. Be sure to always use the same voltage that was used when taking the reading with the known resistors. If you do not, your readings will, of course, be false.

The best alternative to making your own ohmmeter scale is to have a chart or table by which you can read resistance values directly. While such a chart cannot be made universal for all meters, the one shown in Fig. 3 takes in most of the prevalent meter sensitivities and ohmmeter battery voltages.

To use the chart, first determine what the center scale resistance reading of your ohmmeter will be from the previous table of meter sensitivities. If it is not one of these values, a series or shunt resistor must be added to the meter to make it have one of these sensitivities. Next, locate this number or any 10th submultiple of it, such as for 22,500, not found in the chart of Fig. 3 on the line C (Center Reading) use 2,250 or 1/10th this value. For the value 6,000, use double the value for 3,000 or 4 times the value for 1,500.

Typical standardized meter markings are shown in Fig. 3 so that for any meter you can make direct reference to the chart for resistance values. Once you have located the proper center scale resistance and the proper scale corresponding to the DC graduations of your meter, resistance values can be read directly from the chart. For example, if your meter and battery produce a center scale reading of 3750 ohms and its DC graduations are from 0 to 2.5, when the needle reads 2, the resistance under test will be approximately 900 ohms—that is, between 750 and 1000 on the chart. For simplicity in arranging the chart, all numbers have been divided by 1000. In making readings therefore, multiply all values shown by 1000. By a careful study of the chart you will soon see how useful it can be with meters which are not marked with an ohm scale.

Resistor Testing

In order to test any resistor or section of a resistor, it is necessary for at least one terminal of the resistor or of the section to be free from other direct current circuit connections. Connection of a resistor to a condenser or to a tube socket from which the tube has been removed will not affect the test unless there is a circuit defect. However, to avoid a case where a resistor (.5 megohm for example) is actually open and the leakage through a condenser connected to it is .5 megohm (you would read the correct resistance value through the wrong circuit), the resistor must be completely disconnected at one end.

The resistance of any carbon resistor will be lower when at operating temperature than when cold, while for every other kind of resistor its value will be greater when measured at operating temperature. In no case, however, should the resistance change more than 5 to 8% due to temperature and the operation of few circuits in radio will be materially influenced by this much change. Conditions in any receiver are made so that this much change can take place without materially affecting operation.

To more thoroughly understand the things which can happen to resistors to make them defective by op-

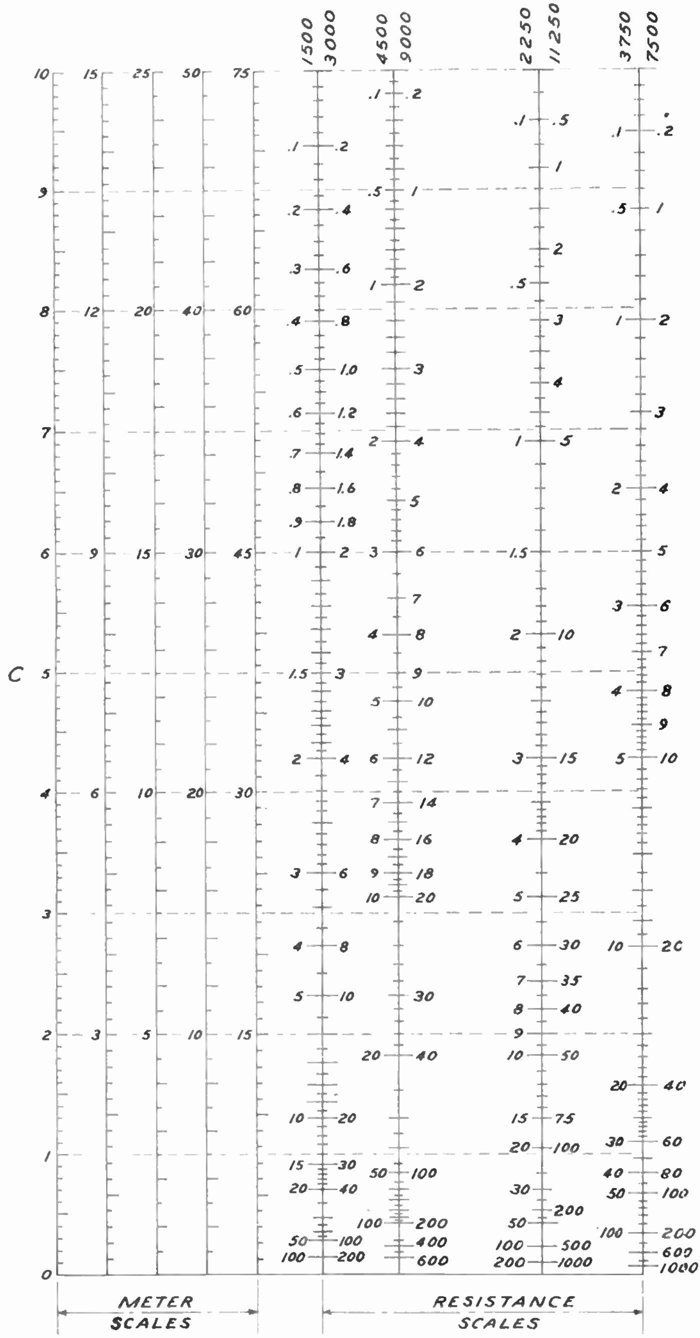

1500
3000
4500
9000
2250
11250
3750
7500
10
15
25
50
75
C
METER SCALES
RESISTANCE SCALES

FIG. 3

ening, changing in value, becoming intermittent in conductivity, over-heating, etc., all resistors may be divided into two general classifications: (1) composition and (2) metal.

The composition resistor takes many forms, making use of carbon generally as the determining factor for its resistance value. A number of materials (some of which are conductive and some of which have very little conductivity) are finely ground and mixed. They are pressed into shape and mounted in a suitable way for use. Some are made by electrical arc processes, using condensed particles of metal or other material. Regardless of the process by which they are made, they are said to be *granular*. By reason of this construction they are subject to severe changes in structure due to temperature expansion, concentration of current into too small an area, and decomposition, due to arcing and its resultant chemical or physical action.

Sometimes after considerable use some of these resistors may open somewhere in their composition or may separate in such a way as to provide much more resistance than was intended for the unit. This is not to be taken to mean that the workmanship is inferior on these units or that it is an improper way to make such units. The best processes known to produce the units are used consistently within reasonable cost, bulk, and weight. Almost perfectly durable resistors can be made but they would require many times the space of the receiver alone; they would weigh with the receiver several hundred pounds and would make the receiver cost several thousand dollars.

Referring to the wire wound resistor as used in modern receivers, there is another class of difficulties. If left partially exposed—that is, by a non-moisture proof covering, they are subject to corrosion, while, if baked in any of the cement or ceramic materials, they are subject to breakage by expansion or mechanically at the terminals. The technique of making these resistors has also advanced to the point where failure is less frequent. but the operating loads of these resistors are very much greater than those of the other types. Moreover, they cannot be made in very high resistance values economically.

Now consider typical uses of resistors and how a change in value or an open or a short will affect the circuit in which it is used. It is well to remember that a resistor with an internal short is a very rare defect while opens or increases in value are common.

In Fig. 4 is shown a circuit in which the details not needed for the resistance study have been omitted. Connections and values of the resistors, however, are shown.

Starting with R1, note it is an AVC filter resistor. Its value (100, 000 ohms) together with C1 determines the filter action of part of the AVC circuit. Since the grid circuit resonant current of the 6K7 RF tube flows through C1, the resistor R1 must be very high as compared to the reactance of C1. On the other hand, R1 cannot be too large because of the possibility of grid blocking of the RF tube. While it may increase in value up to 300,000 or 400,000 ohms without affecting the operation of the receiver, it may not reduce more than 20% without partially detuning the RF circuit. However, if it does increase to a high value as mentioned, the fact that it is subject to change of this kind, is sufficient to justify its replacement. At some later time, it may completely open. If it has reduced more than 20% in value—that

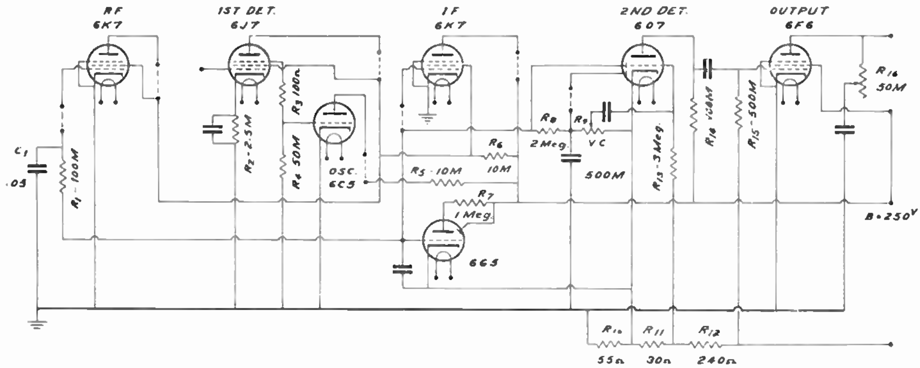


FIG. 4

is, below 80,000 ohms, it should be replaced.

It may be at first tested without detaching either end because when the receiver is turned off, its RF grid end is essentially open. But if it reads open on your ohmmeter, it must be replaced. Note that if it reads open, you know that the resistor is at fault, while if it is shorted, *some other circuit can be at fault*. Thus, if it tests below the required value considering 10% change, it must be detached at one end and tested separately.

Resistance R2 (2,500 ohms) in Fig. 4 in the first detector cathode will probably be a carbon or metalized unit. Because of the circuit in which it is placed the current through this resistor will be essentially constant. Therefore, its voltage will vary as its resistance. Thus a 10% change in voltage can be allowed and hence a 10% resistance change can also be allowed. Here again if open, it is the fault of the resistor, while if apparently shorted, it is more likely to be the fault of the condenser across it which will be found to be shorted internally.

The oscillator grid leak R4 (50,000 ohms) in Fig. 4 determines the value of the automatic bias of the oscillator just as the volume control R9 determines the bias voltage of the diode with a given signal. R4 also determines the power output and grid voltage *swing* of the oscillator and to some extent, its stability of operation. It should be within 10% of 50,000 ohms for the operation required of the oscillator.

In general, values of resistances in receivers are not critical or precise values. It will usually take more than a 10% change in resistance value of any resistance in the circuit to cause a noticeable change in the character of operation of the receiver. Some of them may change even more without change in operation, but this is not the important consideration. If any resistor changes more than 20 or 30% in value, it is not likely to stay at this value and should be replaced.

The plate resistor R14 (100,000 ohms) of the 6Q7 tube in Fig. 4 is an example of this principle. It has a normal value of 100,000 ohms. This resistance may increase up to as much as 250,000 ohms with perhaps no change in operation of the circuit but with a little increase in amplification. But if this happens the resistor should be replaced because it is obviously unstable in resistance value. While replacement could be made with a 150,000 ohm resistor or a 250,000 resistor, it is not advised, as the gain might cause overload of the grid of the following stage on strong signals.

Due to either AC or DC impressed on a resistor it may change its resistance very abruptly or very frequently. If such a resistor is used in a plate circuit such as R14 in Fig. 4, the abrupt changes in voltage across it due to its change of conductivity will cause a frying or crackling noise to be reproduced. Usually the stage in which this defect arises is easily located by a *signal tracing* test in which the signal is picked up at various points in the circuit and separately reproduced or tested (a later lesson treats this subject).

The very circuits in which the defects arise afford excellent means of testing for noise under operating conditions. Unfortunately, it is not possible to distinguish between two or more resistors associated with one tube or stage or to be sure that the fault is due to the resistor or to a condenser, tube or other part. In this event, an individual test should be made on each resistor associated in any way with the defective stage. In such a test the resistance should be required to carry more DC than it would normally and a method must be provided to detect any rapid resistance changes.

The circuit of Fig. 5 has been designed for this purpose. This test circuit is applicable to resistors of rather high values (above 50,000 ohms). As long as the current flow through the circuit containing the resistor under test and a transformer secondary or other choke coil is constant the voltage across Rx will be constant, and there will be no sound in the headphone except a smooth hum. If the resistance Rx suddenly increases the voltage will likewise increase and a voltage impulse will be transmitted through the condenser to the phones or to an amplifier if one is used.

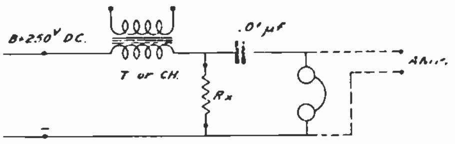


FIG. 5

With the connections in Fig. 5, the resistor will carry much more DC than in any plate or grid circuit of the usual type, and if the resistor is found to be quiet with this test it can be relied upon to be in good condition. The DC voltage to operate the circuit of Fig. 5 may be taken from the receiver on which you are working. It may range from 100 to 300 volts, the value of 250 volts being the average voltage to be found for AC receivers.

Practically any AF transformer may be used for Fig. 5 with the primary open as indicated or a filter choke or speaker field may be used as the inductance. It must not, however, be by-passed with a condenser at the resistance test end. The current should be allowed to flow for a few minutes so that the resistor will have time to heat at least to operating temperature.

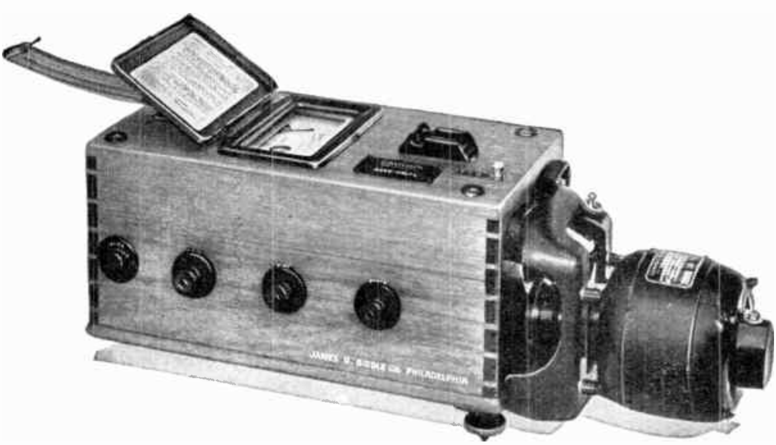
The substitution method of resistance testing in many cases will prove advantageous. Many times the faulty unit is so deteriorated that the color code or other means of identification of its resistance value have been destroyed and unless a manufacturers circuit diagram, with the resistance value indicated, is available, it is rather difficult to determine the exact resistance value to use. When such a condition is encountered a substitution method of testing can be used. It is important, however, that the power rating of the substituted resistor be high enough to dissipate the heat developed by the current in the circuit.

The power rating can be determined with fair accuracy from observing the circuit to which the resistor is connected, and by the current drawn through the circuit as measured by a milliammeter.

Always allow considerable over rating for this approximation—at least twice the approximate power rating for the replacement resistor. There is on the market specially made resistor units for making resistor substitutions. The unit is a variable resistor housed in a convenient case. There is a calibrated scale with a pointer to indicate the resistance value of the resistor over the range of resistance of the unit. These units are available and can be purchased from your radio parts jobber. To use this calibrated variable resistor, just clip the two clip leads which are supplied with the unit to the two terminals where the replacement is needed and adjust the movable element of the variable resistor until the receiver operates normally. When this has been done, note the value indicated on the resistance scale. The replacement resistor should be a value nearest the one indicated and with a power rating large enough for the installation.

When making a resistor replacement, care should be exercised when unsoldering and resoldering the units in the circuit. Resistors of the composition type can be permanently damaged by the heat from the soldering iron. To avoid unnecessary heating, always have the parts that are to be soldered clean and your iron well tinned before attempting to solder. Apply the iron to the joint just long enough to cause the solder of the joint to run freely but not long enough to heat up the entire resistor unit. If you have taken these precautions, the joint will be firm and a good contact made without over heating the resistor unit or the unit to which the resistor is to be connected.

The fixed composition type resistors employed in home and in automobile receivers have been standardized by RMA. The majority of receivers make use of these standard values. Because of this standardization



This photo shows a special type of resistance tester. The power source to operate the meter is obtained from a motor driven generator. This type of instrument is called a "Megger" and will measure resistance values up to 10,000 megohms. Courtesy of the James G. Biddle Co.

and due to the fact that the greater percentage of the standard type resistors fall within the tolerance values of ± 5%, ± 10%, and ± 20%, a smaller number of resistors are required for a complete stock of resistance values. The accompanying table lists resistors within these three tolerance groups and are the preferred resistance values as standardized by RMA. These are the values commonly stocked by radio parts jobbers as they will, in most cases, satisfy the needs of the majority of servicemen.

This table is made up in multiples of 10 ranging from 10 ohms to 10 megohms. The numbers listed can be multiplied by any multiple of 10 up to the value of 10 megohms. The columns marked ± 5%, ± 10%, and ± 20% indicate with what tolerance these resistors can be secured. Resistor units of 10 ohms, 100 ohms, 1000 ohms, 10,000 ohms etc., up to 10 megohms can be secured with any of these three tolerance values. Resistor units of 11, 110, 1,100, 11,000, and 110,000 ohms are available in the

RMA Preferred Resistance (Ohms)	Available In These Three Tolerance Groups		
	±5% (Gold Band)	±10% (Silver Band)	±20% (No Color)
10	*	*	*
11	*		
12	*	*	
13	*		
15	*	*	*
16	*		
18	*	*	
20	*		
22	*	*	*
24	*		
27	*	*	
30	*		
33	*	*	*
36	*		
39	*	*	
43	*		
47	*	*	*
51	*		
56	*	*	
62	*		
68	*	*	*
75	*		
82	*	*	
91	*		

NOTE the asterisks (*) indicates the tolerance value available.

± 5% tolerance only. The table indicates the tolerance and resistance value of the complete preferred list.

The resistance values indicated by the table are the most common resistance values used in all standard receivers. Thus, in securing a stock of resistors for your shop, this chart should prove useful in making the proper selection of resistor values most often used.

When replacing a resistor in a receiver, it is possible to use a lower percent tolerance for the replacement but never use a higher percent. However, the lower tolerance resistors are more expensive because they are more difficult to make accurately. So unless it is expedient that you substitute a lower tolerance value, always use the value indicated by the faulty resistor that is being replaced.

Correct Use of Ohmmeter

The points to remember in connection with the use of the ohmmeter are few, but they are important.

In testing a resistor across which, is placed an electrolytic condenser, always connect the polarity of the ohmmeter test leads with regard to the condenser polarity. The positive ohmmeter terminal connects to the positive condenser terminal. The polarity of the ohmmeter leads is ordinarily the same as for voltage or current measurements made from the same tip jacks of the multimeter and are usually clearly identified. Otherwise, the polarity of the ohmmeter terminals can easily be identified as in Fig. 6. The ohmmeter terminals for the series type ohmmeter are connected across a 1.5 volt dry cell. If the ohmmeter reads less than maximum scale value, zero or tends to read reverse scale, then the ohmmeter terminals have the same polarity as the cell—that is, they will supply a voltage across a

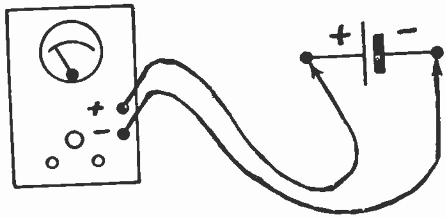


FIG. 6

resistor in place of the cell at the indicated polarity. On the other hand, if the meter tends to read greater than maximum scale current, the polarity of the ohmmeter is the reverse of that shown in Fig. 6.

When measuring resistance of 50,000 to 100,000 ohms and above, be sure that your fingers are not in contact with both test lead points or with both resistor terminals. If your fingers touch these points, the resistance of your body will shunt that of the resistance to be measured and for very high value resistors, a very large error will be introduced. The resistance from one hand to the other quite often runs as low as 100,000 ohms or 75,000 ohms, or even less if the fingers are moist.

There should be no voltage present anywhere in the circuit in which a resistor is being measured, because of the possibility of causing an error in measurement. In most receivers that are power line operated, it is only necessary to switch off the power, but for a battery operated receiver, it will often be necessary to completely detach the batteries because usually the plate circuit is only broken by reason of the filaments being cold or not lighted. The grid and screen grid circuits likewise are not necessarily broken in a battery operated receiver when it is turned off.

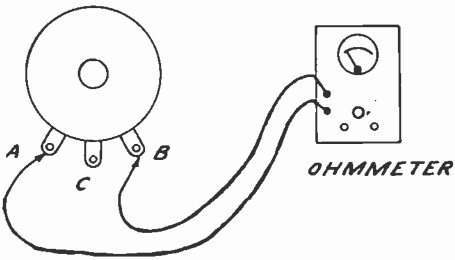


FIG. 7

In testing a potentiometer, one test lead should be placed on the center terminal and one on either end terminal. The potentiometer setting is then varied through its maximum range while the ohmmeter deflections are observed. As the potentiometer is varied from one end of its range to the other, the ohmmeter needle should start at some minimum or maximum resistance value and progress continuously toward the other. While the knob is turned smoothly or evenly, the ohmmeter indicator should move accordingly. The needle of the ohmmeter will move much more rapidly at the beginning or end of its range depending on the taper of the unit, but if the needle reverses even by the slightest amount, there is proof that the actual resistance of the unit has been altered and it must be replaced.

An additional test which will act as a good cross reference to the aforementioned test is a test between the two outer terminals while the unit is being varied. See Fig. 7. If in any of these tests, there is an abrupt change in resistance, an open, or zero reading, at any point within the range (not at either end) the unit is defective. Some units of this type have their end connections shorted to the end position of the moving terminal and this, of course, must be taken into account.

Connection of the resistance element to the shaft or mounting should be observed, and this should be judged with reference to the circuit in question. While the majority of potentiometers have no electrical connections to their shafts, some of them depend on this connection for their center tap or ground.

Heat and Power of Resistors

It appears that less is actually known about the heat and power of a resistor than any other phase of the subject. There is a good reason for this. The study involves other branches of basic physics and measurements which have obscure meanings even with the best apparatus available. The study of heat is made difficult because it has a much more vast field of operation than equivalent studies such as magnetism.

The purpose of considering the matter of heat and its relation to resistance here is to enable you to measure or estimate the probable rating or power handling ability of a resistor unit.

First consider a few simple and basic facts about heat so that you may have a reasonable working knowledge of it.

In the first place, a given power being used or dissipated will always produce the same quantity of heat no matter if the current is flowing through copper, carbon, nichrome, carborundum or anything else. In other words, 5 watts measured electrically will always produce a certain definite amount of heat which often is referred to as watts of heat because of the exact proportionality between the electrical value in watts and the heat.

Unlike power, heat can accumulate or *build up* in a material just as voltage can accumulate across a condenser. Now the only way that heat can escape from a resistor or in fact from any unit in a receiver is from its surface. It cannot vanish from within it if the unit has a higher internal temperature than the surrounding air. Heat actually passes or flows from a point at a higher temperature to a point having a lower temperature.

Like electrical current its flow will be governed by the resistance to its passage. Now, if you are able, for example, to continuously increase a voltage, it may ultimately be made to arc across practically any gap or condenser that can be made. This is what continuous power does to the *heat value* —it produces it steadily, and if it cannot be used or conducted away it will build up indefinitely.

Now as power is continual, heat is produced and as the temperature rises, the surrounding air begins to absorb heat and carry it away. Naturally, the higher the temperature, the more rapidly the air will carry heat away. Finally a point is reached where the heat is carried away *at the same rate as it is produced.*

When this takes place, the resistor *remains* at *a constant temperature.* Now heat can be absorbed by the outside air only where it is on or near the surface of the resistor. Remember that as much heat can be carried away (dissipated) with twice the amount of air at only one-half the temperature increase, or five times the air at one-fifth the temperature increase. It should be obvious that the heat radiation of a resistor thus depends on its *surface area* for one thing.

The same results could be achieved by either contacting the resistor with ten times as much air (with a fan) or by increasing its surface ten times. This gives two hints about resistors, namely, that they must be in a relatively free air space where air may circulate and thus carry the heat away. Thus they must have a reasonably large surface area so that they may operate at low temperature.

There is an additional item for resistors which is important. Naturally, the heat must be conducted to the surface of a resistor before it can be carried away by the surrounding air. If the construction of the resistor is such that the flow of heat from the inside to the surface is made difficult, its heat on the inside will increase its inside temperature. On the other hand. if its heat conductivity is good, there will be little difference between its internal and external temperatures. Comparatively, where there is a given current and the resistance is small, there will be a small voltage difference across the resistor. The same general idea is applicable to heat. Where there is little resistance to the flow of heat. the temperature will be low.

In general, carbon and carbon composition resistors including metalized and insulated types have poorer heat conductivity than wire wound and vitreous enameled types. Both the wire and the enamel types have good heat conductivity. and as soon as the temperature rises internally it heats the entire unit, both internal and external. Thus, the power in heat generated can be carried away rapidly. Such resistors may operate at considerably higher temperatures because they are nearly the same temperature internally as on the surface.

On the other hand, the composition type resistors are not made of solid compact material and their construction produces some heat insulating qualities, making it difficult for heat to *flow* from within the unit to its surface. In this event, the temperature inside the unit may rise to five times as much as that at the surface. To be assured that the internal temperature is not too great, it is necessary to be sure that the surface temperature is not excessive.

Some of the details having to do with heat have been included here to assist you in the judgment of the power rating of resistance units. It has been found, for example, that for carbon and composition resistors, such as are used for grid and plate resistors, screen resistors, AVC filter resistors, etc., a safe figure would be two square inches of surface area per watt rating. Thus a resistor one inch long and as large in diameter as a pencil approximately, could easily handle 1/2 watt or more of power. Accordingly, a resistor of this construction only 3/8 inch long and 1/8 inch in diameter would have a safe rating of .07 watt or even 1/10 watt.

For a wire wound resistor, the rating can be 2 or 3 watts per square inch. This can be in the form of a volume control or a flat insulating strip wound with wire. Resistors of this type are used for voltage dividers, series plate or screen supply units in common B+ circuits, bias resistors, etc. They are intended to operate at high temperature.

Remember that the power rating of a resistor is entirely a matter of its physical size and the material of which it is made. These things have nothing to do with the actual resistance value. Regardless of its resistance value whether it be 1 ohm or 10 megohms, if it is rated at 1 watt, the resistor must be of a given minimum size as explained.

Two resistors in series will have twice the power dissipating ability of either one of them if they are the same size. To get 500 ohms for example at 4 watts, you may use four identical 500 ohm, one watt resistors in series-parallel.

The watt capacity is increased in direct relation to the surface area of a resistor. Two similar resistors *either in series or in parallel* will double the power rating, although their effective resistance values will depend, of course, on how they are connected.

The surface of ordinary carbon or composition resistors should, of course, not become hot enough to burn or discolor the paint by which the resistance is identified. When this happens the resistor has been overloaded or has been forced to dissipate more heat than for which it was rated.

The materials used with wire wound resistors can withstand much higher temperatures, as they are unpainted and are made with hard heat resisting materials.

Absolutely all of the power handled by resistors in radio receivers is wasted in heat. It is not the purpose of resistors simply to waste power in this way, but rather it is a by-product of their use. Their purpose is to divide, apportion, filter and regulate voltage and currents in receivers and amplifiers and no use can be made of the power they waste. All of the electrical power which resistors waste is in the form of heat and it is always exactly related to their electrical specifications. For example, if a voltage divider section carries 20 milliamperes at 150 volts, it must radiate $150 \times .02$ or 3 watts continuously. The instant this voltage is impressed on it, and it carries .02 amperes, it starts to produce heat at the rate of 3 watts.

At 150 volts and .02 ampere, of course, the resistance must be 150/.02 or 7500 ohms. Having these *three values, resistance, voltage* and *current,* you have *three* ways of finding the power rating, as any two may be used to find this value.

The power in watts is equal to the product of the current and voltage or $P = EI$ for the first case. Thus 150

	Value	Voltage and How Obtained	Voltage Squared	Power	Use
R1	100,000	50V* DC Maximum AVC for the 6K7 tube.	2,500	.025W	.3W
R2	2,500	3V DC Bias voltage for the 6J7 tube.	9	.0036W	.3W
R3	100	Negligible.			.3W
R4	50,000	15V AC Approx. RMS grid voltage of oscillator 6C5.	225	.0045W	.3W
R5	10,000	100V DC Approx. voltage drop to oscillator plate.	10,000	1.W	1.5-2W
R6	10.000	140V DC Voltage drop to screen grids at 110V 250 − 110 = 140.	19,000	1.96W	2-3W
R7	1,000,000	240V DC Voltage drop to plate at zero grid of 6G5 (approx.).	57,800	.0578W	.3W
R8	2,000,000	50V* DC Maximum AVC developed.	2,500	.00125W	.3W
R9	500,000	50V* DC Maximum AVC developed.	2,500	.005W	.3W
R10	55	3V DC Minimum bias to 6K7 tube.	9	.164	.3W
R11	30	1.5V DC Bias used at 6Q7 grid.	2.25	.075W	.3W
R12	240	12V DC 6F6 bias (16.5V) minus the voltage drop of R10 and R11 16.5 − 3 − 1.5 = 12V.	144	.6W	1W
R13	3.000,000	1.06V AC RMS of 6Q7 grid signal or .707 × 1.5 = 1.06V.	Negligible		.3W
R14	100,000	150V DC Voltage drop to 6Q7 plate from + 250V to 100 volts.	22,500	.225W	.3-.5
R15	500,000	11.6V AC RMS signal to 6F6 grid 16.5 × .707 = 11.6V.	135	.000272W	.3W
R16	50,000	$E = \sqrt{WR} = \sqrt{3 \times 7{,}000}$ $E = \sqrt{21{,}000} = 145V$†	21,000	.42W	.5-1W

*These voltages are, of course, only developed instantaneously and are not constantly applied. When the receiver dial is set to no signals the voltage marked (*) vanish. The resistors, however, must be rated on the basis of the maximum power handled at any one instant.

†RMS output signal voltage obtained from 3 watts maximum power output of 6F6, 7,000 ohms recommended load.

$\times .02 = 3$ watts. The power is also equal to the *square* of the current in amperes multiplied by the resistance or $P = I^2R$. For this example, $(.02)^2 \times 7500$ or. $0004 \times 7500 = 3$ watts. In this third example, the power is also equal to the square of the voltage divided by the resistance or E^2/R. For this case, $(150)^2/7500$ or 22, 500/7500, which is also equal to 3 watts. This latter means of finding the power rating is most convenient because the voltage drop across the unit and the resistance value is most usually known.

On this basis, consider the actual power rating of the resistors in Fig. 4. In the table on page 19, is listed the resistor identifications for each unit in Fig. 4, the resistance value in ohms, the voltage impressed across it, and how this voltage is determined. Following this, is the square of these voltages, the actual maximum power which the resistor will normally dissipate and the power rating which should be used in view of the fact that resistors are made only in a few standard rated power values, and that some degree of *over-rating* should be used as a safety factor.

Resistors such as R14 in Fig. 4 have not only a DC voltage drop, but also an AC or signal voltage drop. In addition to a safety factor, the resistors must be over-rated for this reason as well. Many of these values are approximate and are too large but allow for a good margin of safety. Note that in most cases the actual power to be dissipated is far below the lowest rated resistor made for practical use which is .3 watt.

For variable resistors such as volume and tone controls the power rating is often not considered as being important. The power rating of such a unit is equally important as that of any other type of resistor. The power rating, of course, depends upon the position of the control in the circuit and where there is considerable current flowing through the unit, it must be large enough to dissipate the heat produced. Heat is generated by both AC and DC currents. When a DC blocking condenser is used in series with a variable control—it doesn't mean that there is no current flowing through the control.

When a variable tone control is used in the plate circuit of an audio amplifier, there is considerable current flowing through the control and unless it is of the correct power rating, it will soon be destroyed. Where a volume control is used as the diode load in an AVC circuit, DC current is flowing through the resistor, whenever there is a signal fed to the detector and the unit must be of the proper rating to dissipate the heat thus generated.

The power rating of these variable resistors as given by the manufacturer *is the rating of the entire unit* and not at any position of the variable element of the control. Thus, as the resistance value is decreased, the power rating is also decreased because of the decrease in surface area of the unit. This must be taken into consideration when controls are being replaced with substitute units and not the exact replacement control.

Testing Potentiometers and Variable Resistors

In a potentiometer there are three things to be noted while making a test: (1) The total resistance value of the unit; (2) the manner of resistance change while moving the shaft and (3) the rate of change of resistance while moving the shaft.

Taking these in order, first the total resistance is measured at the outer two of the three terminals in a cluster.

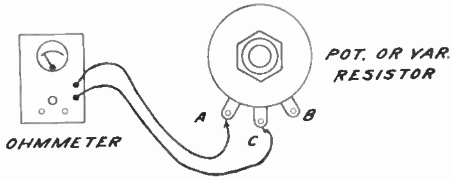


FIG. 8

(There may or may not be an additional terminal at some other point on the control as in Fig. 11). This should be the total rated value of the control. Moreover, it should remain this value as the shaft is turned to any point.

The second thing to be noted is the manner in which the resistance changes when the shaft is turned. For this test the ohmmeter is connected between the center terminal and *either* outside terminal. In Fig. 8 is shown a potentiometer in which this test is made from A to C or from the terminal shown while facing the potentiometer shaft, all the way over to the counter-clockwise position. Slowly rotate the shaft clockwise while the ohmmeter is being observed. If the ohmmeter needle continues to move in the same direction (up scale) for the ohm readings while the shaft is turned, the potentiometer is in good order. If the needle stops or reverses its direction in any part of the test, the potentiometer is defective.

The third test is to determine the type of taper used by the control. This is easily done if the control is not open at some intermediate point. Turn the shaft so that the variable element is in the center of the resistance unit. Now measure the resistance from the center terminal to first the left hand terminal and then measure the resistance from the center to the right hand terminal. (The left and right terminals are referred to when looking at the control toward the control shaft as indicated in Fig. 9). When the resistance from the center to the left terminal is larger than the resistance from the center to the right terminal, the control has a right hand taper. If the resistance is greater from the center to the right hand terminal, it has a left hand taper. When the resistance between the center and the two terminals is the same, there is no taper and the control is said to be a linear taper control.

It may not be clear to the student just why a tapered control is used. The reason such controls are used is due to the characteristics of the human ear. The ear is so constructed that it follows a logrithmic pattern with respect to sound intensity. This means that if you reduce the volume of your receiver so that it appears to be half as loud to your ears, you must reduce the sound intensity of the receiver as measured by a meter 1/10th of the original sound level instead of 1/2. Thus, if a linear volume control is used, the control shaft must be turned down to 90% of its rotation, leaving but 10% of rotation for further adjustment. This, as you can see, would make a control critical to adjust at low volume. On the other hand, if a tapered control is used and the taper is so constructed that when the volume control is reduced from full volume to half volume as indicated by your ear, in one half the rotation of the control a much smoother and less critical control of the volume is ob-

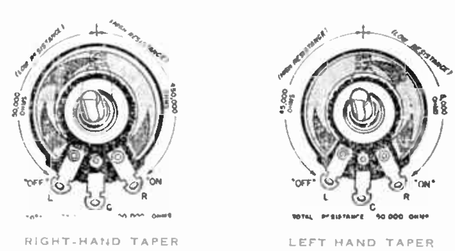


FIG. 9

tained. To do this the resistance of the control must be reduced to 1/10th of its original value in one half of its rotation, and that is what happens in a tapered control as indicated by Fig. 9.

It sometimes happens that a volume control becomes open at some point along the resistance element and if this happens it is impossible to determine the taper by the preceding methods. However, in many cases unless the control is entirely worn out, you can secure enough information to determine the taper by making a few special tests upon the control. With an ohmmeter connected to the center terminal and either side terminal, rotate the movable element until the open is found. Now turn the shaft until you are right at the closest edge of the break, but still making contact, measure and record the exact resistance from this point to the terminal.

Now move the shaft until there is continuity between the rotating element and the other terminal. Record this resistance. Now place the rotating element at the mid point of the control and measure the resistance between the center terminal and the terminal which indicates continuity and again record the results. From the three resistance readings you can determine the taper of the control by a little subtraction and addition. Assume the break is as indicated in Fig. 10. From R to the break there is 20,000 ohms; from L to the break 29,000 ohms; and from the center to L, 5,000 ohms. It is apparent from this that the control has a left hand taper and is no doubt a 50,000 ohm control with 1000 ohms lost in the break. If there is more than one break, and the breaks are not too close to the end terminal, many times the taper can be determined even though the actual resistance of the unit cannot. This is done by noting the resistance per degree of rotation at each end of the control as measured between the center terminal and each side terminal when the shaft is rotated the same number of degrees from the end point of the control on each side. If the resistance of the left terminal to the center is smaller than the resistance from the right terminal to the center terminal for the same degree of rotation, the control has a left hand taper. If the resistance is greater on the left than the right, it has a right hand taper and if they are approximately the same, it is a linear control.

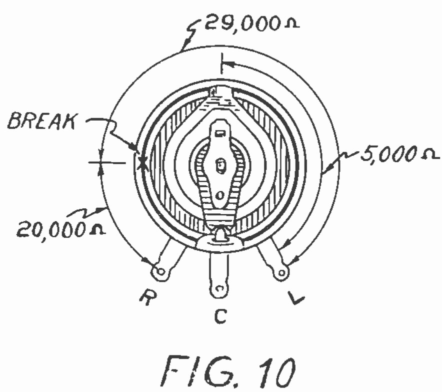
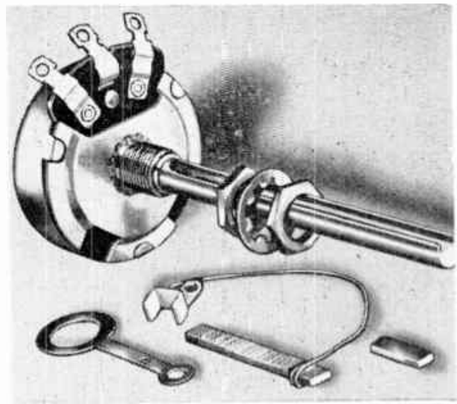


FIG. 10

The volume control of a receiver is one of the most important controls of the receiver and if it is not operating properly, the operation of the entire receiver is impaired. Therefore, it is important when replacing such a unit to replace it with an exact replacement part and also to see that the unit is wired in the receiver properly. If the leads of the control are reversed, the control will not function in the manner for which it was designed, and unsatisfactory control of the volume will be the result. This can also be said of a tone control. The tone control is much more important to the present day receiver due to the improved design of the audio amplifier and speaker system. Most radio listeners of today adjust the tone control almost as often as the volume control. Some like the deep bass. Thus they adjust the tone control to cut out the high frequencies and amplify the bass—while others may like the treble, etc.

During World War II, there was a scarcity of radio parts. Thus, the serviceman of today must be on the constant lookout for substituted parts that are not exact replacements. This is doubly true of tone and volume controls. Thus, it becomes important to know what type of control should be used in the circuit so that when a replacement of one of the substituted parts is necessary an exact replacement or a correct substitution can be had. The manufacturers of radio parts today are always back of the servicemen. They publish different servicemen's guides offering assistance in choosing the correct replacement part for any service job. The manufacturers of variable resistors publish volume and tone control guides and they are available to the serviceman at a very low price. These guides contain information concerning the volume and tone controls of all the standard makes and models of receivers. It is suggested that the student purchase one of these guides. The information which may be needed for a tone control or volume control can usually be secured from these control guides.

There are a few odd type receivers which are not listed in a control guide or in a service manual, or one may come across a receiver where the make and model number is not given. With receivers of this type the serviceman must rely upon the value of the parts in the receiver as they exist or upon his ability to determine the correct value if the value of the part is not given. As has been mentioned, the resistance value of most of the resistors in a receiver can vary as much as ± 20% without causing appreciable change in the receiver characteristics; for this reason where the exact value of a resistor isn't known, its value can usually be determined within the ± 20% tolerance by means of substitution and measurement.



Above is shown a common type of volume control. There is also included a minimum bias fixed resistor which can be connected in series with the control should it be needed. Note the extra long shaft which can be cut to the desired length for a given receiver. Courtesy of the Mallory Co.

This is also true of volume and tone controls. However, there is one more important consideration in choosing a proper control besides its actual overall resistance and that is the type of *taper* the control should have for this installation. Figures 11 and 12 show graphs of how the resistance of the four most common types of controls vary as the resistor is rotated from zero to extreme rotation. An examination of these four controls, listing the recommendations for their use, will prove instructive in showing the general type of resistance variation characteristics required for each different type of control circuit.

Figure 11 shows the carbon type control characteristics and Fig. 12

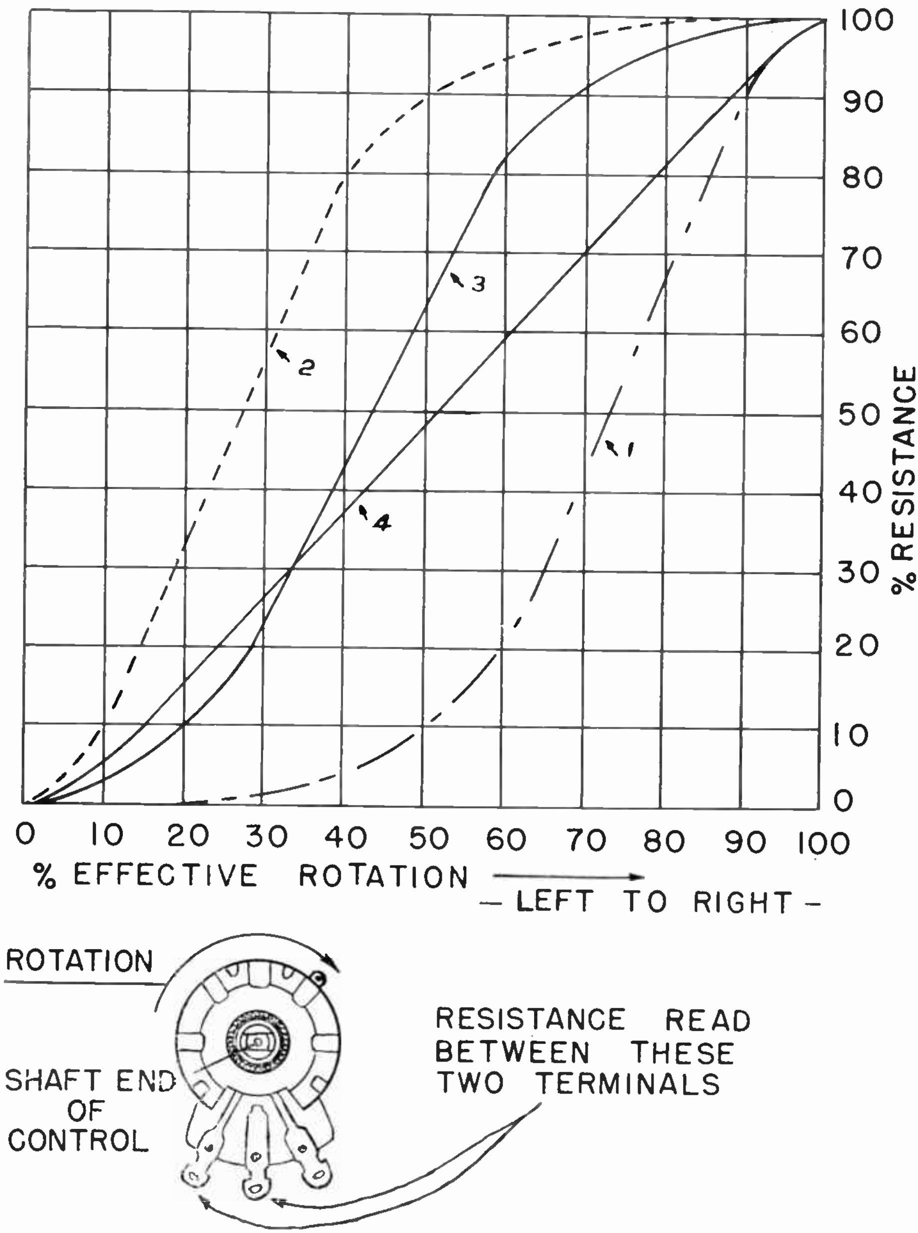

100
90
80
70
60
50
40
30
20
10
0
% RESISTANCE
0
10
20
30
40
50
60
70
80
90
100
% EFFECTIVE ROTATION
— LEFT TO RIGHT —
1
2
3
4
ROTATION
SHAFT END OF CONTROL
RESISTANCE READ BETWEEN THESE TWO TERMINALS

FIG. 11

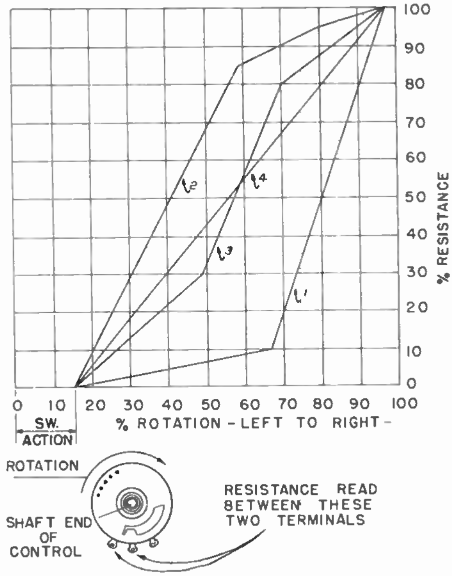


FIG. 12

shows the equivalent types in the wire wound type control as manufactured by Mallory.

The taper number 1 of Fig. 11 is a modified logarithmic left hand taper of the carbon type. Taper number 1 of Fig. 12 shows an approximation of this logarithmic control in the wire wound type. This type of tapered control should always be used in shunt circuits as in the usual antenna and audio circuits, or where only the center and left hand terminals are used. Figure 13 shows one type of circuit for which such a control is used.

Taper number 2 in Fig. 11 shows a right hand logarithmic taper in the carbon and its approximation in the wire wound type is shown in Fig. 12. This type taper is used in a series circuit, as in a cathode voltage control, or where only the center and right hand terminals are used. It is also useful in tone controls where it is desirable to have the bass position at the right hand position of the knob.

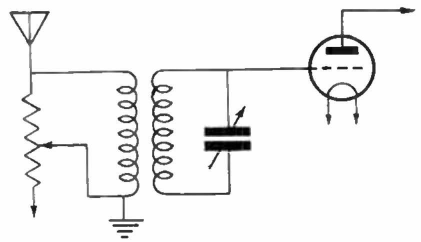


FIG. 13

Figure 14 shows a circuit where this type of taper is used.

Taper number 3 is a combination left and right hand taper. This type of taper has a limited use and is used in circuits where the control must perform both as a shunt and series circuit control as in a combination antenna shunt plus bias circuit. Figure 15 shows a circuit where this type of circuit is commonly used.

Taper number 4 shows a linear taper. Strictly speaking, this type control has no taper although commonly referred to as such. A linear taper is used wherever a control should be such that the voltage is proportional to the degree of rotation of the control shaft. The circuit of Fig. 16 illus-

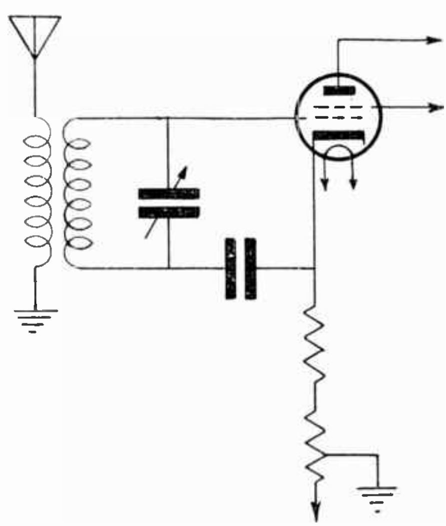


FIG. 14

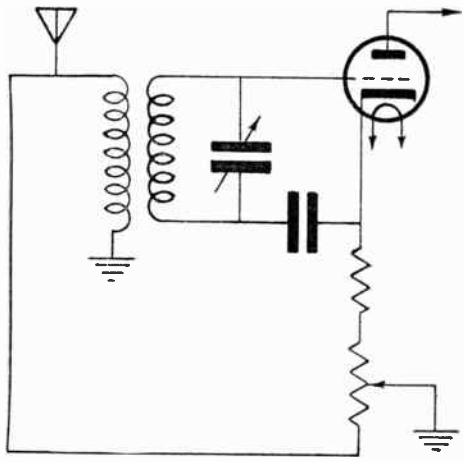


FIG. 15

trates a use where a linear taper might be employed.

As seen from the curves of Fig. 12 wire wound resistors are only approximations of the true taper as achieved with the composition type controls. This is due to the winding complications involved and the cost limitations.

These complicated taper designs are on the other hand comparatively easy to form with the carbon composition elements. Thus, their cost is much lower than a wire wound control of the same type.

Repairing Noisy and Erratic Controls

It is, of course, better to replace a faulty control rather than trying to repair it. However, it sometimes becomes advisable to attempt to make repairs. It is possible in most instances to secure any type of control made, but time is usually involved as well as cost in securing the rare types. Thus, it may prove more profitable to repair such units if it is possible.

The first thing to do in attempting a repair is to remove the faulty control from the receiver chassis. The procedure for doing so varies with the type of installation. When removing the wires from the control, make sure you label them plainly so that there will be no mix-up in rewiring after the control is repaired.

The most common defect encountered with volume and tone controls is noisy and erratic operation. Many times, however, they may become open at some point. Open controls may be traced to a loose contact or warped element, a bent moving arm, and with wire wound resistors, broken wires. The loose contact may be caused by a loose terminal, a loose rotating arm or a loose element. Repairing the loose terminal usually involves nothing more than tightening the supporting rivets or in some cases reriveting. A loose arm may require a riveting job or a screw adjustment and in some cases a slight bending of the metal tension spring. When an element becomes loose it is necessary to cement it back in place with some type of non-conducting non-corrosive cement such as airplane dope.

These loose connections usually cause the control to operate erratically causing considerable amount of noise

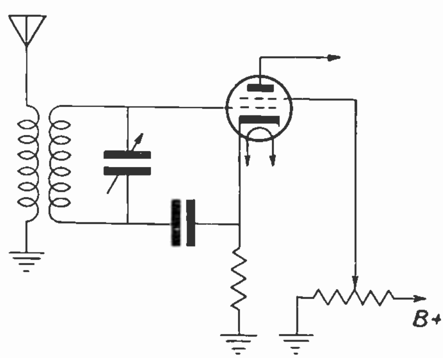
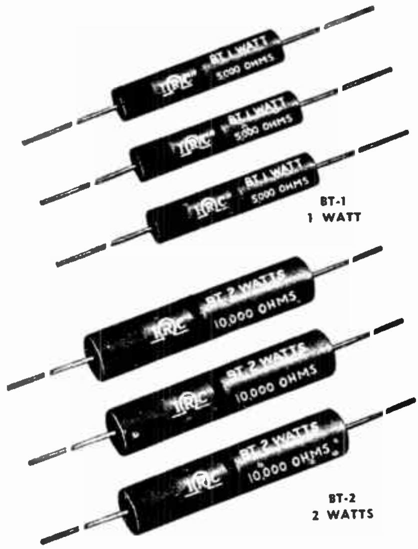
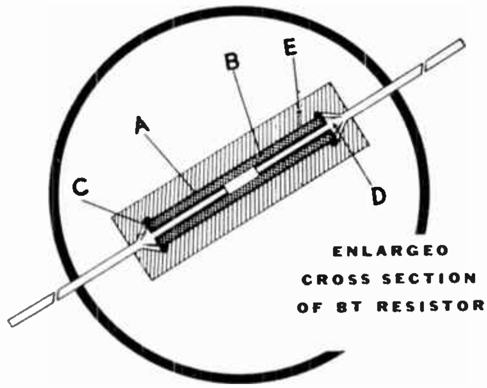


FIG. 16





A Conducting coating of measured resistance value.
B Glass tube.
C Positive contact, low-resistance compound between conducting coating and metal leads, permanently bonded to both.
D Special alloy wire terminal.
E Molded insulating sheath of non-hygroscopic phenolic.

This view shows several types of IRC resistors. These are the popular 1 and 2 watt sizes. The enlarged view to the right shows the construction details of this moulded type of resistor.

to be developed which will usually change in intensity and tone as the control is rotated.

If a resistance element is warped badly, the unit will have to be replaced. However, in many cases a partial repair can be made of the control. It may be possible by making a slight bend in the moving arm to allow the arm to make contact with the resistance element for the complete rotation; or it may be possible to adjust the position of the resistance element so that the moving arm can make contact throughout the rotation of the element by placing wood shims at different points, forcing the element to bend at the point where the moving arm doesn't make contact with it.

A bent moving arm must be straightened. To do this satisfactorily, the unit will more than likely have to be disassembled and the bending done with the aid of a pair of long nose pliers. Be careful that you do not break the arm by bending it too much. Where an open occurs in a *wire wound resistor* due to a broken wire, it can often be repaired by making a small metal wedge which can be forced down on either side of the broken element such that the break will be bridged and continuity restored. Care must be exercised in making this repair, lest you cut more of the wire turns.

Where an open occurs in a composition control, it can often be repaired with the aid of a special conductive liquid which is placed directly upon the element at the point where the element is worn.

A conductive liquid of this type which can be used to repair open controls is called Carbon X and can be obtained from your parts jobber.

Noisy controls many times are caused by dirty contact between the resistance element and the moving arm and can be cured quite readily by giving the unit a good cleaning. The unit should be removed from the chassis and the back cover plate or switch, if one is used, should be removed allowing access to the resistance element and moving arm. Then with a good grease solvent such as carbon tetrachloride (Corbona) or white gasoline clean the contacting surfaces of all foreign material and grease. After the element and the moving arm are clean, it is advisable to place a thin coat of some type of contact lubricant upon the element to afford a smooth operating control. This will also extend the life of the control, making it easier to rotate. There are several good lubricants such as white (uncarbolated) vaseline, Russian mineral oil, Lube Rex and one that is often preferred which acts as a cleanser as well as a lubricant is Grafoline. There are some manufacturers that put out in kit form a complete kit of lubricants and solvents for repairing controls. These kits are often very handy in the service shop. Your parts jobber will know about these.

Never use oil or graphite grease on a tone or volume control. The oil will not stay on the element and the graphite grease contains a conductive substance which will change the resistance value of the control.

If a potentiometer is suspected of noise which the tests mentioned do not show, the next thing to do is to place it in a circuit such as Fig. 5, but with the .01 mfd. condenser connected to the center terminal or moving arm. If there is any defect between the resistance element and moving arm, it will be manifest with noise in this test, while if it is in good condition, there will be no noise. Incidentally not more than 100 volts will be needed instead of 250 for the volume control test although the latter would not be normally harmful.

In early designs the shaft of the potentiometer was often used as the ground connection and no lug was provided for it as it was mounted on the metal frame of the receiver. The mounting including the shaft of the present day control is electrically free from the resistance element and the moving arm. Thus, from any terminal the case and shaft and mounting should test open circuit.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 As the voltage of an ohmmeter battery reduces will the ohmmeter readings be higher or lower than the actual resistance values under test?

No. 2 Why is the receiver circuit itself not a good place to test resistors for noise?

No. 3 Under what condition must you observe polarity of ohmmeter terminals?

No. 4 Which type of resistor can safely operate at a higher surface temperature, the wire wound types or the composition and carbon types?

No. 5 Is there any relation between the resistance value and the power rating of a resistor?

No. 6 Why is a taper necessary on a volume control?

No. 7 Given a choice should a tone or volume control be repaired or replaced?

No. 8 If a circuit requires 1500 ohms at 2 watts for its operation, would two 3000 ohm resistors in parallel, each rated at 1 watt, be satisfactory?

No. 9 If a resistor tests open while connected in a circuit, need it be detached for further tests?

No. 10 If a resistor has increased 50% in value but has had no noticeable effect on receiver operation, should it be replaced or not?

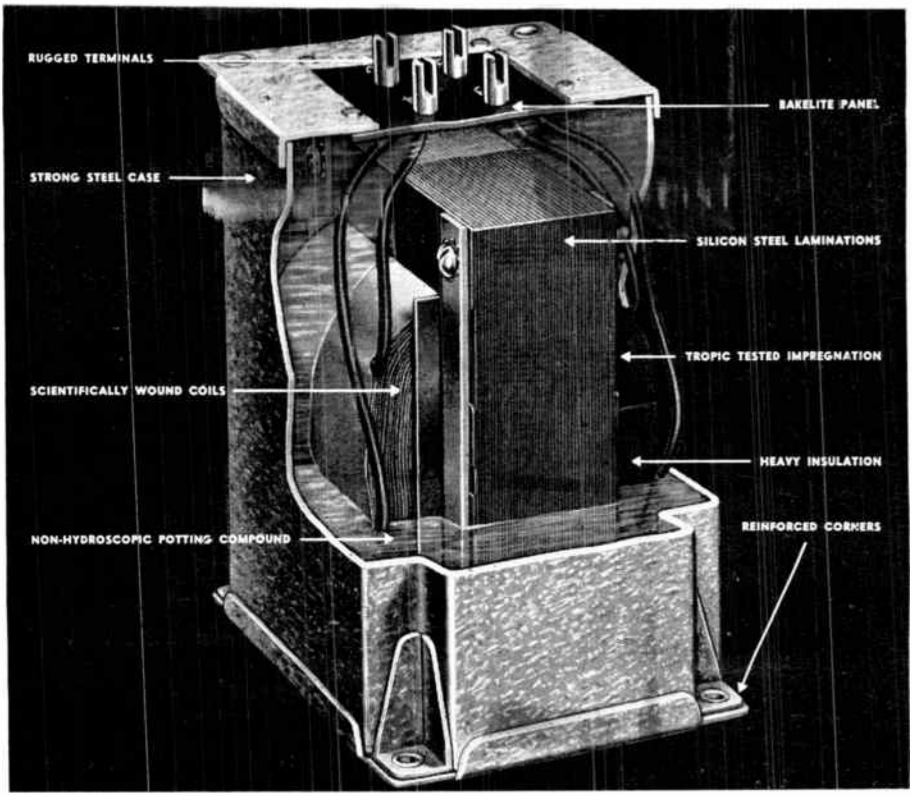
HOW TO TEST FOR DEFECTS IN TRANSFORMERS, CHOKES AND FIELD COILS

LESSON NO. TV-13

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K11542M



The above cut-away view shows the construction details of a well made power transformer. This type is more expensive than ordinary power transformers of the open type. Such a transformer if not overloaded will last for the lifetime of an average receiver.

HOW TO TEST FOR DEFECTS IN TRANSFORMERS, CHOKES AND FIELD COILS

LESSON NO. TV-13

In this lesson you will study the testing of solid laminated iron core inductances of the type commonly used in the modern radio receiver. This will include power transformers, audio transformers, AF filter chokes and speaker fields. Only practical tests which the serviceman is interested in making will be considered. While there are many laboratory tests that can be made on these units, these tests are valuable only from the standpoint of research and design workers. Also these more precise tests require special test equipment, which the practicing serviceman does not have available. Therefore, the tests to be considered in this lesson are practical tests to be made from the viewpoint of determining whether the units under consideration are fit for normal service.

Power Transformer Tests

On these transformers the serviceman is just interested in three tests—the tests for open, shorted or grounded windings. This includes the test for leakage between windings, which comes under the heading of shorts. Any form of continuity tester will determine whether one or more of these defects exists. You have already studied about continuity testers in other lessons. These testers may be in several forms. For instance, a headphone unit may be connected in series with a battery (a loud click indicates continuity), a voltmeter or milliammeter in series with a battery (a constant deflection of the meter needle indicates continuity), a neon lamp in series with the 110 volt line (if the lamp lights continuity is indicated), or a pilot lamp may be connected in series with a small battery.

Any one of these continuity testers or an ohmmeter may be employed to determine whether a power transformer is suitable for further use. Of course, some of these types of testers are more sensitive than others. In general, it may be said that any continuity tester which makes use of a sensitive meter always gives a more accurate test. For this reason, most servicemen use ohmmeters for continuity testing. An ohmmeter is not any more useful than any other DC meter connected in series with a battery if all you are interested in is establishing whether the transformer is shorted, open or grounded. On the other hand, if you are interested in determining the resistance of a winding or the resistance between windings, then a meter calibrated in resistance values (an ohmmeter) is the proper instrument to use.

The circuit of Fig. 1 is a good representation of the type of power transformer usually encountered by the serviceman. The winding between 1 and 2 is the primary. This circuit includes a switch and a fuse. The winding between 3 and 5 is the high

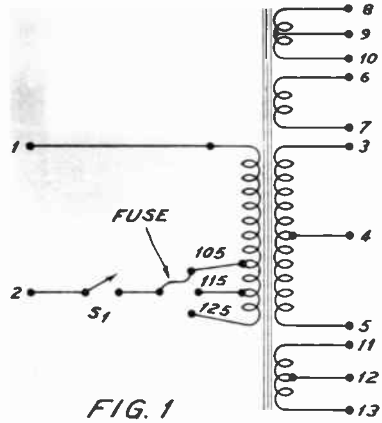


FIG. 1

voltage winding; 4 is the center-tap to the high voltage winding or the B negative lead; 6 and 7 are the filament terminals of the rectifier tube; 8 and 10 are the terminals for one filament winding, while 11 and 13 represent the terminals of another filament winding; 9 and 12 are the center-taps to these two filament windings. Some transformers may include more windings, such as for a tuning motor, etc. In any case, the same tests apply.

Testing the Primary Winding

It will require an unusual amount of judgment and knowledge of the subject to test for certain defects in a power transformer primary. *The reason for this is that the current which it carries is almost entirely regulated by the secondary and its connections.* Unfortunately there are very few ordinary measurements which are reliable in connection with testing the primary.

Power transformers for receivers and for the majority of public address systems of the portable kind, range in power rating from about 35 watts to perhaps 200 watts. The wire size for the primary varies from about No. 18 to No. 26, and there is from 100 to 200 feet (approximately) used for making the primary. This to other windings.

Ohmmeter Tests for Transformer Windings

First disconnect the power line plug from the power outlet. Then connect your ohmmeter to the terminals of the power line plug and close the line switch (for example S1 of Fig. 1). A reading on the ohmmeter simply indicates that the primary circuit is not open. It *does not* tell whether the winding is shorted or grounded. No reading means that there is an open in the series circuit at some point. The open may be in the form of a defective connection at the plug, or it may be in the wires between the plug and the winding, in the fuse, in the switch, or in the winding itself. Before testing further, examine the connections at the plug contacts—these might be improperly made, thereby causing the open circuit.

If you do not get a reading, connect your ohmmeter across the terminals of S1. No reading (be sure the switch is closed) means the open is in the switch. If you do get a reading, it means that you will have to look further for the open. Next connect your ohmmeter across the terminals of the

Since in theory you have tested most of the primary circuit and have not found the open up to now, it means that it must be in the wires between the switch, fuse and plug or in the primary winding itself. To clarify the complete primary test when a fuse and switch are used, see Fig. 2. Connect one of the ohmmeter terminals at point A, that is where the line cord attaches to the switch. Close the switch (the ON position) and connect the other ohmmeter terminal to the line plug terminal which gives a zero (approximate) resistance reading.

Now shift the ohmmeter lead from A to point B at the other side of the switch, with the switch remaining closed. If the reading is still approximately zero, continue moving the probe to C, where the lead from the switch connects with the power transformer primary lug or terminal strip. This, of course, should also show a closed circuit. Continue at D, and if the connection at D shows an open circuit, carefully inspect the connections of the transformer winding to this lug or terminal strip. If they seem in good condition, the transformer primary winding is open internally

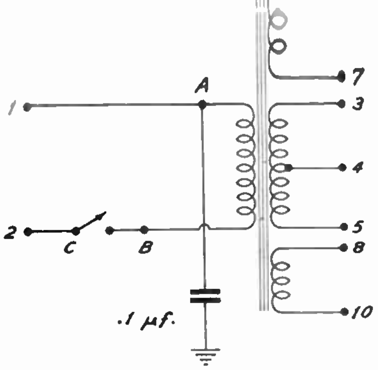


FIG. 3

and it will have to be discarded. If continuity at negligible resistance is still good at D, continue to E and F and finally to the other plug connection of the line cord. If continuity is good at D but not at E, the wiring connecting these two is at fault. If good at E but not at F, the fuse is either defective or not making good contact at its clips.

There is one more important continuity test to make before making any circuit disconnections. Refer to Fig. 3 for this test. Many receivers use a power line condenser such as the .1 mfd. unit in Fig. 3 to ground the receiver where no ground post is provided; to reduce line interference or to reduce hum. One side of the power line is always grounded, and hence if the line plug is inserted in the power outlet so that connection 1 of Fig. 3 is not grounded and connection 2 is grounded, the full AC peak will always be applied across the condenser. This condenser may, in time, become shorted, and in many cases, it will burn-out the house fuse or the receiver fuse if the receiver uses one.

To test this condenser for a short, test from A to B in Fig. 3 with the line cord removed and with the power line switch open. This will test the from either A or B to ground or to the metal chassis of the receiver. If any reading results on the meter the condenser must be replaced.

A condenser such as this in the primary circuit will often be found defective because of the very high peak voltages created across it when the line switch is opened at the maximum current portion of the AC cycle. If such a condenser is replaced, it should have as high a voltage rating as possible within reasonable cost—a voltage rating of from 600 to 1000 volts is commonly used.

The foregoing tests will only indicate if the primary circuit is continuous, and will give no accurate information as to whether it is shorted partially or entirely. As mentioned, the resistance values are too low to be accurately measured and specifications from one receiver to another varies so widely that no specific information is usually available on transformer winding resistance values.

Measurement of the line voltage at the transformer primary terminals is of little value in testing the primary because if there is a partial short, the voltage is likely to be the same as the line voltage, and if completely shorted, it will burn-out a fuse and no measurement will be possible. The difference between the voltage for an open primary or a normal primary will not be enough to be of any value in the test. Practically every power line has good regulation, hence a loaded primary will not affect the line voltage.

The current drawn by the primary will give a little more information but even with this information, you cannot determine a short or a partial short or even the power value that the transformer is consuming. The reason for this is that the primary current is determined not alone by the secondary load but also by the change in phase of the primary current with respect to its applied voltage. The greater this phase angle, the lower will be the power delivered by the transformer. In practice this means that any measurement of the primary current when the secondary is not loaded will be a very poor and inaccurate index of the power that the transformer is drawing while such a measurement under load conditions will be a fairer index of the power being drawn.

For example, you may measure the primary current and find it to be .25 ampere with all of the tubes removed from the receiver and all filament shunting resistors open. This would seem to indicate that the transformer was actually supplying 28.75 watts ($115 \times .25 = 28.75$) to the receiver. However, an *unloaded transformer* has a primary which is almost a pure inductance and this causes a shift in phase of the primary voltage with respect to current of almost 90 degrees.

If this is assumed to be say 85 degrees, the power the transformer will actually be dissipating will be less than 2.5 watts. Now, if you place tubes and resistance loads on the transformer secondaries such that they will actually consume 46 watts, the primary current will rise from .25 to .5 ampere. Note that this is more nearly equal to the product of the line voltage and primary current ($115 \times .5$) or 57.5 watts than for the *unloaded transformer* which draws .25 ampere.

Power transformers for receivers fully loaded, operate at a power factor of almost 80% average, which means that the total power used by the transformer and its load is 80% of the product of its primary current and voltage. Thus if you measure a current of .9 ampere through a 115 volt primary, the total power used by the transformer and load will be equal to approximately $.9 \times 115 \times .80$ or 82.8 watts.

Of course, the approximate transformer load could be calculated by determining the filament, plate and screen current of every tube but this would require a far too laborious precedure for the practical serviceman. If he does test for the primary current he must use this reading only as a very rough guess of the transformer's action.

In order to obtain some exact information as to the primary so that with a minimum of equipment you can determine a great number of important facts, a very comprehensive table of values is included herewith.

With reference to Fig. 4, obtain a 250 ohm wire wound resistor and connect it in series with the line and connect your AC voltmeter across the transformer primary as shown. Now in terms of the voltage which your meter indicates at E of Fig. 4, the following gives the corresponding primary reactance (X_L) of the transformer (unloaded), the full load impedance (Zp) of the transformer primary and the power (W) which it should carry at full load. This will be a little below its rated power value.

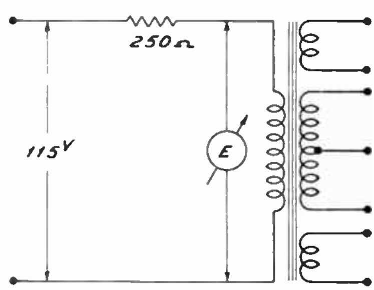


FIG. 4

Certain things must, of course, be assumed about the operation of the transformer in order to get this information but the assumptions are perfectly in line with ordinary practice.

Here is the way to use the table.

If after connections are made and all tubes are removed from a receiver, the voltmeter reading at E is less than 10 volts, you may be sure that the

Table

(E Volts)	Z_L (Ohms)	Z_P (Ohms)	W (Watts)
0	0	0	
10	21.8	17.4	606
20	44.2	35.4	300
30	67.6	53.4	198
40	92.8	74.4	142.2
50	120.7	96.5	110
60	152.6	122	87
70	186	149	71
80	242	194	54.6
90	315	252	42
100	442	372	28.4
110	828	663	16

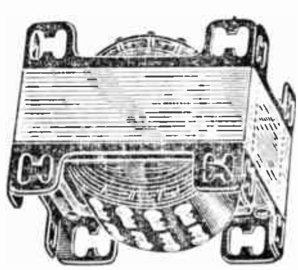
transformer is defective. The reason why this is so is because to get this reading from a normal transformer, its rated power would have to be considerably above 600 watts as indicated in the power column of the table. That is, if the transformer were loaded its maximum amount, its primary impedance would be only 17.4 ohms and at 115 volts it would carry 115/17.4 or 6.61 amperes of current. No receiver has yet appeared on the market with such a high power transformer rating.

If the voltmeter reads zero, there is no doubt that the transformer primary (or secondary) is shorted. If the reading is only 30 volts for a transformer supplying only 5 or 6 tubes in an average size table or console receiver, you may be sure that the transformer is defective with possibly shorted primary turns because the reading should be between 70 and 80 volts in this case for a 50 to 70 watt transformer.

Similarly, if the meter reading is near the line voltage reading, say 105 to 110 volts, you may be sure that the transformer primary is open partially at least, and is therefore, defective. The reason for this is that the primary impedance under full load is too high to permit more than 16 to perhaps 24 watts to be transferred to the load. Receivers consuming less power than this are most usually of the AC-DC type, having no power transformer.

If you wish to check the amount of power that a normal transformer will carry, you can set up this simple circuit—connect the line voltage and from the voltage reading find the power in watts from the table.

If there is an overload on the secondary which would affect the operation of a receiver, it would produce a very low voltage reading (using the circuit of Fig. 4) and would show, beyond question, that the transformer or its wiring is defective. This entire measurement system for the primary is completely independent of the size of wire or number of turns on any winding.



Above is shown a drawing of a universal mounting power transformer. This is a type which can be mounted in several positions. Such replacement power transformers are made by several different transformer manufacturers.

For several reasons a partial primary short is a rare trouble to be found. A transformer winding is built in separate layers, and of course, there is the possibility of a wire of one layer shorting to an adjacent wire of the next layer above or below. Assume that this occurs, resulting in shorting out 10% of the entire primary winding. The 90% of the primary remaining will act as the primary, and the shorted turns will act as a secondary—that is, voltage will be induced in them and because of this very much lowered impedance a large current will tend to circulate in this shorted section. It will act in every respect like a shorted secondary.

The voltage per turn will be the same for this shorted section as for the balance of the primary and thus there will be a step-down voltage ratio of 9 to 1. Accordingly, the current in this shorted section will tend to be 9 times as high as the primary current. Now the wire of the primary is designed only for its full load current plus a safety factor of perhaps 50 to 100% overload for short intervals, and it cannot carry a 900% overload for any great length of time. This shorted section will quickly overheat the entire transformer and it will burn out if left on for a short time. It will usually burn out at or near the short producing (1) an open in the shorted section, (2) an open in the complete primary circuit or (3) open of both the primary and its shorted section.

An open is readily tested with an ohmmeter or by means of the circuit in Fig. 4 where an open is indicated by a full line voltage reading. A closed short as described would be indicated by a very low reading of from 10 to 30 volts providing a low powered transformer is tested and an open of the shorted section with a complete

Here is shown a special type of power transformer as used in transmitters and large public address systems. Note the terminals are insulated with high porcelain posts, indicating the use of high voltage. Such a transformer is no different from the usual types except it is better insulated.

circuit through 90% of the transformer would simply increase the step-up ratio of the transformer approximately 11%. Accurate measurement of the filament voltage or any other secondary voltage will disclose this trouble.

The fewer turns shorted, the higher the resulting current in the shorted section and the greater the chances are of burn-outs. On the other hand, the greater the number of turns shorted, the greater will be the step-up ratio to every secondary winding, and hence the more easily detected.

In place of the resistor in Fig. 4, practically any 50 watt lamp, soldering iron or other resistance operated household unit will be sufficiently accurate for use with the table on page 6.

The test is essentially the same for 25, 40 and 60 cycle transformers. For 220-230 volt primary windings, use 500 ohms instead of 250 ohms and simply divide all the voltages in half to get the values in the table for reference. Thus 160 volts should be read 80 volts, etc.

Completing the primary tests, you must be assured that it has no conductive relation with the core, with any other winding, or with its electrostatic shield if one is used or with ground. On the other hand, the shield and core should be grounded. All of these tests can be made with an ohmmeter. Any resistance below 500,000 ohms between any part of the primary and any other winding, shield or core should be investigated. Leakage could amount to this low a value in extreme cases, but it is very doubtful.

The High Voltage Secondary

You would quite naturally be guided in your suspicion of any trouble in the high voltage winding of a power transformer by some clue derived from the operation of the receiver. Hence it may be assumed that all other defects which could cause a similar effect have been checked and a correction made if needed. Surveys show that only 3% of the total defects in receivers have to do with the power transformer while 27 to 30% of the defects will be found in condensers, among which are the filter condensers. Thus, it is 10 times more likely that excessive hum, low voltage, overheating of the power transformer, etc., would be caused by a shorted filter condenser rather than a defective power transformer. However, when such faults arise, they are always more serious.

The testing of the high voltage secondary is quite simple. With the receiver turned off and the chassis inverted (see Fig. 5) connect the ohmmeter terminals between either plate connection on the rectifying socket and ground. Test first from one plate and then the other. A fairly low resistance range—1500 ohms if available—should be used. Exact resistance values are not important here. Values vary, some being as low as 50 ohms and others as high as 500 ohms. The two readings just described will rarely, if ever, be alike because one half of the secondary is wound on top of the other, and hence has somewhat more wire length. The difference may amount to 10, 20 or even 25% more wire and hence this much more resis-

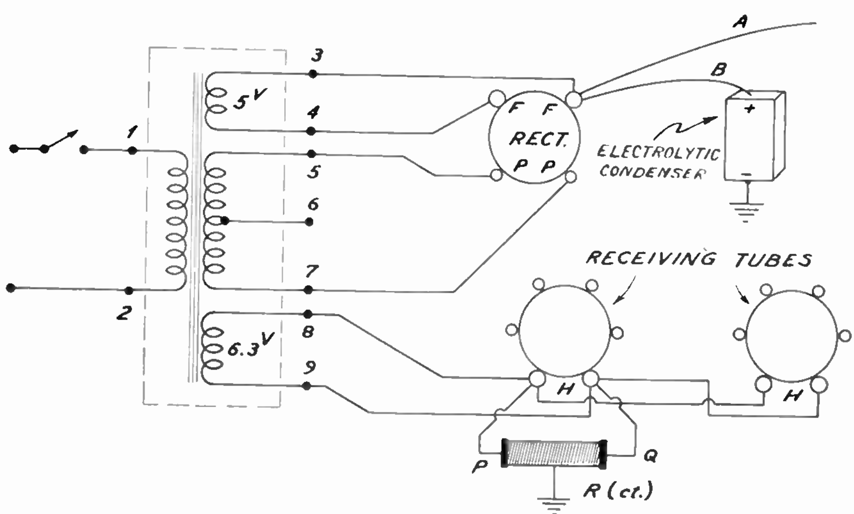


FIG. 5

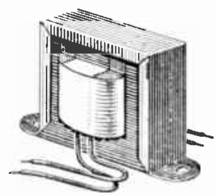
tance. *This is normal* and does not mean that the secondary is shorted. A short is rarely found in such a winding and never is maintained. The shorted section always burns out leaving the winding open.

If a short to ground is indicated from either plate (Fig. 5), remove the rectifying tube. If the short still is noticed, unsolder the wires at the transformer terminals (5 and 7 in this case). If the test of either half of the secondary shows practically zero resistance, the transformer is defective. It is also defective if these windings are open.

Now to make certain that there are no shorted turns even of a temporary character, the next test consists of measuring the AC voltage across the high voltage secondary. The voltage from one plate terminal on the rectifier socket to ground should be the same as that from the other one to ground. These voltages should be within 5% of each other. If they are not, there is likely to be something wrong with the winding. The voltage of each may be as low as 250 volts for a small receiver and up to 450 volts for a large receiver. The exact voltage is not important, as long as the voltages of each half of the winding are approximately equal.

The high voltage may be subnormal or lower than is specified in manufacturer's literature, but this would probably not be the fault of the winding if the voltages of the two halves are equal. Such an effect is more likely due to an overload of some other winding. While this defect is made evident at the high voltage winding it is not a fault of the winding.

Still referring to Fig. 5, all of the tubes connected to one or more of the heater-filament windings should be in their sockets and the filament voltage should be measured. With all tubes



This view shows an output transformer of the type usually used to couple an output power tube to a speaker. This type is also available in several forms. Most radio parts jobbers have a wide selection of such transformers.

in place, the voltage is likely to be lower than that specified for the tube. A 6.3 volt winding, for example, may show from 5.4 to 5.6 volts. This would ordinarily be satisfactory and would indicate no fault of the transformer. A reduction of voltage to 2 or 3 volts here accompanied by overheating of the transformer indicates an overload of the transformer winding. Carefully check the centertap resistor R (Fig. 5) for grounds at ends P or Q or both. Check the terminals at the sockets for grounding. In a great many receivers, one heater or filament terminal is grounded purposely, so don't be mislead by this type of grounding.

Now remove the tube and measure the filament voltage again. This time it is likely to be above 6.3 volts. It may easily reach 7 volts when there is no load placed upon the filament winding. For a 5 volt winding, the voltage may be only 4.6 to 4.8 volts under load (supplying one or more tubes) and from 5.3 to 5.5 volts when no tubes are connected. Similarly a 2.5 volt winding will measure 2.2 to 2.3 volts under load and about 2.8 volts with no load. In every case, no voltage indicates an open and very low voltage indicates a short, either on the transformer winding or in the external circuit.

Any of these low voltage filament windings will carry a very large cur-

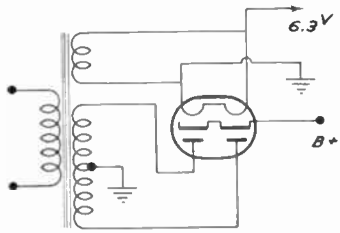


FIG. 6

rent and will not easily burn out even though shorted. Low voltage and overheating of the transformer is an indication of this fact.

Now there is one more test and that is for interconnection of any of the windings. It is obvious in Fig. 5, that without disconnecting any of the wiring, connection 6 will show continuity to terminal 5 or to 7 with low resistance. This is normal and may be disregarded. Practically every heater or filament winding has some connection to ground, or should have, and thus will show continuity to ground. On the other hand, the rectifier filament is usually insulated from ground. The notable exception to this is where the same winding is used for all heaters, including that of the rectifier as in Fig. 6. Here the insulation between the filament and cathode must be provided for entirely within the tube.

Returning again to Fig. 5, you may now test for the resistance between terminals 3 or 4 to ground after removing wires A and B from the rectifier socket. If you do not remove wires A and B, you will get a comparatively low resistance reading of from 5000 to 100,000 ohms, because of a voltage divider arrangement in the receiver circuit or through the leakage of a filter condenser.

If you make individual tests on the units external to the rectifier the leads A and B need not be removed. If you find that there is zero resistance reading, it indicates that the circuit is defective. Detach leads 3 and 4 of Fig. 5 directly at the transformer. Then test from either 3 or 4 to ground. Any reading below 500,000 ohms indicates a defect while a higher resistance or an open assures that the former short had to do entirely with the external circuit. This completes the tests for the power transformer windings.

Testing Other Transformers

First the ordinary coupling transformers as used in the earlier models of receivers will be considered. See Fig. 7. Such transformers are rarely, if ever, found in modern receivers. However, the study of its testing is still of considerable importance. It is still commonly found in many amplifier circuits, not strictly for radio reception.

You should first get a rough idea of the condition of the circuit with a simple continuity test. Remove both the plate and grid circuits associated with the transformer as shown in Fig. 7 and test continuity of the winding from B+ to P and then from G to F. Usually the transformer terminals will be identified as in Fig. 7, but if not, it is easy to trace enough of the circuit to determine the connections.

In this case, as for many others having to do with transformers, accurate resistance values are not important. The value of this continuity

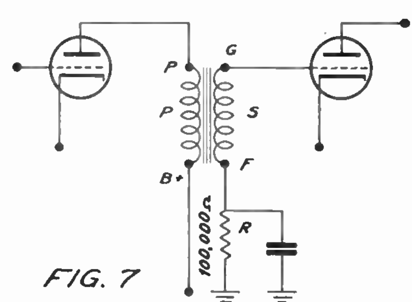


FIG. 7

test is in detecting opens and shorts. Because the resistance of these interstage AF transformers is relatively high, a short is easily detected. An open is also easily detected by an infinite resistance reading.

The primary (P) in Fig. 7 may test as low as 10 ohms or as high as 2000 ohms. Their values are sufficiently defined so that a short or open is easily detected. For example, if the winding on test showed a resistance of 1 ohm, it would be very difficult to distinguish this from a short by the continuity test method.

If a short is indicated, it would be well to disconnect the transformer at terminal (P) and (G) so that the possibility of there being a short at the sockets of the tubes would be eliminated from the problem. An open winding or one showing an excessive resistance indicates a defect which cannot be repaired from a practical viewpoint, and the transformer must be replaced.

There is one other very important continuity test for transformers that is too often neglected. That is the test for leakage or a short between the windings. Detach either the B+ or the F connection at the transformer and test between terminals (P) and (G). A leakage resistance of less than 1 megohm indicates a defective condition of the transformer. Note carefully if there is a grid circuit filter as indicated in Fig. 7. If there is such a filter, the presence of any measurable leakage between the transformer windings will be all the more serious because the leakage resistance will act as one section of a voltage divider with the filter resistance (R) as the other, thus raising the grid voltage to some positive value above ground. This, of course, will cause incorrect operation of the amplifier tube.

Occasionally there may be a need for finding the turns ratio of an AF transformer. While not of very general use, the following information is included for reference.

The wiring for determining the turns ratio is given in Fig. 8. A 50,000 ohm wire wound linear potentiometer is used. Any AF signal from 400 cycles to 2000 cycles may be used at the terminals marked AF and headphones are connected from the movable arm of the potentiometer to the plate terminal of the transformer under test. The B+ terminal is *temporarily* shorted to the F terminal, both of which must be grounded.

The AF signal is impressed across the AF terminals and the potentiometer is adjusted for minimum signal in the headphones. The resistance remaining from C to B of the potentiometer is then a measure of the turns ratio according to the accompanying table:

Resistance from C to B	Transformer Step-up Ratio
50,000 Ohms	1 to 1
25,000 Ohms	1 to 2
16,660 Ohms	1 to 3
12,500 Ohms	1 to 4
10,000 Ohms	1 to 5
8,330 Ohms	1 to 6
7,140 Ohms	1 to 7
6,250 Ohms	1 to 8
5,550 Ohms	1 to 9
5,000 Ohms	1 to 10
4,550 Ohms	1 to 11
4,170 Ohms	1 to 12
3,840 Ohms	1 to 13
3,575 Ohms	1 to 14
3,330 Ohms	1 to 15
3,125 Ohms	1 to 16
2,940 Ohms	1 to 17
2,780 Ohms	1 to 18
2,630 Ohms	1 to 19
2,500 Ohms	1 to 20

If desired you can make a chart or dial under the potentiometer control

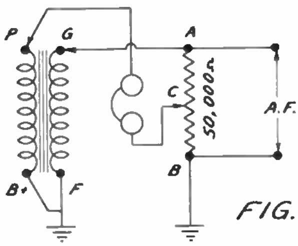


FIG. 8

knob marking these values where the position of terminal C intercepts from C to B and adjust for the resistance values. Then mark at the dial or knob pointer the ratio corresponding to this resistance value. If you fail to get a minimum signal, reverse the primary terminals. In some cases this will be necessary to get the proper polarity of the applied and induced voltages.

In many cases a transformer will be defective and yet will not show the defect in a continuity test. This is usually due to corrosion at the connection of its windings with its external terminals. The best thing to do when this type of trouble is suspected is to give each winding of the transformer an overload test.

It is most convenient to give the transformer this overload test while it is still in the circuit because many of the circuit connections and facilities are of value here. Figure 9 shows the manner in which overload tests are made. In both cases the instruments are DC milliammeters of the largest possible current ranges.

For the first test the meter simply shorts the plate terminal to ground through a 2500 ohm resistor and allows a large DC to flow through the plate winding of the transformer. This may amount to almost the total current available at the rectifier. The resistor limits the maximum current to a reasonable value. This is essential in the case of a battery operated and for many DC type receivers. At 250 volts the current will be a little less than 100 milliamperes because of the resistance of the primary and the 2500 ohm resistance value.

This overload test circuit should not be maintained for more than a few seconds or for just enough time to get a reading from the meter. Practically any transformer should be able to carry this much current for a short period of time. If the meter holds a steady reading you may be assured that there is no trouble in the primary. If corrosion has decomposed the end leads to any appreciable extent, the winding will burn out or break at this point. If, in spite of corrosion, the circuit is maintained, you may be assured that the corrosion has not seriously advanced and will give no present trouble, but in the future it may cause serious trouble. Make and break the circuit several times to make sure that the transformer does not burn out the first time the connection is broken.

Since the secondary has considerably more resistance and is made of somewhat smaller wire, its current carrying capacity is much less than that of the primary. Any secondary should, however, be able to carry 10 milliamperes for a short time. Thus from the B+ supply as in Fig. 9 a milliammeter is connected through the 25,000 ohm resistor to the grid. Be sure that terminal F is grounded. If

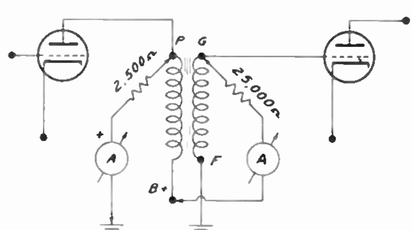


FIG. 9

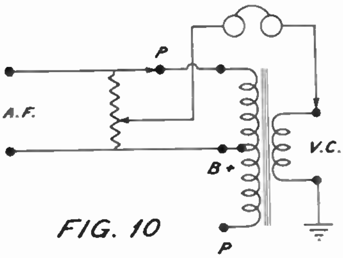


FIG. 10

not, temporarily ground it. In the same way, this winding will burn out if defective and will not be harmed if it can stand this overload. In some rare cases it has been possible to repair transformers but usually this is an obvious open in one of the windings or terminals where it can be easily reached and corrected.

Push-Pull Transformers

In no fundamental sense does the push-pull transformer differ from the single winding type. Each half of the plate and grid windings are tested just as described for the ones in Figs. 7, 8 and 9. In connection with Fig 7, the B+ and F connections will be center-taps instead of the lower ends of the transformer, but their connections to the receiver will be essentially the same. Of course, two grid terminals and two plate terminals must be tested instead of one. Where a transformer couples a single tube stage to a push-pull stage naturally one winding will be tested as usual and one as for a double winding.

In regard to the turns ratio test, the same applies as for a single winding. The correct ratio is the same for one-half of the primary and one-half of the secondary as for the entire primary and secondary. Or, if the transformer has a single primary winding and a center-tapped secondary, the ratio for purposes of determining gain, etc., is the ratio of the entire primary to half of the secondary. The test is made accordingly. One grid connection will produce a minimum signal while the other will not. The test lead connected to G in Fig. 8 would simply be shifted to the other grid connection if no minimum signal could be found.

Output transformers which couple output tubes to speakers are step down transformers. The DC resistance of the secondary winding of these transformers is very low for they consist of only a relatively few turns of large wire. Thus, it is easy to identify output transformers for the resistance of the secondary is very low. Class B transformers are also step down transformers. Thus, the resistance of the primary is greater than the resistance of the secondary. This will aid in identifying them. A simple test as shown in Fig. 10 is sufficient for determining its turns ratio.

Finding the Impedance of Transformer Windings

The impedance of a transformer winding has remained an unsolved mystery to the untrained serviceman and technician. While it is true that replacement transformers can be chosen by catalog number and wired in a receiver by color charts and manufacturers' numbering codes, the one who depends on this type of information is never sure that his work is correct if he

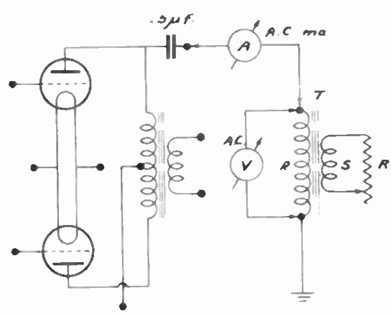


FIG. 11

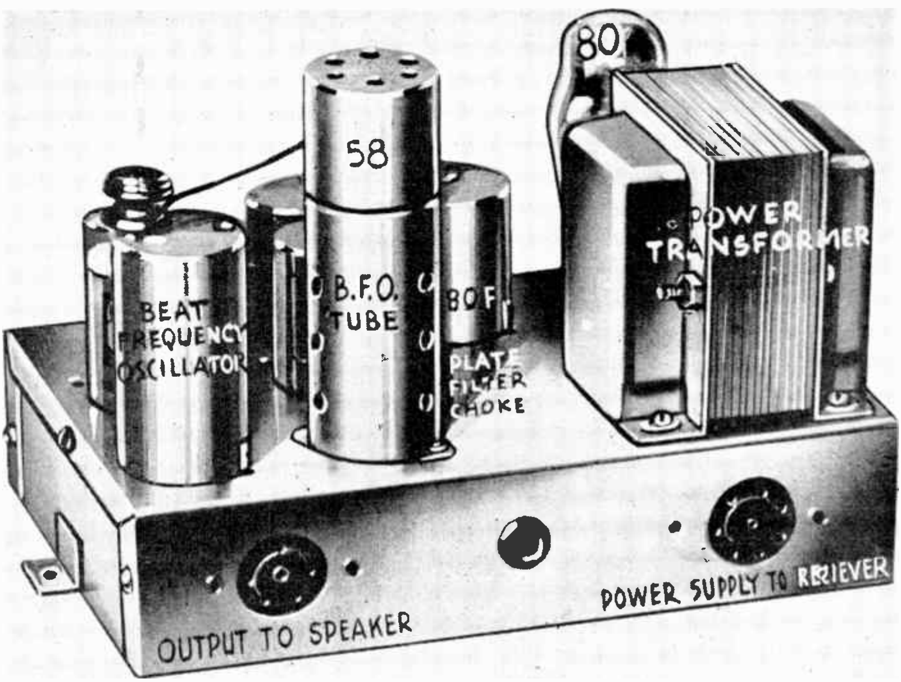
must make the simplest alteration in wiring or use of the transformer. While it is rarely ever necessary to measure the impedance of a transformer winding, it is always a good idea to know how it is done and how the transformer is applied to a circuit. This is more important for output transformers because they must be replaced as a rule more often than any others.

A method in Fig. 11 is shown for determining the impedance of both windings of an output transformer in one operation and for determining its turns ratio from this information.

The first thing that is needed is a large signal source which can be provided from the output of any receiver or power amplifier. The input of the receiver is fed with a modulated signal generator and its volume is kept at a high level to be determined by factors to be described.

A coupling condenser (.5 mfd.), an AC milliammeter and an AC voltmeter are connected to the receiver or amplifier and transformer as shown, and the load resistor R on the secondary is turned to open circuit or actually disconnected. This resistor should be a heavy wire wound rheostat (up to 50 watts) and having about 25 to 30 ohms total resistance.

Adjust the amplifier or receiver volume control until you get a steady reading on both the ammeter and voltmeter. Practically any modulation from 400 cycles to 2000 cycles will be satisfactory for this purpose. Resis-



The above photograph shows one use of a power transformer. In this case it forms part of the power supply of a beat frequency oscillator. This one is of a standard type which can be mounted flat on a metal chassis. This transformer is similar to those used in the average manufactured receiver.

tance R is now placed across the secondary and adjusted for about 30% increase in the reading of the ammeter. The voltmeter reading will reduce as the transformer is loaded and hence the volume of the input signal will have to be increased. Continue to adjust R and the volume of the receiver so that the milliammeter reading is increased 42% or to as close as you can estimate this increase. This job will be simplified if you start the work with some even reading of the milliammeter by proper adjustment of the volume control.

Next disconnect one terminal of R and measure its resistance. This will be essentially the output impedance for which the transformer was intended. The primary impedance will be equal to the primary voltage divided by the primary current at its last measured value. For a push-pull output transformer, the test should be made on only one-half of the primary.

These measurements are not to be considered perfectly accurate but they are entirely suitable for practical purposes. For example, suppose with your first circuit set-up you adjust the volume for a reading of 5 milliamperes with 12.5 volts across the transformer. Adding 42% of 5 milliamperes you will have 5 × 1.42 or 7.1 milliamperes approximately. R and the volume level are now adjusted to give 7.1 milliamperes with 12.5 volts still maintained across the transformer. The impedance will then be 12.5/.0071 or 1760 ohms approximately for the primary or the half-primary for a push-pull transformer.

Assume that for this reading R was adjusted to 16 ohms. The entire primary impedance would be 4 times the impedance of one-half of the winding or 7040 ohms from one plate terminal to the other. Thus, the transformer would be suitable for use with two 6F6 power amplifiers which in push-pull require 7000 ohms load from plate to plate or the entire winding could be used for a single type 47 tube at 7000 ohms.

The voice coil impedance is approximately 16 ohms and can be used to supply a speaker having a 16 ohm voice coil impedance. By calculation, the turns ratio of the transformer is the square root of 7000/16 or the square root of 437.5 which is very nearly 21. This simply means that the primary has 21 times the number of turns of the secondary and that the wire of which the secondary is wound must have roughly 21 times the cross sectional area of the wire in the primary or a diameter a little over 4.5 times that of the primary wire. The square root of the area ratio which is governed by the current ratio is the diameter ratio. Thus, the square root of 21 is just a little more than 4.5.

Wire used for transformers and chokes can safely carry AC or DC with respect to size according to the following table:

Wire Size (B&S Gauge No.)	Current in Amperes
8	11
10	7
12	4.5
14	3
16	1.7
18	1.1
20	.68
22	.43
24	.27
26	.17
28	.11
30	.067
32	.042
34	.026
36	.017
38	.01
40	.006

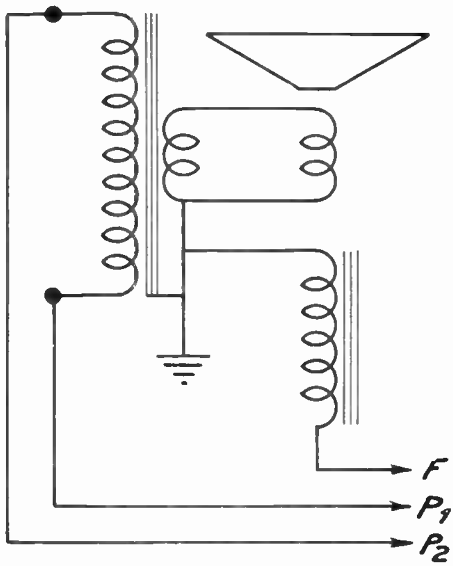


FIG. 12

Knowing the size of the wire by making use of a wire gauge you can tell from this table what current it can safely carry continuously. You may have use for this table as a reference in connection with a power or an output transformer.

The Filter Choke and Speaker Field

For the most part, the filter choke and speaker field are combined as one unit. The DC resistance of iron core chokes and speaker fields is of the most importance from a practical consideration. This resistance should check to within 10% of that specified by the manufacturer.

If the speaker cable can be detached, it is best to disconnect it from the receiver, as then it will be known that no other circuit is affecting the reading. The reading should be very close to the value specified by the manufacturer. If no reference is made as to whether it should be tested when hot or cold, its reading should be taken when cold. Some manufacturers, however, specify that the field resistance should be so many ohms when hot— that is, while in use with the receiver operating. In this case, the receiver is allowed to operate for a half hour or so and then tested immediately after it is turned off. It will rarely, if ever, be necessary to alter the circuit in any way to test the speaker field.

For any speaker field the resistance should not increase more than 10% while in use. If it does, it is being overloaded or it is otherwise defective. A normal increase with operating temperatures from 5 to 10% may be expected, and for any field, if the resistance is increased by 20% or more, it is definitely too hot to be safely operated. This applies to the choke as well as the speaker field and is just as true for any winding of a power transformer. This means is not commonly used as a method for determining overload because of the lack of the required accuracy of ohmmeters to detect a 2 or 3% increase in resistance.

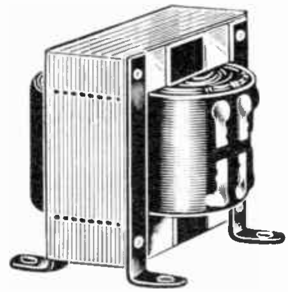
A group of shorted turns in a choke coil will cause no significant defective action although it can easily be detected by a resistance measurement as a rule. If it is undetectable it can cause no trouble unless it shorts a large percentage of the turns. In this case, it must be replaced.

Note the wiring of the choke and field, and if it is in the positive filter supply. If this is the case, its insulation from its core is of great importance. Test for leakage or shorts between either lead of the field or choke to the metal frame of the speaker or choke. If a reading of less than 500,000 ohms is indicated, a defect is evident in the insulation. For this test both ends of the choke or field winding must be detached from the circuit.

For a speaker which can be detached, the test is made from either field terminal to the frame of the speaker.

A great many speakers will be wired as in Fig. 12. Frequently the ground shown here will simply be a shield over the speaker cable, while a separate lead for ground is commonly used. This type of field winding is tested for continuity between point F and ground.

If a field winding is burned out and you cannot find out what its resistance was intended to be, replace it temporarily as in Fig. 13 with a resistor. A 3000 ohm variable power resistor should be used. Without regard for the hum produced in the receiver, turn it on and adjust the resistor until you can read the specified voltage across the voltage divider (V_D) as indicated or, if no divider is used, the voltmeter is simply placed from B+ to ground. Even if the voltage for the tubes is not specified, you can choose a voltage which will be suitable, and adjust the resistor R in Fig. 13 until you get this voltage. Of course, you must be sure that the tubes are in good condition and that there is no short or open in the receiver to upset this reading. Now the adjusted resistance of R which you must measure, is the proper value for the field winding resistance. Simply use a value as near this as possible. For example, if it measures 625 ohms, you can use a 600 ohm or even a 500 ohm field if a 600 ohm unit is not available. Moreover, you can use a 750 ohm field if it is the only type that you can get to fit the speaker magnet.



This transformer represents the type employing soldering lugs for its terminals. These lugs extend through to the other side of the insulation and the ends of the various windings are soldered direct to them.

The most prevalent reason for field coils burning out is shorting of the output filter condenser such as C2 in Fig. 13. Before replacing a field coil be sure that this condenser as well as all other filter units are in good condition.

Identifying Transformer Windings

Before an actual test can be made upon a transformer the winding of the transformer must be identified. This, of course, is an easy matter

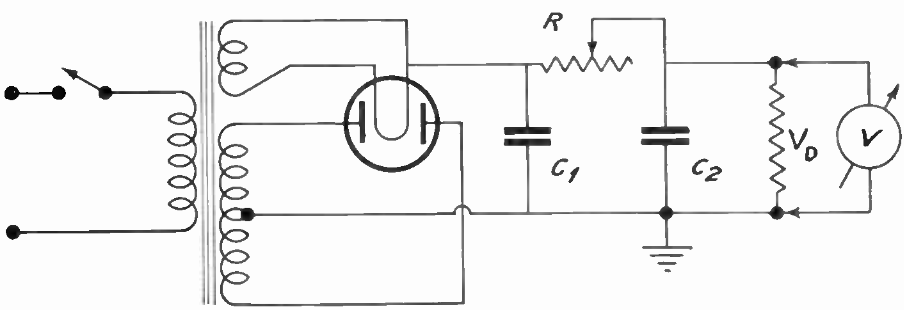


FIG. 13

when you can trace out the leads from the transformer to every point in the circuit but this is not always possible. Some receivers use cabling between the different units and to trace out the connections between the transformer, tubes, etc., is not always possible. To aid in the identification of the leads of a transformer manufacturers have standardized on a color code for identifying the leads of a power transformer. This simplifies the process of identifying the winding, aiding the serviceman considerably when replacing a transformer. A few years back some of the leading receiver and transformer manufacturers did color code the transformer leads but each manufacturer used a different color code. There were also many manufacturers that did not use a color code of any kind. Thus, to check or to replace the transformer in many of the older receivers was rather confusing.

R.C.A. was one of the first to use a color code for identifying the windings of their transformers. The old R.C.A. color code was somewhat different from the new system. The old R.C.A. color code along with the new standardized color code is outlined in the accompanying table.

Figure 14 shows the schematic diagram of a transformer using the standardized color code. Not all transformers have as many windings as this transformer but those it will have are color coded according to the standardized color code.

Although the older model receivers use transformers with an old color code or no color code at all, when a replacement is necessary a new transformer using the new color code can be used provided you connect it in the circuit according to the new color code.

Replacement Hints

Often it becomes necessary to install a substitute power transformer. When this becomes necessary there are several factors to consider.

1. What type of power source is the transformer to operate from?

	Old R.C.A. Color Code	New Standardized Color Code
Rectifier filaments	green and red tr.	yellow
Amplifier filaments	blue	brown
High voltage secondary	brown	red
High voltage center tap	brown and black	red and yellow
There are three different types primaries:		
Single 110 volt primary	red	black
Double primary:		
110-120 Volt		
No. 1 primary start	red	black
No. 2 primary start	red and yellow	black and green
No. 2 primary finish	black and red tr.	black and red
Tapped primary:		
110—125—150—210—240 volts		
Start	red	black
110 volt tap	red and black	black and yellow
Finish	black and red tr.	black and red

2. How many different filament voltages are necessary?
3. What is the voltage of the high voltage secondary?
4. What current must each secondary winding deliver to its load?
5. What is the best type according to shape for the installation involved?

The type of power source for a home type receiver is usually 110 to 120 volt 60 cycles AC. This is not always true, however. There are some localities where other voltages and frequencies are used.

25 and 50 cycle power sources are common. A special transformer is required for 25 cycles but usually transformers are made to operate from both 50 and 60 cycles. Thus, 50 cycles presents no special problem.

Not all power sources are 110 to 120 volts. Some are 220 to 250 volts. Here again a special transformer must be used. A step-down transformer ahead of the receiver will have to be used in case the receiver transformer is designed to operate from 110 to 120 volts AC.

One other special type transformer is the transformer used in the automobile type receiver. These transformers are designed to operate from a 6 volt interrupted DC source. It may be necessary to secure the exact duplicate of some of these specially made transformers if a replacement is found necessary.

The number of filament voltages necessary can easily be determined from the type tubes used in the receiver. Usually there are just two filament windings, one for all the 6.3 volt tubes and a 5 volt winding for the rectifier. Some receivers use 6.3 volt separate cathode type rectifiers. Here only one filament is needed. The older receivers used 2.5 or 1.5 volt filament windings instead of the 6.3 volt windings.

In some of the larger more elaborate receivers the output tube filaments

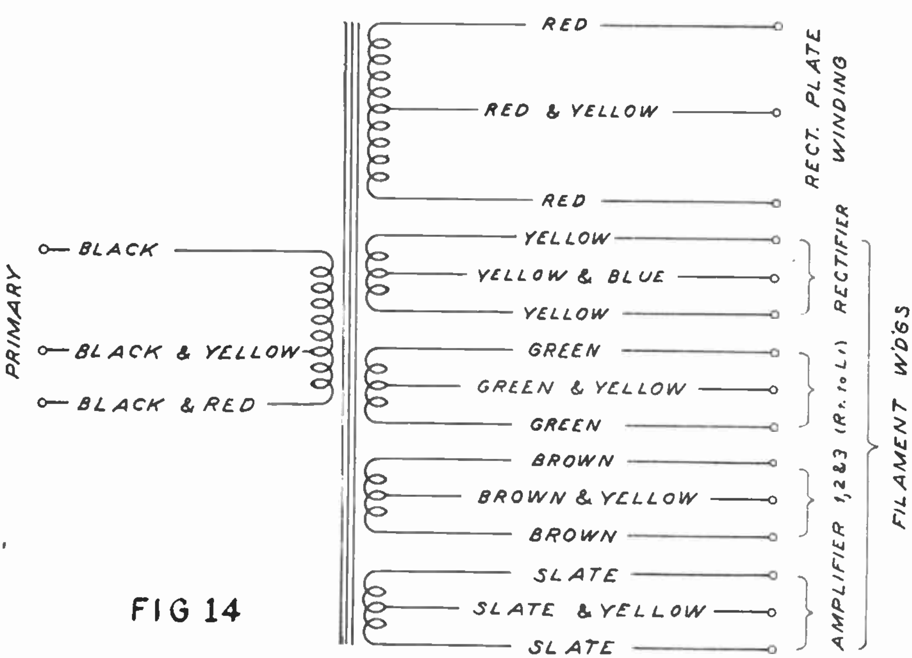


FIG 14

are supplied from a separate filament winding. This makes three filament windings necessary—seldom are there more than three filament windings used.

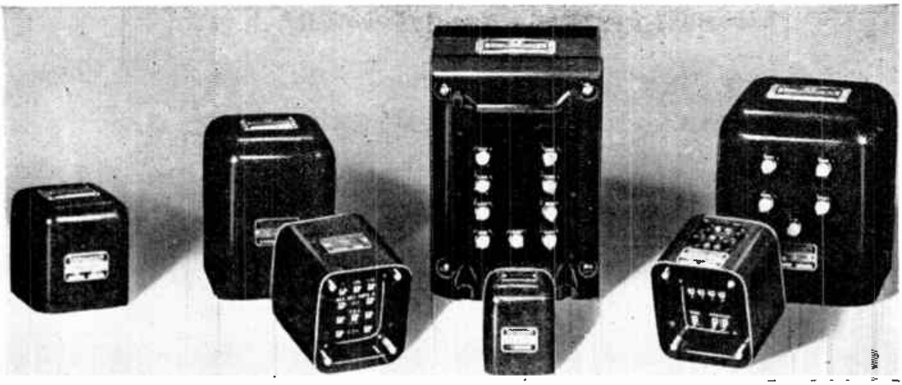
The voltage necessary for the high voltage winding can vary considerably from the rated value but is usually chosen so that the DC voltage from the receiver power supply is within 10 to 15 per cent of the rated value. The voltage of the high voltage secondary usually varies from about 450 to 800 volts. By careful observation of the voltage ratings on the filter condensers, output type tubes and the number of tubes, a very close approximation can be determined. The voltage rating of the input filter condenser is the best clue to the proper voltage. Condensers are usually rated both for AC and DC. If so, the AC rating of the input condenser will be approximately equal to half the total high voltage secondary voltage. Condensers are usually rated slightly higher than the voltage expected to be impressed upon them. If the voltage rating of the input filter condenser is 450 volts AC, the transformer winding is more than likely 800 volts, etc. This refers to the entire winding—each end of the winding to the center tap would, of course, be rated at 400 volts. If it is rated as a maximum DC voltage of 450 then by multiplying 450 by .707 will give the maximum AC rating. $450 \times .707 = 318$ and the voltage rating of the entire secondary is more than likely 600 volts. This method of determining the secondary voltage is very simple and in most cases quite accurate, unless the input condenser has been replaced with a condenser with a voltage rating considerably higher than the one intended for the receiver. This can usually be determined by the voltage rating of the second filter condenser. If its voltage rating is considerably lower than the first filter condenser it is reasonably sure that the first filter has a higher rating than the original condenser.

The voltage rating of this second condenser then can be used to approximate the correct secondary voltage. The type tubes, of course, limits the voltage allowable upon them. This will also aid in determining the voltage necessary. Very seldom is a voltage of more than 350 volts DC used in a receiver.

To calculate the current rating of each secondary winding is simply a problem of addition. From a tube manual the filament current rating for each tube can be found. Adding these values together for all the tubes in the receiver, the total current necessary for each secondary winding can be found. The current for the filament or heater winding is determined by adding the total current rating of each tube connected to this winding (assuming a parallel connection).

The rectifier filament is usually connected to a separate winding. Thus, the current rating of this tube gives the load value or rating for the rectifier winding.

The current rating necessary for the high voltage winding is a little more complicated. The plate current and screen current for each tube will have to be added. These values can be obtained from the tube manual also. As the tube manual usually gives several different combinations of plate and screen voltage the voltage value you choose should be the one closest to the voltage supplied to the tube from the power supply of the receiver. As you will have already determined the approximate DC voltage when you determine the voltage of the high voltage secondary this should aid you



Here is shown several types of enclosed transformers. These are usually of the high quality type used in the more expensive manufactured receivers and amplifiers. Specifications on such transformers can be obtained from manufacturers and radio parts jobbers.

in determining the correct voltage on the tube making it easy to find the current rating of the tube from the tube manual. If a bleeder resistor or voltage divider is used across the DC output the current through this resistor will also have to be added to the tube ratings. When the total current is found by adding these values together a safety factor of about 10% of this total should be added to account for any discrepancy in calculation and to allow for a slight overload. When all these values are determined you will have sufficient information to order a transformer which will operate the receiver in question.

The next problem to consider is the best shape and arrangement of the leads for the replacement transformer. The old transformer should aid in this respect for it will give you one possible shape and lead arrangement. There are several different transformer styles and from these you can no doubt choose one that will serve well for the replacement. Many times there is plenty of space for the replacement and in this case the shape isn't critical, but where space is limited the shape will have to be chosen with more care, making sure that the dimensions of the replacement transformer are such that it will fit in the space available.

In some instances it may prove desirable to repair a transformer that has a shorted or open winding. Shorted terminals are not very common, however, loose solder or excess paste can cause a short between two terminals. A visual inspection should soon reveal this difficulty and if the short has not over heated the transformer causing the insulation of the winding to be destroyed, removing the short will restore the transformer to normal operation.

Where terminal lugs are used to connect the different leads from the transformer to the terminal strip expansion, corrosion, or a poor solder connection may cause an open circuit. Again, a visual inspection of the terminal strip may reveal the open. If it is due to a poor contact caused by poor soldering or corrosion, a visual inspection may not prove satisfactory. To make sure that the open isn't due to a poor solder connection, re-heat the soldered connection and remove the old solder and then check continuity between the two ends of the winding before they terminate at the terminal strip. Make sure that the ends are well cleaned allowing a good contact to your test leads. If there is continuity all that is necessary to make the repair is to resolder the lead to the terminal strip.

If the short or open is due to an internal defect the transformer will have to be replaced. *Rewinding a transformer requires considerable skill and the use of machinery and is therefore not practical for the serviceman.*

A power transformer, choke or audio transformer may be found to vibrate causing audible noises to be produced. This is usually due to loose laminations or a loose winding. Usually the vibration can be cured by tightening the core laminations. It may be necessary to remove the laminations and restack them as tight as possible with the metal core clamp or supporting bolts. Many times a wood or fiber wedge driven in between the loose laminations will cure such vibrations.

Audio transformers are constructed similar to power transformers but of smaller size and usually a larger number of turns giving a much higher resistance for each winding.

The repairing of audio transformers is not usually practical if they are found to have an internal short or open. However, a thorough test should be made to ascertain that the short or open is not external. The tests made upon the power transformer to determine if the short or open is due to the terminal lugs should be made. The problem of knowing what type of replacement transformer to order is usually more difficult with audio transformers than other receiver parts. The response of the entire receiver depends upon the impedance ratio of the audio transformers and unless the replacement transformer has the correct turns ratio to give the required impedance ratio the receiver will not function properly. If the receiver where the faulty trans-

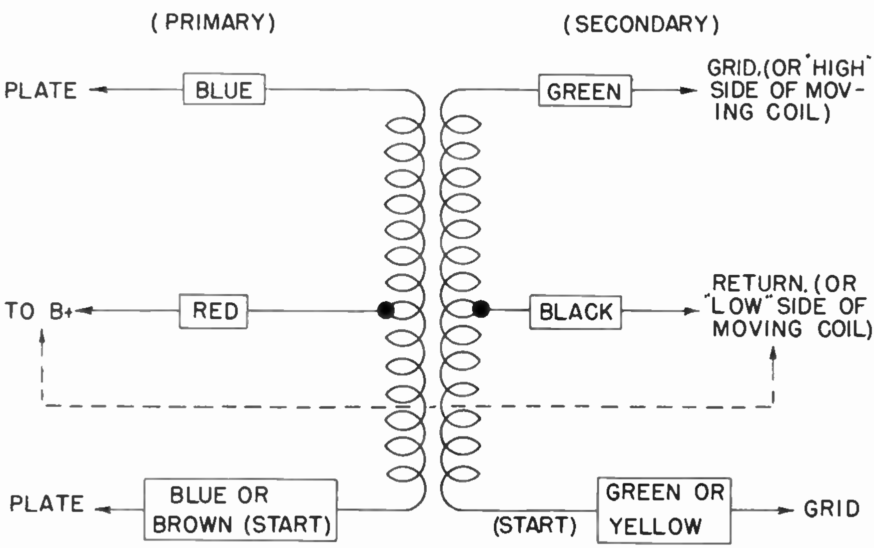


FIG. 15

former is located is of a standard make and not too old exact replacements can usually be obtained by ordering the transformer according to the part number in the receiver. However, if there isn't a part number the problem of ordering the correct transformer is not so simple. Manufacturers of transformers send out literature which in most cases will give sufficient information for selecting the correct transformer from the type tubes used and the circuit involved. Also, tube manufacturers publish tube hand books which give the correct load impedance for all type tubes. This along with the transformer manufacturer's data should give sufficient information to allow you to find the correct replacement transformer.

There is a standard color code used with audio transformers just as there is with power transformers. Figure 15 shows a schematic diagram of a transformer using this standard color code. Not all transformers have center tapped windings. In transformers having but two leads per winding, the color code above the dotted line in Fig. 15 is used.

In some of the new type receivers there are specially made audio transformers for supplying inverse feed back to improve the receiver response. It is important when making a replacement of these transformers that the exact replacement of the transformer be obtained and that all leads from the transformer are soldered in their correct places. It is a good practice to label all leads as you remove them and unless the old transformer must be sent in to the factory for identification that you leave it in the receiver until the new unit is available. In this way you are less likely to forget the correct wiring arrangement.

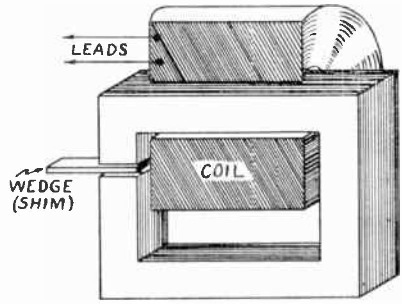


FIG. 16

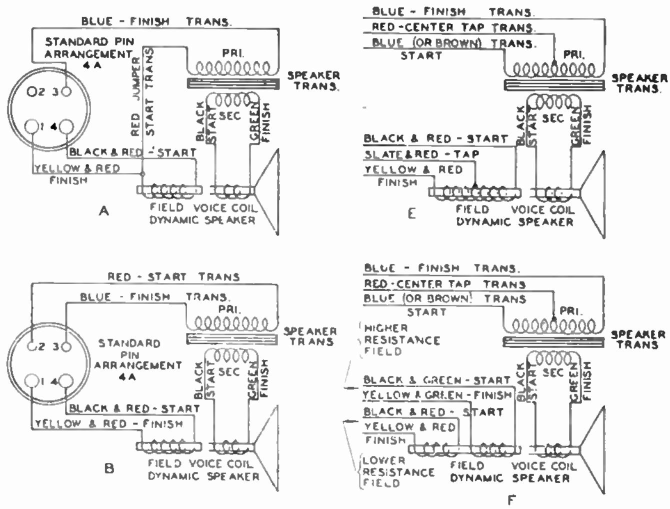
The audio transformer being one of the most important parts in a receiver it is very important that this replacement be accurately made. Make sure that all wiring is arranged in the same manner as the original transformer and that the position of the transformer with respect to the other parts of the receiver is such that a minimum of hum will be picked up. Make sure that it is mounted rigid thus allowing no chance for mechanical vibration.

Many times transformers are damaged because of a failure of some other part and unless you locate this defecttive part before the new unit is installed the new unit will also be damaged. Therefore, it is very important that all parts associated with the faulty transformer be checked before installing the new unit.

The replacement of filter chokes is much simpler than for a transformer as there are just two leads. Because of the air gap in audio and filter chokes hum is often introduced due to a loose lamination near this air gap. This hum can usually be stopped by forcing a wood or fiber wedge in between the laminations at this air gap (see Fig. 16). Never use a metal wedge for this purpose. There is no need for a color code with filter chokes because they have but two leads and

Color Coding for Wiring for Electro-Dynamic Speakers

M5-181 When one of the following arrangements is used to connect an electro-dynamic loud speaker to a radio receiver chassis, it shall be standard to use the color coding and connections shown.



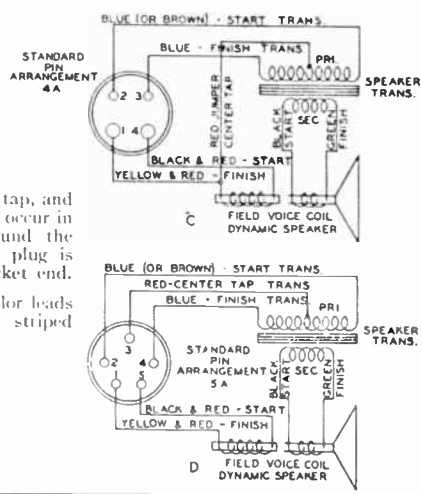


FIG. 17

Note 1: The start, tap, and finish of all windings occur in clockwise order around the plug pins when the plug is viewed from the socket end.

Note 2: All two color leads are to have 50/50 striped designs.

Note 3: When two fields are used on a single speaker, the field of lower resistance shall have leads using common red color; and the leads of the field having a higher resistance shall have a common green color. In the case of three fields the fields having the highest resistance shall have a common orange color.

Adopted Standard November, 1936

it makes little difference which way the choke is wired.

In replacing faulty filter chokes the inductance, the size and the DC resistance of the choke must be considered. The inductance of the usual filter choke varies between 15 and 30 henries. The DC resistance varies considerably depending upon the installation. The DC resistance is important because of the voltage drop across the choke. A choke may have the same inductance as the original but twice or three times the DC resistance. This will mean that the current carrying capacity of the unit is smaller. Usually a higher resistance choke of high inductance is small in physical dimensions. Thus, they are easy to identify. When a high resistance choke is used the voltage drop across the unit will reduce the available DC voltage of the receiver, thus changing the operating characteristics of the receiver which may prove unsatisfactory. Thus, it is very important when replacing a filter choke that approximately the same type choke be used.

As already mentioned the speaker field is usually used as the filter choke and if the speaker needs replacing some identification of the speaker leads will aid in making the replacement. Figure 17 shows a complete speaker lead color code for dynamic type speakers. This will aid you in making tests and replacements.

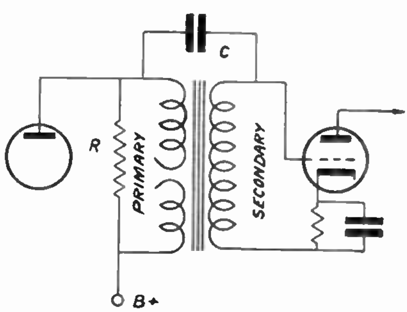


FIG. 18

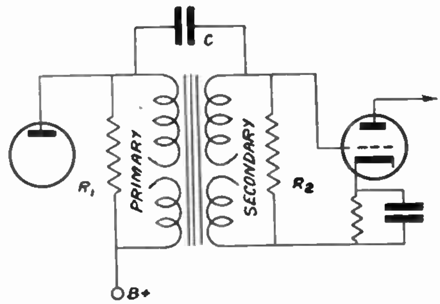
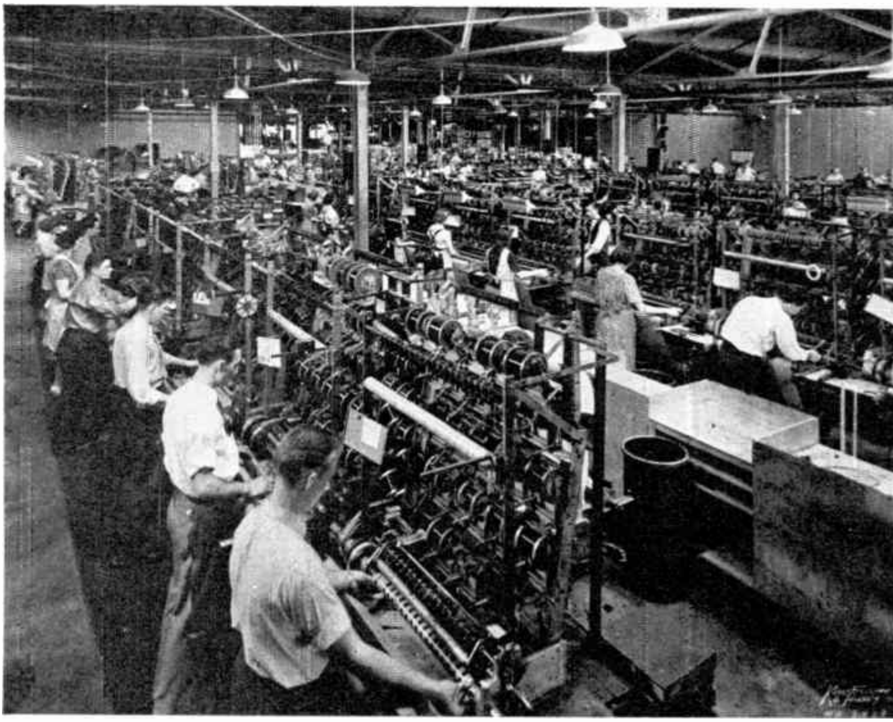


FIG. 19

Simple Repairs

It is better, when possible, to replace a defective radio part. However, there are instances where it is impossible to obtain a replacement; and with some of the older receivers, a new unit would make the repair cost more than the receiver is worth. When such conditions exist, a simple repair which will not impair the operation of the receiver will often prove more satisfactory. In the case of an interstage audio coupling transformer, a repair can be made of an open primary, an open secondary, or both at a very low cost and it can be done in a very short time.

Figure 18 shows a circuit diagram of how an open primary winding in an interstage amplifier can be repaired without replacing the transformer. The value of the resistor depends upon the type of tube feeding the transformer. The value of the condenser should be in the neighborhood of .01 to .1 mfd. This circuit puts a resistive load on the plate of the driver tube. The value best suited for this purpose can be secured from any good tube manual. The tube manual will give a list of possible operating conditions for the tube in question; and from the data given, the correct load resistance for practically any tube can be found. With the information given in the tube manual the operating con-



This photograph shows a view of the winding department in the factory of the Chicago Transformer Co. Wire for the windings of transformer is fed from spools as shown. The winding form may be very long and thus several windings may be completed at one time. Later the form is sawed apart to provide separate windings for several transformers.

ditions and the proper circuit part values of almost any radio tube can be found.

When the primary shows continuity and the secondary is open, the repair is very much the same as for the open primary with the exception that the resistor is placed in the grid circuit of the tube being driven. Operating in this manner changes the stage from a transformer coupled amplifier to capacitive coupling as in the preceding case. The plate load on the driver tube is an impedance load rather than a resistive load in this case. Again the value of the resistor depends upon the tube involved. The tube manual should be consulted to determine the best value to use for this particular tube.

Figure 19 shows how an open primary and secondary can be repaired. With this circuit the transformer is completely replaced with resistance-capacitive coupling. The value of the resistor as in the preceding cases can be secured from a tube manual.

With either of the three repairs mentioned, the characteristics of the audio amplifier in the receiver will be changed and the gain of this stage reduced. This is especially true where both windings are open. Therefore, you can expect a difference in the performance of the receiver. Audio circuits using a single tube audio coupling transformer are not common in the later type receivers, however, many of these later receivers where a push pull output stage is used, use a trans-

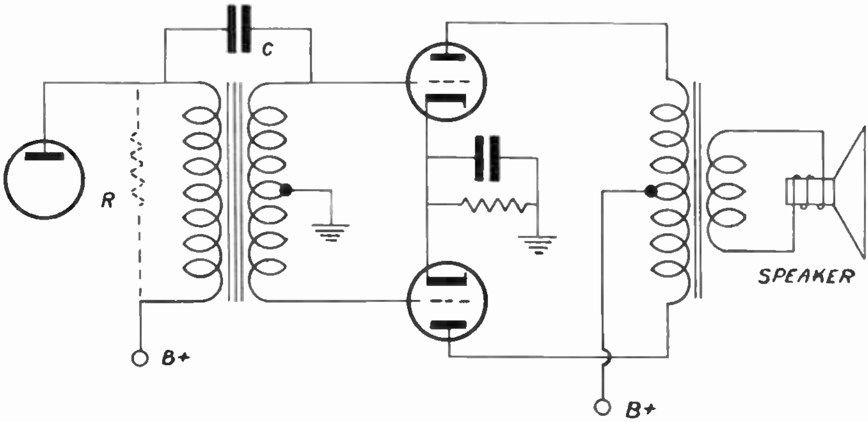


FIG. 20

former to drive the grids of the push pull tubes. Figure 20 shows a circuit of just such a stage. A temporary repair of this transformer can be accomplished quite easily, if the primary winding is open.

The value of the resistor shown in dotted lines will have to be secured from a tube manual. The operation of the secondary then is just as a tapped choke and acts to invert the voltage so that the grids of the push pull tubes will be of proper phase. As you will remember, to operate a push pull stage, the grids of the two tubes must be operated in opposite phase. That is they must be 180 degrees out of phase with each other.

When the secondary of a push pull driving transformer becomes open the problem of repair is more complex and will require an extra tube or a tapped choke for the repair. As phase inversion is necessary to drive the push pull grids, it will be necessary to devise some means of accomplishing this if a driving transformer for this receiver is not available. The use of a tapped choke used in the same manner as for the secondary of the transformer of Fig. 20 or a separate phase inverter tube will have to be added.

When it is necessary to add tubes and a number of parts, the service cost of a repair goes up considerably and unless it is absolutely essential that it be done, it should not be attempted.

There are conditions which may require a separate tube to be added to obtain the correct phase relation when replacing the secondary of a push pull driver transformer. Figure 21 shows a diagram of a simple, yet effective phase inverter. The phase inverter tube is usually so operated that it has an amplification of unity, that is, it has no amplification at all. The

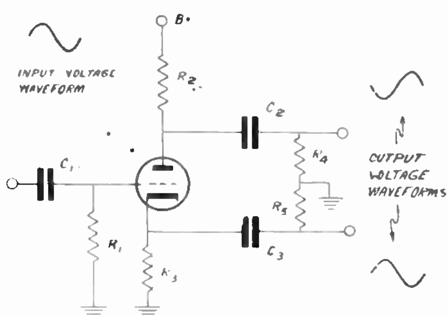


FIG. 21

cathode resistor R3 has no by-pass condenser and its resistance value is the same as R2. Thus the voltage developed across R3 is equal to the voltage across R2, but as the cathode voltage is in phase with the grid voltage and the plate voltage is 180 degrees out of phase with the grid voltage, two equal but out of phase voltages are developed at C2 and C3, giving the correct phase relation for driving a push pull amplifier stage. Thus, this circuit can be used to replace the driving transformer if it is necessary to do so. As in the previous methods of repairing audio interstage transformers, the gain of the driver stage is reduced due to loss of the transformer gain. Also the audio response of the receiver will be different. It is important when making changes of this type to select the correct parts so that the receiver performance will not be altered too much and improved if possible.

The output transformer of a receiver is less adapted to repair. Thus, if it becomes faulty a replacement will have to be obtained. If the exact replacement is impossible, a substitute can in most cases be found which will prove as satisfactory as the original (use a universal output transformer).

The selection of the proper replacement can be made by the use of the information supplied by the transformer manufacturers or by the use of a tube manual. The function of an output transformer is to match the speaker impedance and to provide the proper load impedance for the output tube or tubes.

A tube manual will aid in securing information concerning the proper load for the tubes involved. The impedance of the voice coil of the speaker will determine the secondary impedance. The impedance of most speaker voice coils vary from about 3 to 15 ohms. The impedance of the speaker voice coil is usually given upon the diagram of the receiver. The manufacturer of transformers or your radio parts jobber can usually supply you with the correct transformer if you send them the make and model number of the receiver and the type and number of tubes employed.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 What is the principle use of the ohmmeter in testing power transformer primaries?

No. 2 Would measurement of the line voltage at the power transformer primary give any information as to a partial short or open of the primary?

No. 3 If a radio receiver is rated at 55 watts and you removed all the tubes and tested the power transformer in accordance with Fig. 4, what approximate reading on the voltmeter would indicate that the transformer was in good condition?

No. 4 If you measure the voltage of a 6.3 volt heater or filament winding with all tubes of the receiver in place, are you likely to measure 6.3 volts or more?

No. 5 What test should be given a coupling transformer which shows continuity and yet will cause interruption in reception?

No. 6 Which circuit in this lesson is used to determine the impedance of both windings of an output transformer?

No. 7 With respect to a speaker field or filter choke what is the maximum percentage resistance change at operating temperature?

No. 8 By what simple method can you determine the proper resistance value for a replacement speaker field coil?

No. 9 Is an input transformer feeding a class B stage of amplification of the step-up or step-down type?

No. 10 Would a leakage resistance of 450,000 ohms between primary and secondary of the transformer in Fig. 7 indicate that a replacement was necessary?

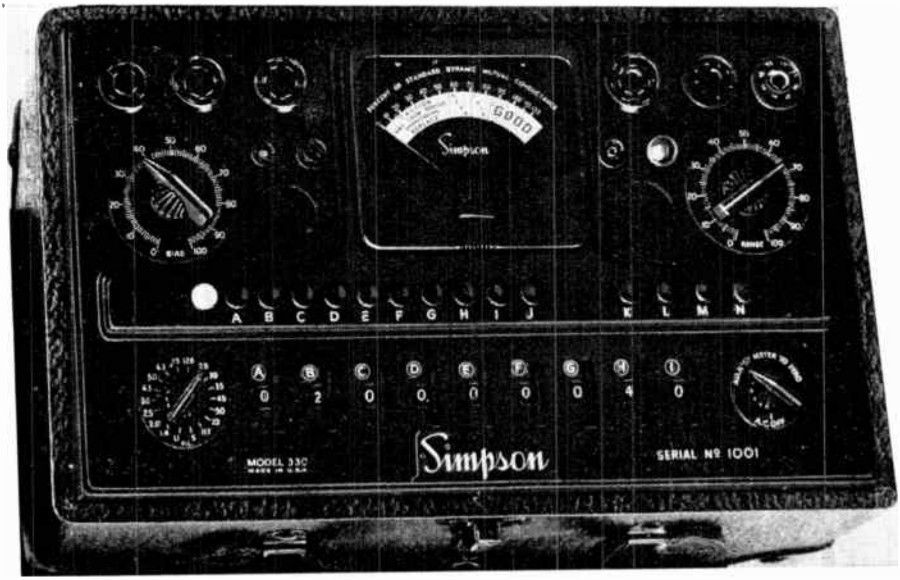
HOW RADIO TUBES ARE TESTED

LESSON NO. TV-14

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K9542M



The above photograph shows a manufactured tube tester such as will be found in thousands of radio stores and service shops all over the country. This particular unit is made by Simpson and is their model 330.

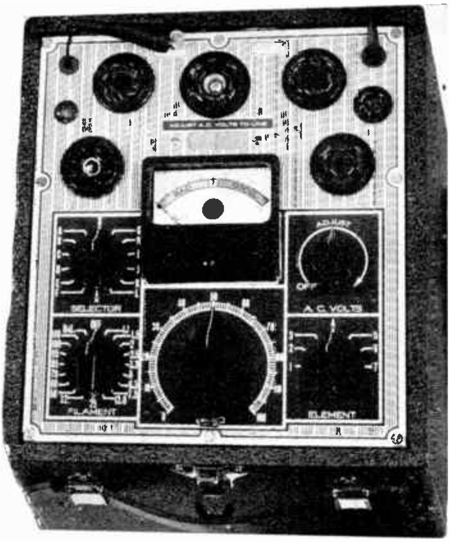
HOW RADIO TUBES ARE TESTED

Lesson TV-14

The radio vacuum tube is by far the most complex single unit used in a radio receiver. Unfortunately from the testing viewpoint, the average tube has a number of characteristics which it is desirable to measure. For amplifier tubes, some of these would be amplification factor, AC plate resistance, mutual conductance, DC plate current, power output, plate dissipation, etc.

Now a tube is designed to operate in a certain way in a radio circuit, and a change in any one of the characteristics as mentioned will have some effect on the operation of the entire circuit in which the tube is used. To correctly test any tube you would need to make an individual test of each important characteristic of the tube. Further along in this lesson you will recognize the importance of the different tests which can be made on different type tubes.

Tube testing is employed by the tube manufacturer and is considered a necessary part of the manufacturing process. It is very important to the manufacturer because of the wide variations which can occur in the making of a product of this type. Although each manufacturing process can be very closely controlled, the finished tube is the result of so many operations that its characteristics may have quite wide variations. As a result, the testing of tubes constitutes a a substantial part of their ultimate cost. A great number of *finished tubes* must be discarded because their characteristics are not within the toler-



This photograph shows a Triplett manufactured tube tester of the portable type. It employs seven sockets and a large square meter which is calibrated in terms of BAD, QUESTIONABLE and GOOD to indicate the condition of the tube under test.

ances required by the manufacturer.

For example, gauging of the wire of which grids and screens are made and size of their diameters can be controlled to better than 1 or 2%. Likewise, element spacing, material alloy content, welded connections and degree of vacuum can all be controlled within close limits. However, when such a factor as AC *plate resistance* is measured for example, you might find that it is 15 or 20% higher or lower in one tube than in another of the same make and model. The value of the AC plate resistance will depend upon almost all of the factors serving to make up the tube.

Fairly large tolerances in some of the characteristics of a tube may be permitted in order to sell them at a reasonable price and fairly wide variations in many of the characteristics will actually make no material difference in the tube's operation. Such a thing as the filament current depends on the length, diameter and material composition of the filament and on the welded points and leads. For this reason, tubes can be manufactured with filament currents uniform within 2% without much difficulty. Thus, is explained why a 2% change in the filament current of a normally operating tube will make no material difference in its operation.

On the other hand, a characteristic such as the *amplification factor* of a tube is subjected to many other factors in the construction process of the tube and cannot be controlled so closely.

The amount and kind of testing done by the tube manufacturer is quite extensive. If the serviceman had to make such tests, it would require much of his time and the cost of equipment would be prohibitive. Notwithstanding this fact, every serviceman can make satisfactory tests on the average type of tube.

For a number of years *new tube types* have been introduced to the market at an average rate of approximately one every week. For receiving and public address purposes alone, there are some 500 different receiving tube types in use, and new types are still being developed at about the same rate.

This makes it apparent that the more basic the tube testing apparatus, *the more easily it can be adapted to the ever growing list of tube types.* Therefore, basic test methods will first be discussed for determining individual tube characteristics. You will then see how some characteristic tests can be combined in a single test and how various tests are made in the various tube testers in present use.

Manufacturers of tube testers are

very much aware of the changing tube design. Therefore, many of the new type tube testers are designed with a separate selector switch which allows for connections between all elements of the tube, reducing the possibility of the tester becoming obsolete. Some tube testers are provided with spare socket buttons so that a new socket can be installed if a new type of tube base is designed that will be different from those already in use.

The Filament Test

Except in rare instances, the filaments of tubes are not directly tested. In all glass tubes, continuity of the filament circuit is assured by the light emitted by the filament when connected to a filament voltage source. Of course, this cannot be done in the case of metal tubes but heat from the envelope of a metal tube is evidence to indicate that the filament is operating. In most tube testers the filaments are supplied with AC from a step-down transformer. Even tubes designed for battery operation may be operated with an AC filament supply for the purpose of testing.

With the low voltage, low current type tubes such as those used in portable battery receivers and in some AC-DC receivers, the filament when burning is not bright enough to be seen and the heat generated is so small that the tube may not heat up enough to be noticeable to the touch. A continuity test across the tube filament pins will reveal any open filament in this type of tube.

To obtain the correct filament voltage for each tube type to be tested the power transformer secondary in the tube tester is tapped for accurate voltages. These voltage taps begin at 1.1 volts and usually include every voltage employed for receiving tubes which have been in use the last 10 years. A representative list of such filament voltages follow in table form:

1.1	5.0	35.
1.4	6.3	45.
1.5	7.0	50.
2.0	7.5	70.
2.5	12.6	85.
3.3	14.0	117.
	25.0	
	30.0	

Besides the list of filament voltages given in the table, there are a few special type tubes using different filament voltages. These tubes are not common, but as they do exist their filament voltage should be known by the serviceman so that he will know what to expect when he encounters an unfamiliar tube. These special tubes have the following filament voltages: 32.5, 28, 20, 21, 2.8, 1.25, 3.2, and .625 volts.

This tube tester is of the large upright type for counter use. The meter is located at the top of the instrument in full view of the customer so that he too may read the condition of the tube under test. Various switches are provided which must be changed for different tube types according to the manufacturers instructions.

In order to get the proper response from each tube under test, it is necessary to have these voltages very accurate. Moreover, it is not possible to put a winding on a transformer and expect it to maintain an accurate fixed voltage under all conditions of load and line voltage variations and also for load variations placed on the transformer by the very tube under test. This involves both a means of adjusting the primary turns-per-volt and a means of measuring or indicating the secondary voltage or the correctness of the primary adjustment.

In Fig. 1 several methods of adjusting the number of primary turns to the line voltage are shown. You are, no doubt, familiar with the fact that the voltage available at an electrical outlet will vary somewhat throughout the day because of load conditions. The power company can compensate for this at the plant but not for the unequal distribution of loads throughout all of their lines. Thus, the line voltage may easily vary from 105 to over 125 volts for a regular 115-117 volt line.

The simplest type of line voltage adjustment consists of using three taps on the transformer as in Fig. 1A for high, low and normal line voltage. This method of line voltage com-

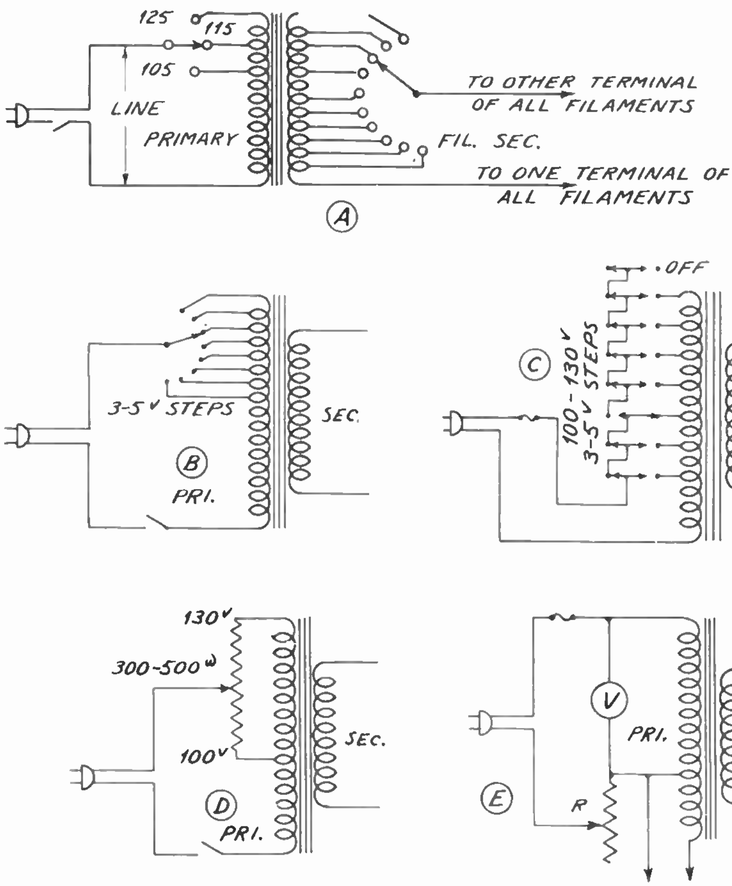


FIG. 1

pensation is widely used for receivers but is not considered adequate for modern tube testing requirements. This method may be found on some of the very inexpensive tube testers and is sometimes used for home made testers. The conventional filament switching system is shown with this diagram for the secondary side of the transformer.

A more accurate line voltage compensation adjustment may be had by using a number of taps as in Fig. 1B, where a tap is attached at every 3 to 5 volts above 105 volts along the primary. From 7 to 10 taps may be used to extend the range from 100 to 130 volts, and the line compensation is better than 3% for 3 volt taps or 4% for 4 volt taps.

When push-buttons were introduced into tube tester design, this same method was used except that push-buttons did the switching instead of tap switches. A push-button switching system would appear schematically as in Fig. 1C.

Although less efficient, the most rapid and accurate methods appear in Figs. 1D and 1E. It is less efficient because a certain amount of power is wasted in the resistance but this is not objectionable because the tube tester is used for only a short time. It is not turned on continuously like a receiver or public address amplifier.

At Fig. 1D, a 300 to 500 ohm wire wound resistor is connected from a 105 to a 125 volt tap on the power transformer or from a 100 to a 130 volt tap. The movable element of the potentiometer may be adjusted for the exact voltage for perfect line compensation. The variable resistor in Fig. 1E is a series resistor used with a transformer, having a 100 to 105 volt primary. When the voltage is above this value (100 to

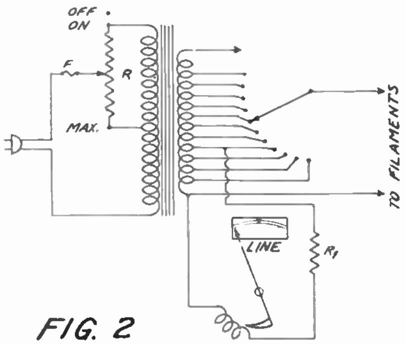


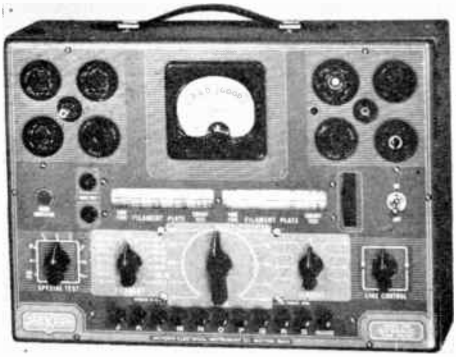
FIG. 2

105 volts), the resistance is increased to reduce the additional voltage across it. An AC voltmeter is used across the transformer winding in this case to determine the correct setting of the resistor but the voltage need not be measured in this way as will be explained.

A load placed on any transformer winding will reduce the voltage of every tap on the transformer. For example, if a load is placed on the 6.3 volt winding of the filament secondary as in Fig. 1A such as to reduce the voltage 10%, it will reduce all of the voltages of the other 17 taps by 10% as well. It is assumed, of course, that this filament winding has 18 taps, as described by the 18 filament voltages in present use.

It should then be obvious that it is only necessary to measure the voltage at one tap to determine the correct voltage for all of them. The minor variations which would enter into the problem may be neglected without reasonable loss of accuracy.

Figure 2 shows an ordinary iron vane type of AC voltmeter connected permanently to one of the filament taps. A fairly low voltage tap is chosen so that the load and hence loss provided by the meter will be negligible. A resistance R1 is then chosen so that the meter will read center-scale or to any predetermined mark



The above view illustrates another manufactured tube tester as made by the Jackson Electrical Instrument Co. Sockets are included for all types of tubes in general use. Just under the meter note the use of the roll type of chart. By turning the control knob which controls this chart printed directions are brought into view for testing the many types of tubes in general use.

on its scale when R is correctly adjusted.

Assume that a tube with a 5 volt filament, such as an 80 rectifier is to be tested. The filament switch is set to 5 volts and the tube is inserted in the proper socket of the tester to be described later. The two terminals marked *To Filaments*, in Fig. 2, supply this tube filament. The line switch is usually associated with the line compensator adjustment R. Note the arrangement of the switch and resistance in Fig. 2. The magnetic vane meter, is connected to the 2.5 volt filament winding and will read center-scale, or to any other predetermined mark, when the voltage here is exactly 2.5 volts. The movable arm of R is moved gradually toward MAX until the voltage rises to 2.5 volts at the meter tap, and this means also that at the 5 volt tap the voltage will be exactly 5 volts. Since the tube is drawing its proper filament current as the correct setting is found, the transformer is adjusted under load and since the correct adjustment is always approached from a lower voltage value there need be no danger of overloading the tube. If the line voltage is high (120 to 123 volts) the correct adjustment will be quite near the ON position of R, while if the line voltage is low (105 to 108 volts) the movable arm of R must be moved near the end of its clockwise direction of rotation.

For gas tubes, such as the OZ4 having no filament, the line compensator setting is made simply without placing the tube in the tester. For glass tubes, filament operation can be observed by the light emitted and for metal tubes filament operation can be determined by heating of the tubes. If the tube has not definitely heated in 1 minute, it may be assumed that the tube has a defective filament. In most cases, a half minute is sufficient time to determine this.

If the circuit of any tube is shorted, either the line fuse or a part of the tester will burn out or the correct line adjustment cannot be made. Tube testers are not usually provided with a means of measuring filament current as any serious deviation in filament current from the normal value will be reflected in other tests. For example, if for some reason the filament current is only half normal, the plate current of the tube under test will likely be half or much below half normal if any plate current flows at all. The tube is, therefore, defective and because of this, it does not really matter what the nature of its defect

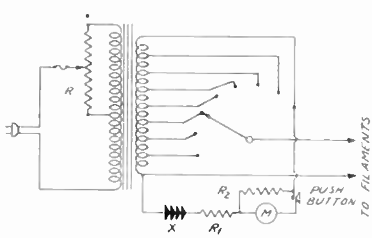


FIG. 3

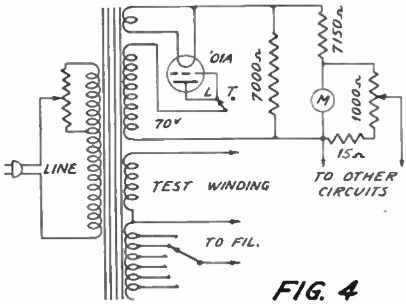


FIG. 4

may be. It must be discarded in any event.

Once the correct filament voltages are found there is no further use for the *line meter*. Thus, instead of using a separate meter for line adjustment, more often the regular meter used in all other tests is used first for line adjustments and then switched to other circuits for other tests.

The regular test meter is always a DC meter because although the AC is not rectified before being applied to the tube under test, the tubes under test serve this purpose so that the ultimate reading is always DC. It is, therefore, necessary to provide a separate rectifier just to operate the meter for the purpose of line voltage adjustment. An application of this method is shown in Fig. 3. The meter circuit is wired across the lowest convenient filament tap in series with a copper-oxide rectifier X and a calibrating resistor R1. Sometimes a push-button is included for line voltage adjustment but usually the selector switch for various testing purposes takes care of this switching. After the voltage is adjusted with the tube to be tested in the tester socket, the meter is switched to other circuits for making tests to be described.

If the meter is an 0-1 or 0-2 milliammeter it will usually require a shunt such as R2 to enable the circuit to draw enough total current through the rectifier X so that it may be depended upon. The characteristics of a copper-oxide rectifier at low currents are not sufficiently constant to be depended upon. Since this involves additional switching it has generally been found more satisfactory to use a tube rectifier for this purpose.

An application of the 01A tube as commonly used in many testers for this purpose is shown in Fig. 4. The tube with grid and plate connected together form a rectifier. It has a separate filament winding of its own as a rule and the transformer is provided with an independent 70 volt winding. This voltage value as well as the resistor values have been chosen for the rectifier tube so that when the correct voltages are at the filament terminals under load, the meter will deflect to a predetermined mark usually indicated as described with a red line or an arrow and marked *Line*. After line compensation has been achieved, the rectifier is simply switched out of the circuit so that the meter is available for other purposes.

Figure 5 shows a method using a 6H6 rectifier for line voltage adjustment. Note that the primary and filament windings are in this case combined into one winding, the transformer acting as an auto-transformer. The 6H6 filament is, of course, permanently connected to the 6.3 volt filament winding. The various other leads go to other testing circuits to be described.

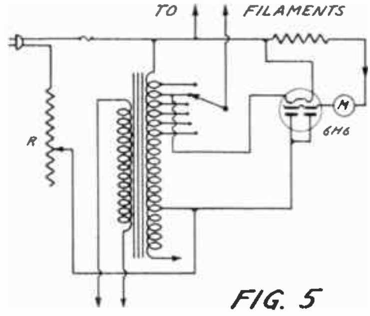


FIG. 5

1. Ep....................Plate supply voltage (maximum or recommended).
2. Ip....................Plate current flow, at recommended plate voltage and with all other conditions under consideration.
3. Esg....................Screen grid voltage (maximum or recommended).
4. Isg....................Screen grid current flow at recommended screen grid voltage and other conditions stated.
5. Eg....................Grid bias voltage (for type of operation stated).
6. Rp....................AC plate resistance (under stated conditions).
7. Gm....................Mutual conductance (under stated conditions).
8. Mu....................Amplification factor.
9. Po....................Power output—watts.
10. Pp....................Plate dissipation—watts.
11. Psg....................Screen grid dissipation—watts.
12. D%....................Distortion percentage.
13. RL....................Recommended load resistance (under stated conditions).
14. Eout....................Filter output voltage of rectifier with inductive or capacitive filter input.
15. Inv.P....................Inverse peak voltage of rectifier.
16. C In....................Input capacity (input to all other elements).
17. C out....................Output capacity (output to all other elements).
18. Cgp....................Capacity (grid to plate).
19. Cgf....................Capacity (grid to filament or heater).
20. Ion....................Gas content of tube.

The many characteristics of tubes which you must know about in order to determine if a tube will work properly in a given circuit will now be considered. Remember that it is never necessary for the serviceman to test all of these characteristics of a tube to determine its condition. The complete list is given, however, for purposes of their relative values in this study. (See the above table).

These are some of the characteristics specified for tubes. Obviously, if you had to test tubes under even one set of conditions such as detector operation, amplifier operation, oscillator operation, class B audio operation, etc., it would require an elaborate outlay of equipment for even one tube type. Multiplying this by 60 or 70 radically different tube designs you would have an entirely different situation.

Now consider which of these characteristics you must test to determine the real worth of the tube. Obviously, the plate and screen voltages are externally supplied and do not have to be tested. At the recommended plate and screen voltages (for screen grid, beam and pentode tubes) and at a recommended bias or class of operation the plate and screen currents will give an idea of the emission of the cathode or filament. In fact, for any positive plate voltage and any positive screen voltage a current will be drawn from the cathode which may be used as a measure of the *electron emission* of the tube. If the emission is only half or one-third normal at normal plate and screen voltages and bias value it will likewise be only one-half or one-third normal at other plate and screen voltage values. Of course, these voltages must not be so high that the maximum emission of the tube or its saturation point has been reached nor too low to get a satisfactory measure of the emission current.

As long as the grid influences the

plate current it may as well be connected to the plate, screen and all other elements for the emission test.

Now, if you take a tube to be perfect, such as a type 6SK7 for example, and connect the plate, suppressor, screen grid, and control grid together and impress, for example 20 volts, between this common connection and the cathode with the cathode negative, of course, a certain value of current will flow through the tube. Assume that this is 1.2 milliamperes. Now, if you obtain another tube of this type, make the same connections and also obtain a reading of 1.2 milliamperes, there is at least some probability that the second tube is as good as the first. There is, of course, the possibility that the plate may be shorted to the suppressor, or screen or even to the control grid within the tube. In this case, the defect would not be evident through this test because these elements are connected together.

Typical connections for the emission type tube test are shown in Fig. 6. The setup here shows a test of a tube such as a 6C6. The line compensator R has already been set with the filament switch to 6.3 volts with the tube in the socket. One setting of the selector switch SW1 connects the plate, suppressor, screen and control grid to one terminal of the meter while another connects the cathode to one side of the filament.

A 30 volt transformer winding supplies AC to the tube acting as a rectifier with the meter in series. A push-button is provided which allows the reading to be made.

It would, of course, be possible to use a fixed resistor in place of R1 and then to specify the value of current flow to be expected from *each tube type*. The great variation in current ranges, however, for the various tubes would require more switching for various shunts across the meter. It is, therefore, much simpler to use a potentiometer at R1 and to mark its scale 0-100. For each tube, a number on this scale is specified, which will give exactly the same reading for practically every tube (every one tested on this scale), and the meter range is automatically set in this way.

Since there is a range of values for which a tube may be regarded satisfactory, a large portion of the maximum deflection end of the scale is usually colored green and marked GOOD. This simply means that, if the meter deflection is anywhere within that zone of deflection, the tube may be regarded as in good condition. Below this zone is a narrow yellow segment usually marked DOUBTFUL, while the lower end of the scale (usually the lower half) is marked BAD on a red background.

All tubes with the 6 pin base are placed in this socket (the one shown in Fig. 6) and many of them are tested with the same setting of SW1 but with a different setting of R1. Some of them are tested with a different setting of SW1 because of their base connections with the same or different settings of R1. Other connections of the complete unit which would only confuse this basic circuit have been omitted in Fig. 6.

By use of this circuit the tests for other basic tube characteristics has by no means been exhausted. Only the first five items of the aforegiven table have been combined into one test. Re-

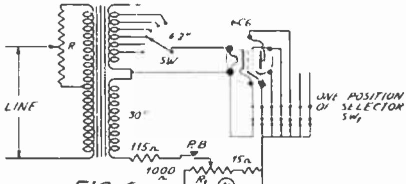


FIG. 6

Here is shown a very popular Philco type of manufactured tube tester. It is push-button controlled as are many of the most modern tube testers. Note the use of blank sockets. These may be removed in case new tube types are brought into use. This makes it possible to provide for new tube types without having to buy a new tube tester.

ferring to the AC plate resistance (Rp), this characteristic of the tube is not tested by the emission method. If the emission test shows satisfactory results, and tests for shorts, leakage and gas in the tube, is at a minimum or shows no indication, you can ordinarily assume that the AC plate resistance of the tube is satisfactory. Since the AC plate resistance depends on element spacing within the tube, and since this also affects the emission, as a rule the AC plate resistance will be satisfactory if the emission is satisfactory.

The emission test gives little information about the *mutual conductance* of a tube which is by far the most important characteristic of any tube having a control grid. The mutual conductance depends on how much change in plate current can be brought about by a given change in grid voltage under certain specified conditions of operation.

Naturally the emission test can give no idea of this fact, but remember what factors affect the mutual conductance of a tube. These are principally the size of the grid, its ratio of open space to wires, its relative spacing from the cathode and plate, spacing of all other elements in the tube, the element arrangement, and type of tube—that is, triode, tetrode, pentode and degree of vacuum, etc.

It should be carefully noted that all of these items are *physical characteristics*, which normally do not change with the operation of the tube. Once a tube has been constructed in a certain way to attain certain operating characteristics, these physical qualities of the tube do not change. Of course, if the tube is severely jarred so that the elements are bent out of position or shorted, or if any of the elements undergo any chemical change which would release gas in the tube due to impurities, the mutual conductance or transconductance will most certainly change. In some cases, such changes will cause the emission to be higher or lower than normal but in other cases they may not.

It is on the basis of the rare probability of this happening, that the emission test can be used to indicate the entire condition of a tube.

Although the emission test will allow for a test of the majority of tube failures, most of the modern tube testers provide a means for checking the mutual conductance. They do not give an actual numerical value of the tube's mutual conductance but a comparison with a standard set-up by the tube manufacturer which will aid in identifying faulty tubes.

The Short Test

A tube must first be tested for internal shorts before other tests are applied. This is specified as a first test because it safe-guards the instrument and meter against damaging currents. The short test, of course, is an essential test for a tube and it is usually worth less if any two of its elements are shorted.

A short test must be applied with the heater under operating condition because this is the way the tube will be used, and it is possible for a short to be formed after the elements are raised to operating temperature due to expansion. It is also possible for two elements to short only when a tube is cold but this is very rare and of little importance if the short is always broken when the tube is heated.

In the rapid development of tube testers there have been a number of methods used for determining shorts. Being based on circuit continuity, they are all basically very simple. The most widely accepted method of short checking in present use is the *neon tube*. One method of its application is shown in Fig. 7. Terminals X and Y are the actual terminals across which a short is indicated. Across the line voltage is placed a condenser C in series with the neon tube circuit R-N and the test terminals X and Y.

Now, if point X is connected to each element of the tube individually, with all other tube elements connected, it can be determined if each element has any direct connection to any of the others. Obviously, if points X and Y of Fig. 7 are shorted, there will be a completed AC circuit producing a large voltage drop across R and the neon lamp. There will be no voltage drop across terminals X and Y and the voltage drop across C at 60 cycles will be very low compared to R. The neon lamp will, therefore, flash 120 times per second for 60 cycles and appear to be lighted continuously.

Connections from each of the socket terminals are brought to individ-

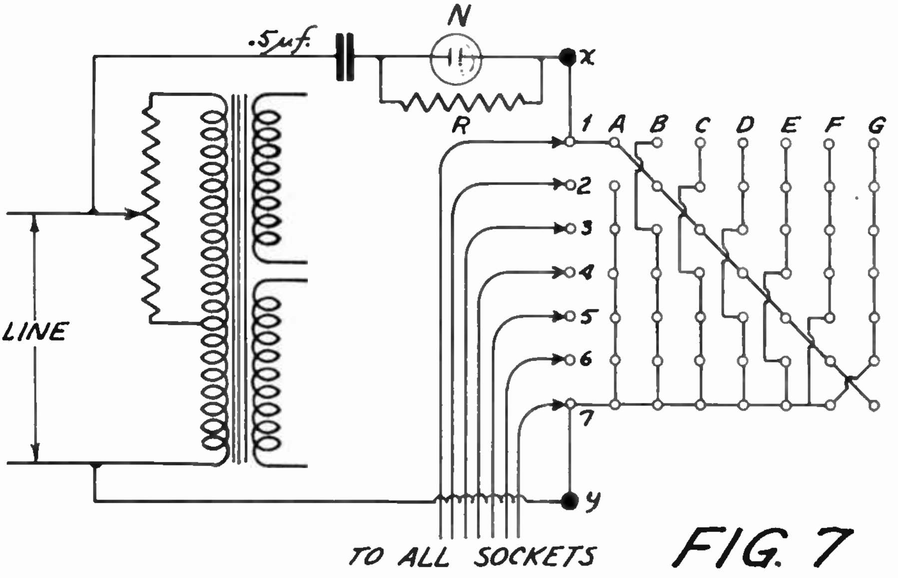
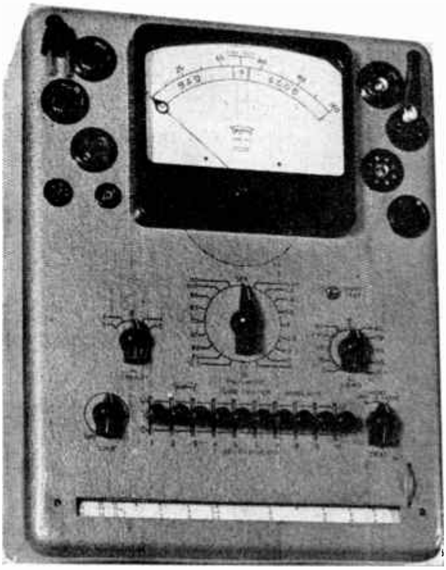


FIG. 7



Above is shown another type of manufactured Triplett tube tester. A large square meter is used and it is calibrated in terms of GOOD, QUESTIONABLE, and BAD tubes. This makes it possible for non-technical help to test tubes because if the simple directions are followed it is no trouble at all to test tubes with this type of tester.

ual switch terminals. These terminals in many types of testers are actually switch points and go to a number of sets or rows of terminals for making various connections to the SHORT TEST circuit as well as other circuits. Figure 7 shows these rows as A, B, C, etc., while the switch points are numbered 1 to 7.

At position A, for example, the plate of the tube under test may be connected to point X while all other elements are connected together and to point Y. In position B, for example, the suppressor may be connected to X and all other elements are connected to Y. Thus each element is individually selected and tested for a short to all other elements within the tube.

As mentioned before, the short test is made while the filament of the tube is in operation. This means that the cathode is active and that for most positions of the switch there will be rectification in one direction or the other, depending, of course, to which terminal (X or Y) the cathode is connected.

For either direction of rectification, however, the condenser C will charge to very nearly peak voltage of the supply and with no appreciable internal leakage will retain that voltage. There will thus be a single flash of the neon lamp due to this initial charging of C and then the neon lamp will go out for the duration of the test. This is perfectly normal operation and does not indicate any defect in the tube.

The neon lamp will almost always flash once as the switch is changed from one setting to the next. If it remains on for any one setting, one of the tube elements is shorted to another. No method is provided for determining which two elements are shorted because this does not matter. The tube is useless for the purpose intended and for test purposes it makes no difference which e l e m e n t s are shorted. In any case, the tube must be replaced with one which does not have an internal short.

There are some tubes designed in such a way that certain elements are connected together internally and, of course, these types will show a short when tested as described. The tube chart or manufacturers instructions supplied with the tester will indicate when these shorted elements should be expected. That is, the chart may state that positions 1, 2, and 3 of the shorting switch should show a short when one particular tube is being tested. If no short is indicated between these points it will mean there is an open circuit and the tube will need replacing.

Although only one socket is shown in Fig. 7, it must be understood that all of the sockets in the tester are interconnected. Other sections of the selector switch as in Fig. 7, beyond F and G (not shown) can be wired to make connections as in Fig. 6 for the emission test, and still another section can be wired to make the line voltage test as in Fig. 5 or any other line voltage test.

So far, only a small number of the possible tests mentioned in an earlier part of this lesson have been described. The other tests with the exception of the test for *gas content* are of interest to the tube makers only. These characteristics are found by laboratory procedure and it would not help the practical serviceman to know such values as plate dissipation, or distortion percentage, etc. These characteristics are provided by the manufacturer so that the equipment designer may be guided in working out circuit designs. Several of the items, such as numbers 13 and 14 (previously mentioned) cannot actually be called characteristics of tubes, but rather specifications of their operation.

Gas Test

In the manufacture of tubes all possible traces of gas are usually removed in the evacuation process. This, of course, refers to the high vacuum tubes which do not require gas to operate. Certain other tubes, such as the mercury vapor type, the thryraton and the cold cathode rectifier, operate by virtue of their gas content. Thus, this reference refers to the ordinary type of amplifier, converter, detector tubes, etc.

In ordinary use tubes will often *acquire* traces of gas. In some cases this is gas which was absorbed by the metals in the tube in the manufacturing process and in other cases gas is formed by decomposition of impurities in the metals of which the elements are made. This will frequently happen in tubes which have been overloaded.

The presence of gas in any quantity which would affect the correct operation of a tube will cause some amount of grid current to flow with no external voltage applied to the grid but with AC or a positive voltage applied to one or more of the other electrodes. This suggests the method by which a test may be made for gas in any tube.

First it is necessary to connect the grid directly to the cathode and then connect all other elements together and to a voltage source through a meter. Next note the meter reading. Then connect a large resistance in the grid circuit (500,000 ohms) and note any change in the meter reading. The circuit for making this gas test is shown in Fig. 8.

The five terminals of the test selector switch make the proper connections shown and the push-button switch marked GAS TEST is pressed while observing the meter reading. Under conditions of no gas there will be no change in the meter reading, while the presence of gas will be indicated by a change in the meter reading (usually a decrease although not

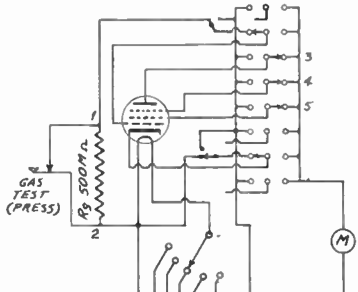


FIG. 8

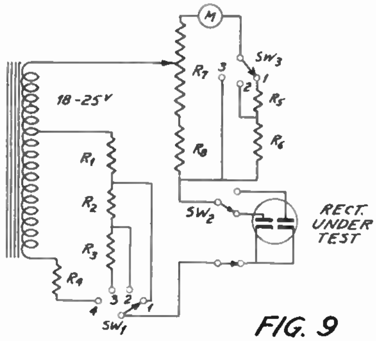


FIG. 9

always so.) Only in the case of a power amplifier can the presence of gas be tolerated, and in this case only where experience shows that it has no ill effects.

Since the gas test is not absolutely essential it will not be found on all tube testers.

Rectifier Testing

Being practically the only possible test which can be applied to a rectifier, the emission test is the ideal one. However, the range of emission currents for all of the rectifiers used in radio is so varied that many circuit changes must be made to test them.

In the first place, for small diode rectifiers, such as the 6H6 or the diode units in various other tubes, such as the 75, the meter is not intended to indicate within its section marked GOOD. The current that a small diode of this kind will carry will deflect the meter perhaps only one-fifth full scale. Instructions with each tube tester will give the proper information by which to judge the condition of the diode.

Part of an actual tube tester circuit is shown in Fig. 9, in which a diode section is being tested. Switch SW1 is part of the test selector switch, as described before and selects the proper voltage to be impressed on the diode and the proper series resistor for each tube group. Terminal 1, for example, would be used for mercury vapor tubes where a low voltage (just sufficient for ionization) is used. A series resistance Rl is used to limit the rectified current to a value which would be safe for the tube and which would fall roughly within the meter range. The higher voltage would be used for high vacuum rectifiers carrying low current.

Switch SW2 of Fig. 9 also a part of the test selector switch, selects first one plate of a full-wave rectifier and then the other as rectifier plates must be tested individually for the proper results. The SW3 section of the switch chooses the proper meter loading in case the current range involved through R7 and R8 does not produce the right voltage drop for the meter.

Mutual Conductance Testing

As outlined in the foregoing, any tube found to have normal emission will usually have satisfactory mutual conductance. Many tube testers are arranged to make this test in addition to the emission test. The great majority of this type of testing is done by the *so called static or grid shift method*. One of the earlier forms of circuits for this test is shown in Fig. 10. A dry cell is included for the grid shift voltage.

The rectified plate current which flows with the grid connected directly to the cathode is first observed and then the grid-shift push-button is

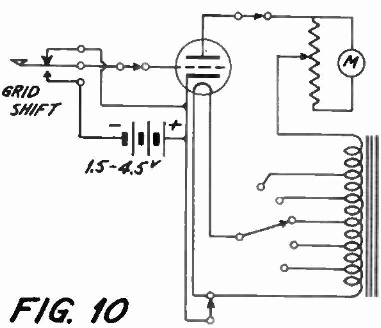


FIG. 10

used to place a bias on the grid. *The new plate current reading is then noted.* The difference between the two readings of plate current is an index of the mutual conductance of the tube.

Unfortunately the applied plate voltage is much smaller than that normally used and is, of course, usually AC. Moreover, the meter is not calibrated to read any specified current in milliamperes. It is adjusted to various sensitivities for convenience of the emission test. When other elements such as screens and anode grids are introduced they do not have their operating voltages applied. These are some of the reasons why this grid shift test is not a specific value but simply a relative measure of the change in the plate current, due to a given change in grid voltage. It is called a mutual conductance test because the mutual conductance of a tube is defined as the ratio of plate current change to grid voltage change.

That is

$$\frac{I_{p1} - I_2}{E_{g2} - E_{g1}} \times 1000$$

$= Gm$ (mutual conductance).

I_{p1} is the initial plate current with a grid potential of E_{g1} and I_{p2} is the resulting plate current when the grid potential is changed to E_{g2}. For an example assume that a 5 volt bias is placed upon the tube (E_{g1}). With this 5 volt bias, 6 milliamperes of plate current flows (I_{p1}); when the switch is changed, a 10 volt bias is placed upon tube (E_{g2}) and 3 milliamperes of plate current flows (I_{p2}). Then the mutual conductance (Gm) is:

$$\frac{6 - 3}{10 - 5} \times 1000 = 600.$$

Another method as shown in Fig. 11 makes use of from 5 to 7.5 volts

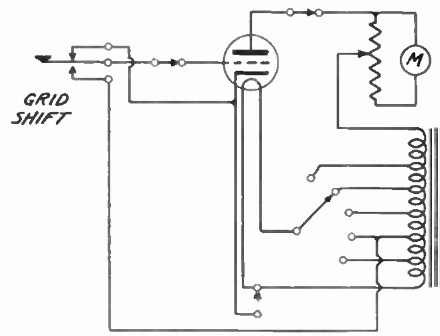


FIG. 11

of the filament voltage for the grid-shift test. Normally the grid is connected to the cathode but when the grid-shift test button is pressed, the grid is supplied with a low voltage AC. This voltage is in phase with the plate voltage, that is, they both reach positive maximum at the same time. The average plate current is, therefore, increased and the increase is a measure of the mutual conductance of the tube.

There are tube testers available which provide testing for the dynamic mutual conductance—that is, the mutual conductance under operating conditions with a signal supplied to the grid and a reading taken of the signal current in the plate circuit. In the static mutual conductance test, two readings must be taken while in the dynamic test, only one reading is needed.

A circuit used in dynamic mutual conductance testing is shown in Fig. 12. Its power supply uses a 25Z5 rectifier which produces a high DC voltage for plate and screen voltage supply and a lower voltage from which a bias may be obtained. Both sections are half wave rectifiers and each has its own complete filter. Another winding produces a total of 18 volts and any AC 60 cycle signal from about 12 volts to zero may be selected from a potentiometer (R1). This

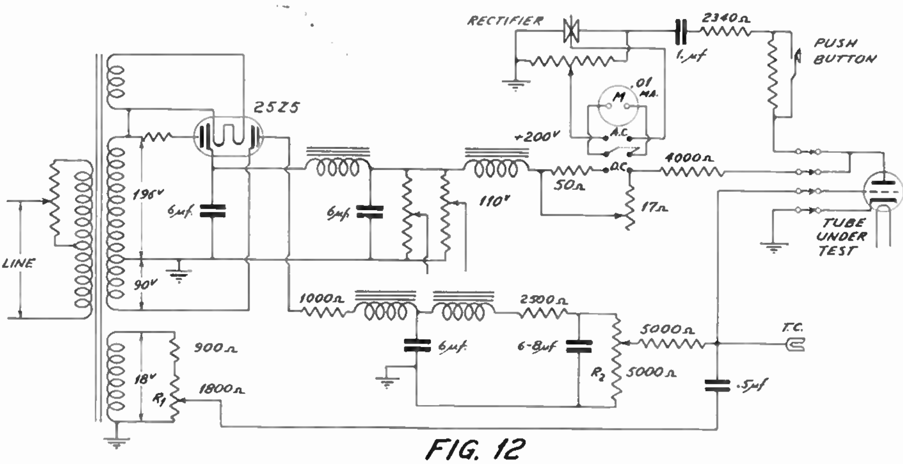


FIG. 12

winding being used for other purposes is larger than necessary for this purpose alone.

Connections in Fig. 12 are shown to a triode tube under test. The 4000 ohm resistor serves as its plate load and another connection to the plate allows a reading of the AC voltage developed at the plate and the current which results from this AC signal voltage. An appropriate bias is selected at R2 and the 5000 ohm series grid resistor serves to isolate the bias supply from the grid signal voltage.

The plate voltage and plate load are at fixed values and if you know the bias and grid signal voltages you can calculate the mutual conductance. Moreover, if the settings of R1 and R2 are specified on a tube chart the mutual conductance may be marked directly on the meter in terms of micromhos.

The difficulty with this type of measurement from a practical standpoint lies in the large range of values which must be dealt with for all tubes. The grid signal voltage of various tubes varies from below 1 volt to 50 volts or more, the plate loads for normal operation varies from a few thousand ohms to over a megohm, and the actual signal at the plate will vary through a correspondingly wide range.

This condition is further complicated by the switching system to make the tester adaptable to all tubes. In addition to this, the mutual conductance of an RF pentode may not indicate as well at 60 cycles as at 1000 KC. In a tube such as the 6K8 the transconductance and translation gains can only be determined through use of the proper frequencies.

Not only the frequency but also the grid, plate and screen voltage of a tube affects its mutual conductance. In other words, the mutual conductance of a tube is far from being a c o n s t a n t. The operating function which a tube is fulfilling determines the value of its mutual conductance and as a given tube can be operated for several different functions the mutual conductance changes for each function making it necessary to know the actual function of a tube to accurately measure the mutual conductance.

For this reason, it is impractical and gives you little information concerning the tube to measure conductance at some specified function. Be-

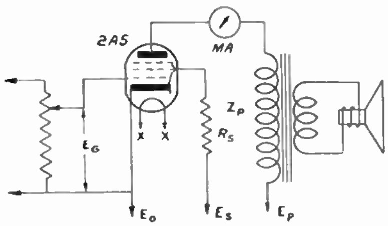


FIG. 13

cause of this, most tube testers which give a dynamic mutual conductance test of a tube do not give an absolute value of the mutual conductance but a value which is proportional to the mutual conductance. Some tube testers test a tube under its normal operating conditions. In this way a combination of dynamic mutual conductance and emission test is made at the same time.

Figure 13 shows how a 2A5 tube is connected in a typical audio power output stage. The primary purpose of this power tube is to deliver power to the load Zp such that the most electrical power will be applied to the speaker through the transformer. With filament and plate operating voltages applied and with zero signal applied to the grid, the plate current indicated by the plate milliameter will be some steady value depending upon the emission of the cathode and upon the potentials of the elements within the tube. Now by applying an audio signal Eg to the input grid, *the plate current through Zp must vary in accord with the change in grid voltage.* This changing amount is proportional to the dynamic mutual conductance of the tube. The greater the AC grid voltage the greater the AC plate current and accordingly the louder the sound from the speaker.

Now suppose that the peak grid voltage to the tube is in keeping with the operating condition of the tube and all other voltages upon the tube are normal, but severe distortion is produced at the speaker, even though all circuit components are normal except the tube. This indicates that the emission from the cathode of the tube is below normal, causing the tube to overload on the peak excursion of the grid. In other words, there is an insufficient quantity of electrons available to handle the peak power requirement.

Now assume that the same signal as in the previous case is applied to the grid and all the circuit conditions are normal except the tube, yet the output volume from the speaker is much too low. This is due to a low value of mutual conductance. In other words, the magnitude of the plate current variation versus grid voltage is not in keeping with the standard value of mutual conductance of the tube as indicated by the characteristic curves of the tube. This condition can be caused by a multiplicity of internal tube conditions, including open, misplaced and shorted screen grid, control grid, suppressor grid, or plate even though the tube's cathode emission is absolutely normal.

It can be readily seen from the preceding discussion that the condition of a tube is dependent upon both the emission from the cathode and the mutual conductance of the tube. Both of these factors must be considered if an accurate check upon the tube is to be made. The fact that the mutual

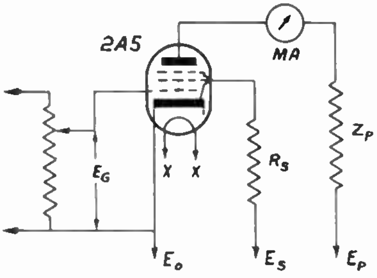


FIG. 14

This type of tube tester is more elaborate than the straight emission type of tester. It is manufactured by the Hickok Electrical Instrument Co. and is of the combination emission and mutual conductance type. Several controls are provided which must be set in a precise way for a given tube type. Specific manufacturers instructions are included with each instrument which tells how to make each test of which the instrument is capable.

conductance is changed due to the physical structure of the tube, it is less likely to cause tube trouble. Therefore, poor emission is by far the greater cause of tube failure.

Figure 14 shows a circuit used to test a 2A5. Note the similarity of the two conditions (Figs. 13 and 14). By testing the tube with the maximum operating conditions as given by the tube manufacturer and in a circuit very similar to the operating condition of the tube both the emission and mutual conductance of the tube will affect the plate current.

With the circuit of Fig. 14 placing the correct operating voltages and plate load upon the tube under test, the plate current as indicated by the milliammeter in the plate circuit will be directly and simultaneously proportional to both cathode emission quality and dynamic mutual conductance; and if the meter circuit is properly calibrated the tube tester will reject all tubes which do not come up to the standards as determined from the original laboratory tests from which the tube chart data is gathered.

The correct operating conditions for the tube in question are secured by properly manipulating the adjustments of the tester. A chart is always provided giving the proper setting for all tubes that can be tested upon the tester. These charts as stated are prepared from extensive laboratory tests upon each tube type. This method of testing will reduce the number of tube failures missed by the tube tester, giving a better average of faulty tubes rejected by the tester.

The Cathode Leakage Test

In a good many radio circuits any leakage between the cathode and heater will cause faulty operation. A good example of such a circuit is a phase inverter, having a high resistance load in the cathode circuit and causing the cathode to operate at plus 50 to 100 or more volts. The filament being at ground potential causes this voltage to be impressed across the cathode-filament electrodes. Another example is in the cathode tap oscillator circuit when the cathode voltage must change at radio frequency.

The cathode leakage test consists simply in disconnecting the cathode while the tube is being given an ordinary emission test. If any plate current remains it is obvious that it is leaking from filament to cathode. Thus, a good tube would indicate no plate current while a poor one would show some current flow even with the cathode curcuit open. Connections for the test are shown in Fig. 15.

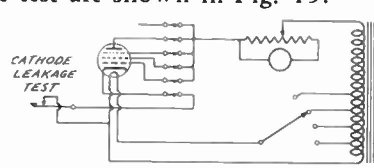


FIG. 15

General Wiring of Tube Testers

Most of the individual tests which have been covered are rather simple circuits. The combination of all of these circuits with a socket for each tube type makes the wiring and switching fairly elaborate. Arrangements must be made to change the filament connections for the octal and loctal sockets as there are five ways to connect the filament in this tube group. As only one socket in the tester is used at one time all sockets may be directly connected. Since the wiring is different for each make and model of tester the manufacturer always supplies charts for setting each of the controls for each tube type.

Recommended Tube Handling Procedure

At this writing there is no substantial sign that the creation of new tube types will not continue as before. Even if there was assurance that no new tube types would be introduced, the present tubes in use will probably be improved, which fact will present practically the same problem as a new tube type.

The nature of tube tester design is such, as a rule, that it is not easily adapted to the testing of new tube types. Perhaps the new tube will be made to fit one of the 7 or more sockets in the present tester but its filament pins may not agree with the wiring of the tester or the general arrangement of wiring of the elements to all pins may not be adapted to the switching systems of the tester.

These facts simply mean that the tube tester has the highest obsolesence of any instrument used by the serviceman. Replacement tubes of the newer types cannot be sold rapidly enough by the small or medium sized business to compensate for the cost of obsolesence of tube testing equipment.

This tube tester is made by the Radio City Products Co. It includes the roll chart feature, push-button switches, the usual selector switches and an adequate number of tube sockets. Like most modern tube testers a large square meter is employed and is calibrated in terms of good and bad tubes.

Many servicemen have learned this by making careful reference to their various costs and have developed a tube handling which avoids the use of a tube tester. While not at all new to the serviceman, this method has not received wide acceptance until recently.

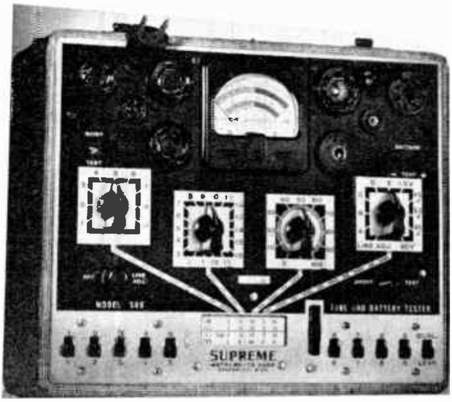
The test consists in substituting tubes in a properly operating receiver to determine the worth of the tube. To the receiver is attached a signal generator connection at the antenna (usually) and the output meter may be used. The signal is, of course, modulated and the output meter is placed across the voice coil. In this way, every tube in the receiver that is not simply a tuning indicator or an intercarrier noise suppressor, etc., will have some effect on the ability of the receiver to carry a signal.

Where there is an AVC system used with a receiver. the RF and IF tube faults may not be disclosed because of the AVC action. When the new tube is installed if the AVC is acting properly, the gain of the receiver will be reduced—thus. causing no appreciable change in the output of the receiver. Thus, with these tubes, it may be necessary to stop the action of the AVC while making the substitution tests. or measure the AVC voltage with a vacuum tube voltmeter before and after the new tube is installed. If the AVC voltage increases appreciably when the new tube is installed. it is quite evident that the old tube is weak.

When making a tube substitution test, it is best to make sure that the circuit the faulty tube is removed from is not the cause of the tube failure. If it is. the new tube will be damaged if placed in this circuit before the fault within the circuit is corrected. This difficulty is more prevalent with AC-DC receiver rectifier tubes.

Of course, in cases where a portion of the receiver is not in proper adjustment, the signal can be introduced at any stage and the output meter can be placed at the output of any stage with the necessary adaptations. This. however, is of secondary consideration.

The signal generator output and the volume control of the receiver are adjusted for a satisfactory output and any tube of which there is any question regarding its condition is replaced by another tube selected for this purpose or a new one. For any of the high frequency or low powered AF tubes in an AC receiver the replacement may be made without turning the receiver off. When replacing rectifier tubes, power amplifier tubes or



This is another example of a fine manufactured tube tester. It is made by the Supreme Instruments Corporation. The instrument is arranged for both counter and portable use. It also includes the roll type of chart and modern switching methods. Like all testers of this type the switches must be set in an exact way for each tube type. This is covered by manufacturers instructions.

any tubes in an AC-DC receiver. it should always be turned off while the replacement is being made.

Without any change being made in the volume control setting or signal generator setting. the reading of the output meter is noted and compared with the former reading. In receivers where the volume control and line switch are combined and the receiver must be turned off when replacing tubes. the line cord should be pulled out of its socket so as not to change the volume control setting.

The output meter is, of course. simply an AC voltmeter. If the new tube shows a reading twice as great as the former it simply means that the power delivered to the voice coil has been increased four times. It also means that the signal output of the new tube is just twice that of the tube which it replaced. This does not mean that the amplification factor of the new tube is twice that of the old tube or that the gain of the stage is twice that before due to the amplification factor of the tube alone. The gain of the stage has been doubled but the former tube may have had the correct amplification factor but with lowered emission. This lowered emission may have affected the AC plate resistance in such a way that the output of the tube has diminished although the amplification factor may not have changed. Just exactly what was wrong with the old or original tube is not of very great importance or interest to the practical serviceman, as he knows that the tube should not be used anyway.

Even this procedure is difficult and costly when it is realized that a good tube of practically every type must be reserved for test purposes. However, it is more practical to buy one new tube when it is introduced than to buy a new tube tester.

While not as perfect an index of performance as regards gain and power, the speaker reproduction is more valuable in the tube test than the output meter. Any distortion noted on changing tubes could be identified with the tube changed. The tube substitution method is applicable to *servicing in the home* making use of the reproduction of the receiver entirely without the output meter. This test is superior to any tube test for oscillation because an emission test will not disclose whether or not a tube will oscillate in its proper circuit.

Considerable caution should be used in testing tubes by this method of substitution. In addition to the facts mentioned it is not generally wise to replace tubes in a receiver which will not operate at all. For example, in an AC-DC receiver, very often a shorted filter condenser will destroy the emission of the rectifier tube. If a new rectifier is substituted, its emission will likewise be destroyed almost immediately. Be sure that the filter condensers are in good condition before replacing rectifier tubes. This is important in AC receivers as well but is absolutely essential in AC-DC receivers.

The question, of course, arises that if the receiver is not working because of a tube, how are you to restore operation of the receiver before a new tube is tried? In this event, it is a good plan to inspect and test the circuit in some detail to be sure that the tube is not at fault. This may be done by passing a signal around a stage or attaching the signal generator at the inout circuits of various stages, or in other ways, as described in other lessons. Once assured that the fault lies in the tube, it may be replaced.

If the receiver lacks sensitivity and the tube substitution does not improve it, then obviously the tube is not at fault. Alignment, antenna, etc. would be the first things to check.

The insertion of new tubes in a circuit will in some cases shift the circuit out of adjustment, due to the difference in mechanical structure between tubes. In recent receivers, this is of little importance as tubes have little effect on tuning or adjustment of circuits.

The final or ultimate test of a tube is its operation in a receiver and this procedure simply omits the preliminary step of the tube tester. It is a procedure well worth considering, but it should be kept in mind that it takes more time to check by this method than when using a manufactured tube tester.

Typical Manufactured Tube Testers

The manufacturers of test equipment are always developing better types of test equipment. This is true

This photograph shows a combination tube and receiver tester. It is made by the Precision Apparatus Corp. and its circuit is shown in Fig. 16. This is an example of putting one instrument to maximum use. The one instrument can be employed to make practically any meter test that is required to be made on a radio receiver.

of tube testers. It is true that the tube tester, due to the many newly developed tubes, often becomes obsolete in a very short time. Manufacturers of tube testers sense this difficulty and for this reason have designed their testers such that they are less likely to become obsolete. This is done by leaving space for extra tube sockets and also leaving extra switching positions on the selector switch.

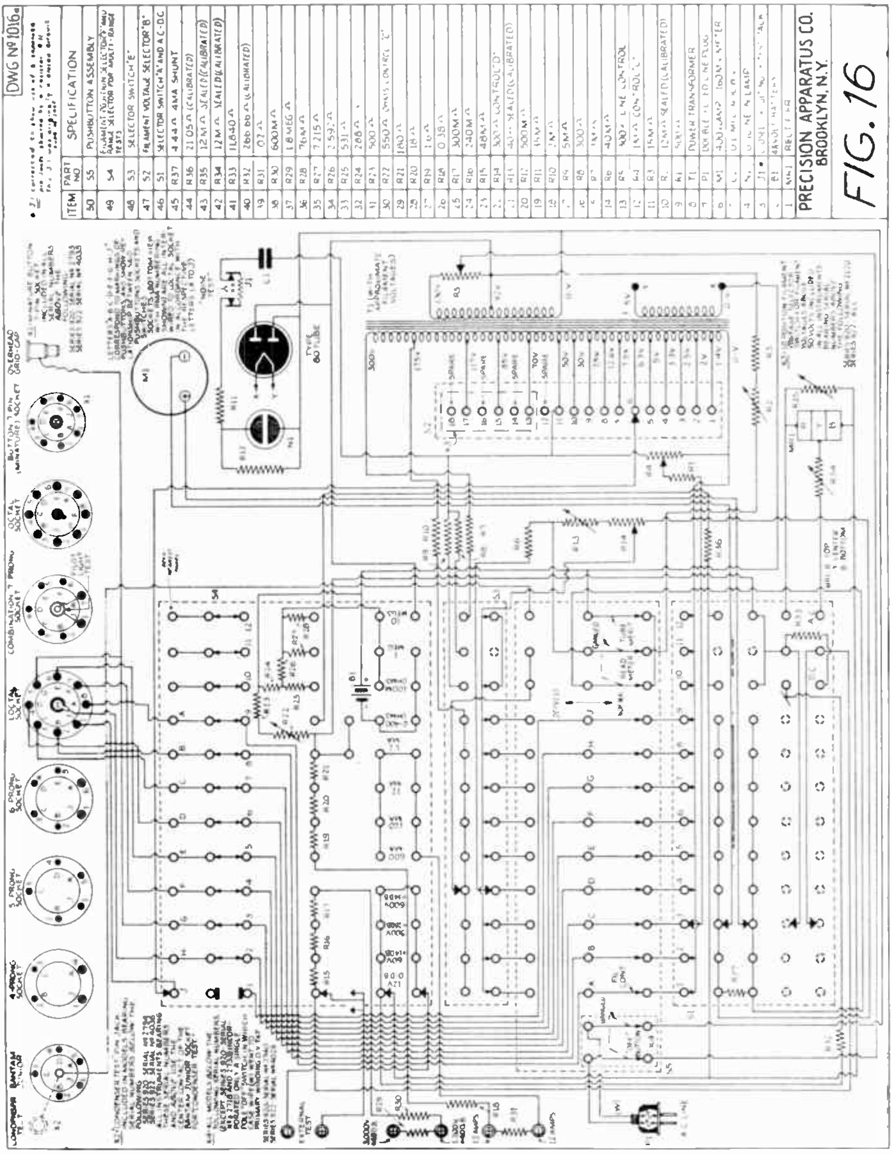
It has been pointed out that tube testers are not always necessary and that many servicemen are using the substitution method of testing because it is a dependable test. As mentioned, if this method of testing is used a complete stock of all types must be on hand. For a serviceman strictly confined to service work, the substitution method of testing may be more satisfactory, but if you run a service shop where you sell tubes, a tube checker is useful in making tube sales. A considerable part of the profit of a radio shop is in the sale of tubes, and as a good share of these sales are made without ever seeing the receiver, the tubes as used in the substitution method of testing is of no value.

It is found by long experience and testing that about 90% of tube failure will be revealed with a simple emission test on the tube. If a tube tester is arranged for an accurate emission test, a good share of the faulty tubes will be caught. A mutual conductance test will increase the tube rejects about 2 to 3% and short, gas, and noise tests will add to this percentage. However, there are still a few tube failures that will not be revealed with a tube tester. A well designed tester capable of accurately making these tests should prove of value to a serviceman where tube sales are a good portion of his profit. Tube testers with a large easily read GOOD-BAD scale is especially adapted to counter tube sales.

There are numerous makes and models of tube testers. Some are more elaborate than others, but in general most of the tube testers on the market will give a fair indication of the condition of the majority of tubes.

For the convenience of the serviceman, many of the latest type tube testers are a combination tube tester and receiver tester. By combining the two units a convenient test instrument is obtained for the serviceman and it reduces the total cost of his test equipment. The advantage of having both instruments combined in one easily portable case allows for a more portable unit when making service calls.

Figure 16 shows a circuit diagram of a typical unit of this type manufactured by the Precision Apparatus



Company, Model 920. The tube tester is designed to accommodate all filament voltage requirements from 1.4 through 120 volts. This tester tests all new loktals, octals, bantam octals, single ended, television and FM amplifiers, bantam junior and the new button 7 pin socket radio and hearing aid tube regardless of the filament or any other tube element positions.

The tube tests include dynamic conductance and emission tests of the operation of the tube, a complete test for shorts between any two elements in the tube, open elements, hot cathode leakage, and a noise test. There are several other features not connected with tube testing which include battery testing, pilot light testing and a good volt-ohm-milliammeter for receiver testing. The tube testing arrangement is such to minimize the possibility of the tester from becoming obsolete.

Figure 17 shows a circuit of the Triplett Model 2413 tube tester. The filament voltage range varies from .75 volts through 110 volts in 19 steps and makes possible a test of all types of receiving tubes up to date.

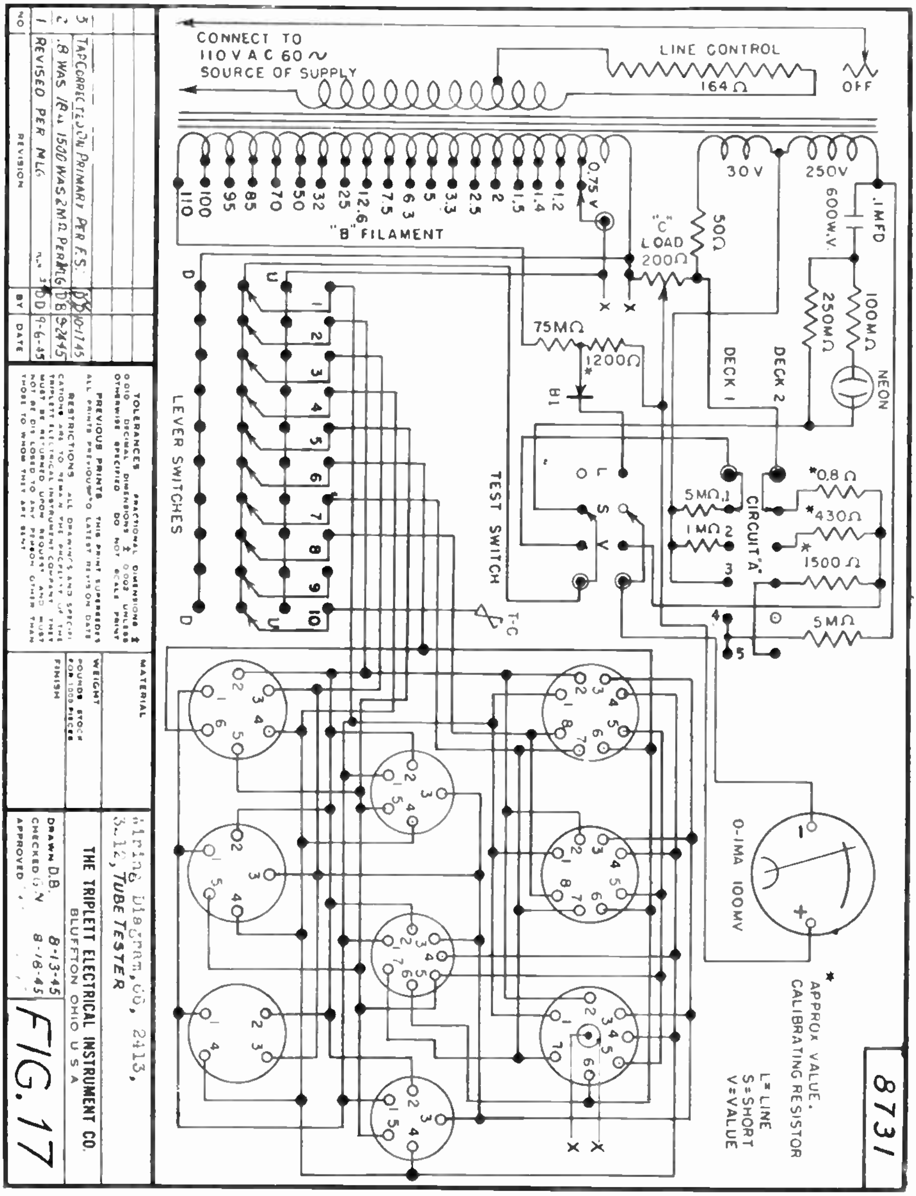
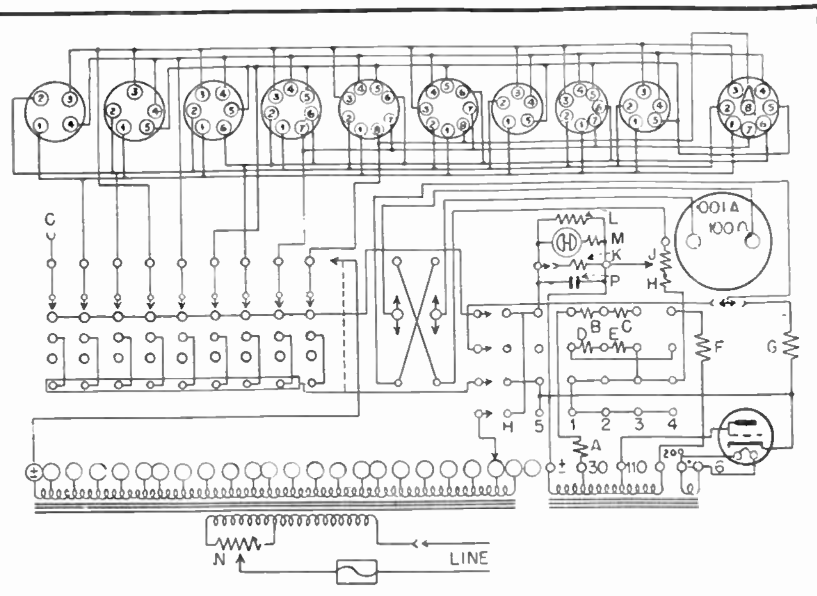


FIG. 17



A	200 OHMS	D	200 OHMS	G	115,000 OHMS	K	1 MEG	N	350 OHMS
B	800 "	E	70 "	H	5 "	L	1.5 MEG	P	.00025 MFD
C	4000 "	F	2000 "	J	50 "	M	200,000 OHMS		

FIG. 18

The type of switching arrangement allows an open or short test between any two elements of any tube. It is provided with a spare socket button to allow for any new designed tube, making it less likely to become obsolete.

There are many other tube testers besides these described here, most of which are just as practical and will prove satisfactory within the limits of their design.

To design an accurate tube tester which will give a satisfactory test on all types of tubes, requires considerable research and testing. The actual measurement of the different characteristics of a tube requires a very elaborate tester which incorporates several meters and many controls. This type of tester would be costly, inconvenient to operate and requires considerable time for the test. Thus, they are not practical for a radio serviceman. The designer of tube testers realize this and try to simulate these tests into one or two simple tests. Although these tests do not actually measure the tube characteristics they will give a good indication of the condition of the tube and will in most cases reveal if it is in operating condition. The serviceman is not interested in the tube's actual amplification factor or its AC plate resistance; he is only interested in the condition of the tube—is it good, bad, or questionable. The only way that a tube tester can be designed that will actually give the operating condition of any tube is to set up a standard of comparison for every tube made and design a tester that will indicate any discrepancies from this standard.

Figure 18 shows a complete diagram of a Simpson Model 305 tube tester. This tester is provided with eight separate sockets as follows: 4, 5, 6 and 7 pins; also octal, loctal, miniature, and a spare socket is included for any new developments in tubes which may occur. The connections for each tube socket is brought to an individual terminal of a sliding contact switch as indicated to the left in Fig. 18. The upper set of contacts above the sliding switch contacts are not a part of the sliding switch. These controls are the contacts of a rotating switch which is connected to one side of the filament transformer.

This rotating switch provides a means for connecting one side of the filament transformer to one side of the tube filament regardless of its location on the tube base. The other terminal for the filament is connected to the desired filament tap by throwing the sliding switch to the operating position. In this way any tube can be tested regardless of which pin the filaments are connected to on the socket.

There is a meter reversing switch provided with the tester which when in one position allows a measurement of the line voltage so that any correction of line voltage can be made by the line voltage adjustment provided for this purpose. This voltage control

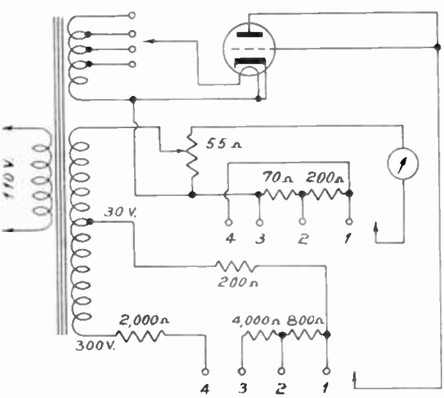
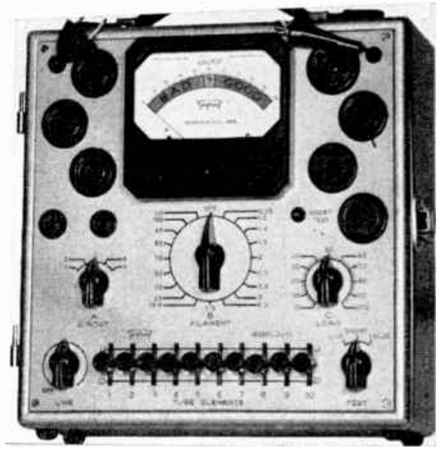


FIG. 19



In the above photograph is shown a panel view of the Triplett tube tester model 3212 the circuit of which is shown in Fig. 17. This instrument can be used for both counter and portable testing. Its various functions are discussed in this lesson. Like all other testers of this general type specific manufacturers instructions must be followed for each type of tube to be tested.

is a variable resistor in the primary circuit of the power transformer and is labelled N in the circuit of Fig. 18. This line voltage adjustment will allow for a correction of the line voltage both above and below the rated voltage of the tester. When the meter reversing switch is in the other position, the meter is used to measure the condition of the tube under test. Figure 19 shows a simplified drawing of the tube testing circuit only indicating how different load conditions can be placed upon the tube under test.

Included in this tester is a neon short test which is unique in that it has two separate sensitivities for the leakage test. This allows for a wider and more exacting short test. The sensitivity is controlled by a switch which is connected to resistor K in the circuit of Fig. 18.

Resistor L is connected across the neon test light all of the time and as it has a resistance value of 15 meg-

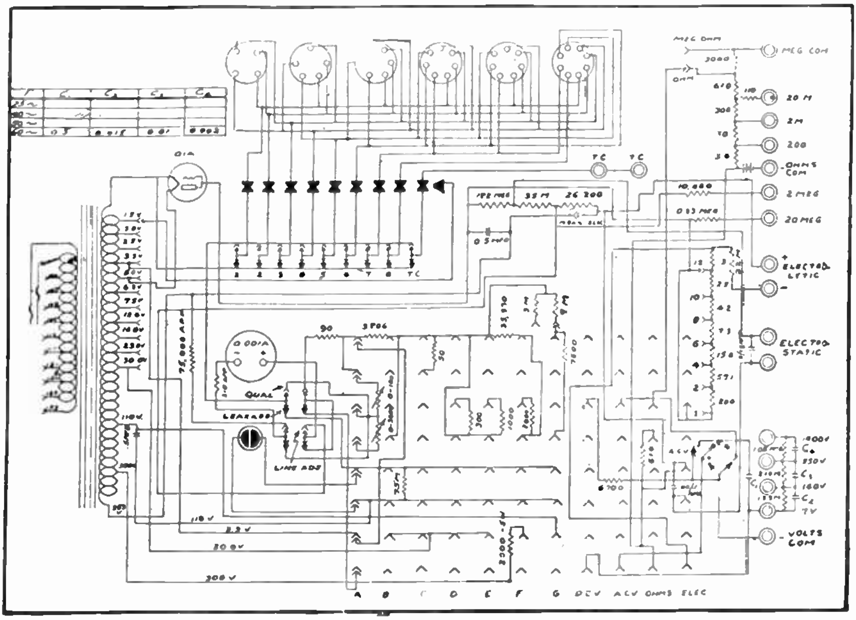


FIG. 20

ohms, the lamp circuit responds to very small element leakage but when the switch which connects resistor K across the lamp is closed the sensitivity of the test lamp is lowered because resistor K has only 1 megohm of resistance.

Figure 20 shows a complete circuit diagram of the Supreme Model 502 tube tester and set analyzer but for this lesson only the tube tester section will be studied.

This tester includes all of the standard tube sockets but has no spare. The switching arrangement of this tester is somewhat different than for the previously described tester but approximately the same tests are made. The total emission of the cath-

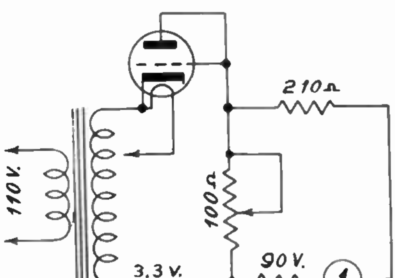


FIG. 21

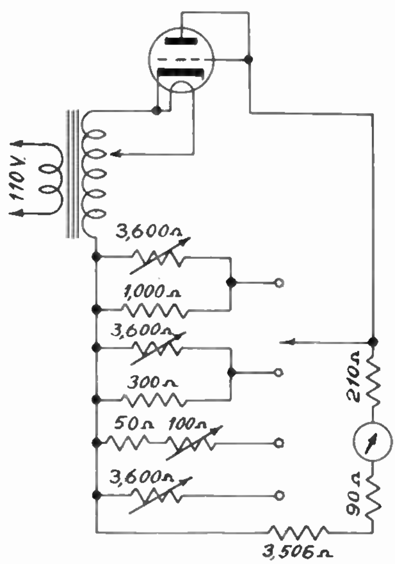


FIG. 22

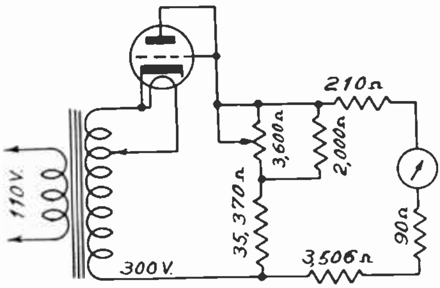


FIG. 23

ode can be measured by connecting all the elements in the tube together except the filaments and cathodes and then measuring the current drawn at certain definite voltages across the tube or separate emission on each element within the tube envelope can be measured. As there are many different type tubes and many tubes of each type it is necessary to make a tester which will allow for the different tubes. Thus, there must be a method provided for several different load conditions to account for all the different type tubes. As seen on the diagram of Fig. 20, there are a number of selector switches. These switches are connected to the circuit in such a way as to provide a different test condition for every different type tube as well as to make circuit connections for using the set analyzer section of this unit. Figure 21 shows the equivalent circuit of the tester when the circuit selector switch is in position A, Fig. 22 shows the circuit for position B, C, D, and E; and Fig. 23 shows the equivalent circuit when the switch is in position F. This circuit selector switch is indicated in the main diagram of the tester at the bottom and center of the diagram.

For each tube type there is a certain position for each control knob of the tester for testing a particular tube. The data supplied with the tester gives the correct control knob setting for every tube that can be tested with this tester.

Most of the tube tester manufacturers supply additional data for their tube testers for testing new tubes as they appear on the market and many manufacturers supply adapters so that their tester will test as many of the newly designed tubes as possible.

Most of the manufacturers of tube testers work in cooperation with the tube manufacturer to determine the limits of their tubes. As already mentioned, it is impossible to design a tester that will reveal all defective tubes. However, if a tube tester is so designed to detect 95% of the defective tubes, it will be of value to the serviceman. Most of the well designed testers will reveal at least 95% of the defective tubes.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 If the emission of a tube is normal under test, would you consider that the filament of the tube is in good condition?

No. 2 What is done in the tube tester to insure that correct filament and other test voltages will be applied to the tube under test?

No. 3 Why is it that by finding the emission of a tube good, you can usually assume that its AC plate resistances, its amplification factor and its mutual conductance are satisfactory?

No. 4 In the emission tube testing method, how are the elements of any tube connected?

No. 5 Can you determine from the usual commercial tube tester short test which two elements within a tube are shorted?

No. 6 With a neon tube short tester, how is an internal short in a tube actually indicated?

No. 7 Will the presence of excessive gas in a tube cause its plate current to differ with varying grid resistance values?

No. 8 Should the two plates of a full wave rectifier tube be connected together and tested as one plate?

No. 9 Is the grid shift test considered a static or a dynamic tube test?

No. 10 For what purpose is the circuit shown in Fig. 12?

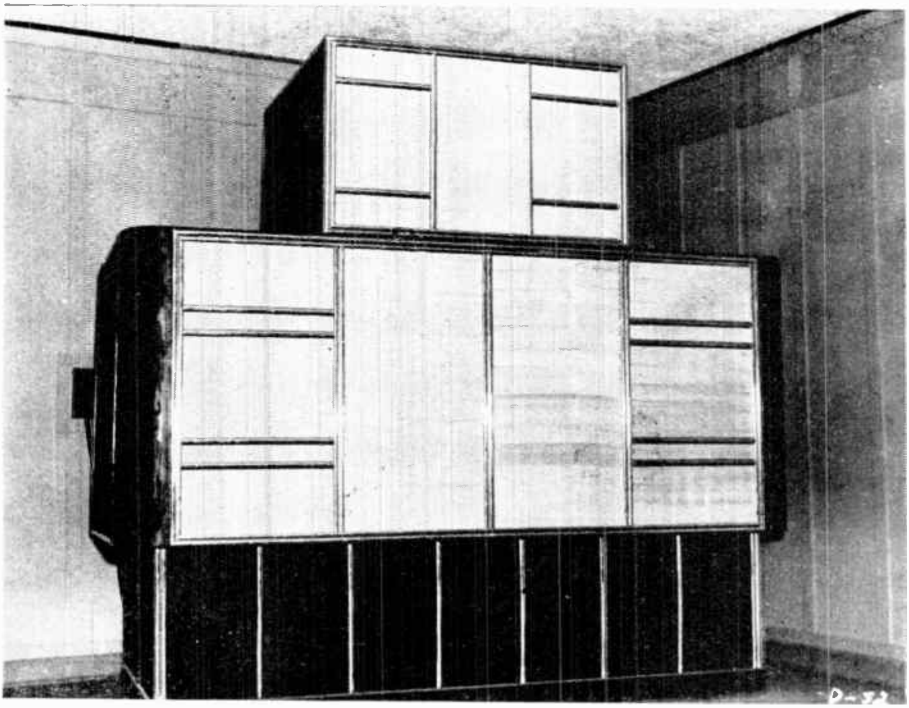
HOW TO TEST FOR DEFECTS IN SPEAKERS

LESSON TV-15

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K3552M



The above photo shows a large high fidelity speaker used in the Dubbing Room of the Republic Studios. *Courtesy of Republic Studios.*

HOW TO TEST FOR DEFECTS IN SPEAKERS

LESSON TV-15

Being the ultimate interpreter or *voice* of the receiving equipment, the speaker in one way or another manifests all of the defects in the receiver. For this reason, the speaker is very apt to receive the blame for much trouble for which it is not at all responsible. Very common in the early days of radio was the suspicion of speaker defects which might cause many faults such as loss of low frequencies, rasping, booming, frying noises, etc. Only heterodyning and motorboating or microphonic troubles were recognized definitely as having other sources than in the speaker.

Hence, of great importance in testing is localization of the defect, or definitely identifying it as originating in the speaker or elsewhere. Remember, it is rare for any noise, sound or symptom to be called characteristic of speaker defects as any such condition could be caused by some fault in the receiving circuit.

Unless you can visibly see the source of the defect it is best by far to make a few simple tests which will quickly determine whether it is in the speaker or not. For example, if the receiver is inoperative and the voice coil of the speaker is visibly open, it should naturally be corrected before going further.

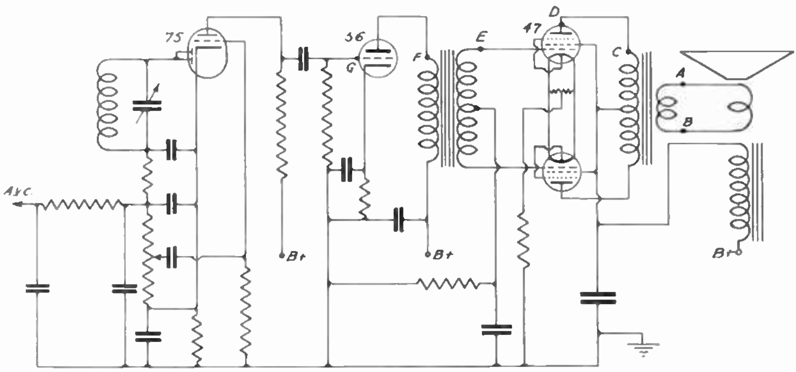


FIG. 1

The entire audio system of a typical conventional receiving circuit is shown in Fig. 1. First to follow a sure and rapid testing technique if the speaker is entirely inoperative you must know whether or not this is the fault of the speaker. By means of headphones with a .01 mfd. condenser, or preferably with the potentiometer shown in Fig. 2, touch one test lead to point D, Fig. 1, and ground the other test lead. The potentiometer will be found to be very useful here, as you will be dealing with very high signal voltages. Now, if the signal is not reproduced by the headphones at this point with the receiver volume control at maximum (the receiver of course being tuned to a station), and the potentiometer at maximum, obviously there is a defect in the receiver circuit. This, of course, must be corrected before giving attention to the speaker. Defects may, of course, exist also in the speaker, but you must first be sure that the speaker is properly supplied with a signal before you can logically proceed.

If there is a good signal at D, and it is of good quality as determined by reception in the headphones, the next thing to do is to test at A or B (the voice coil circuit) to ground or across the secondary winding from A to B in Fig. 1. (The simple test circuit of Fig. 2 is sufficient for these tests.) Considerably less volume will naturally result when connecting across the winding A-B because of the lowered impedance and lowered voltage of the signal.

If the signal is at all present or of good intensity across A-B with the potentiometer set at the maximum volume position with the speaker entirely inoperative, then you may be sure that the voice coil circuit is open or something else is seriously wrong with the speaker. However, if there is no signal at A-B while there is a signal at D, the output transformer is at fault.

Now there is more possibility of finding serious distortion than there is of finding an inoperative speaker, and you must, in this case, make certain that its source is not in the speaker. The distortion in this case will be easily distinguished by any normal ear. If the same distortion is heard at A, D, E, F and G in Fig. 1 with the test circuit shown in Fig. 2 it is in the audio system, but if not, it is in the speaker. Correction, of course, must first be made in the receiver as usual. Thus try and remember how a simple circuit like Fig. 2 can be used to get a check on the operation of any speaker.

The Magnetic Speaker

Assume for this discussion that every test to be described using the headphone circuit of Fig. 2 shows that the receiver is in good condition, and that reproduction is poor in quality from a magnetic speaker (includes the PM type speaker).

Symptoms which indicate a loose connection, a break in either lead of the speaker or a short of the connecting leads or terminals are intermittent operation and a *rasping* tone resembling continuous static. From tip to tip of the connecting leads (or from terminal to terminal) the speaker should first be tested for continuity. While bending and twisting the leads the resistance of the speaker winding should remain perfectly constant. If the circuit changes resistance (opens or shorts), the connecting leads should be carefully examined and repaired or replaced if necessary. The insulating washers (if used) on the speaker frame and the terminal mounting should be examined. The connecting wires from the terminal lugs to the actual winding should be inspected closely and the speaker coil alone should be tested for continuity after the connecting leads are detached.

The usual ohmmeter battery has enough voltage to actuate the speaker when tested for continuity if in good

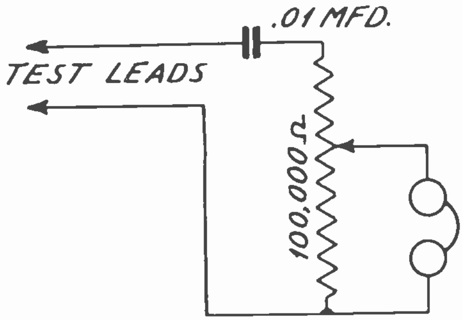


FIG. 2

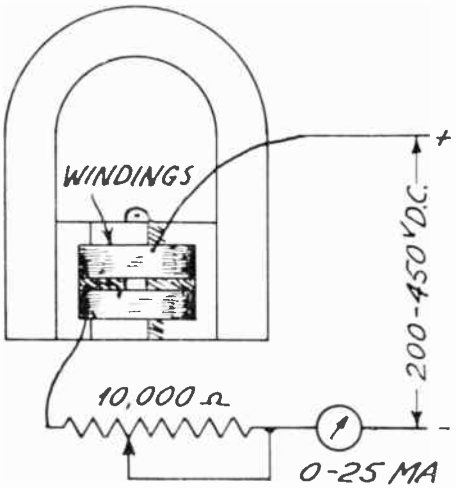


FIG. 3

condition. If it responds with a *click* or *thud* when the test circuit is completed or when opened, it is an indication that the speaker is at least a continuous circuit, and is capable of operation.

The coil resistance value of a magnetic or PM speaker is not important. These windings may vary from several hundred ohms down to 50 ohms or less, but they must not be shorted or open and must show a perfectly constant value. To insure against a temporary contact of a badly corroded lead, inspect the winding, bending aside any insulating cover on it and noting if there is any green deposit or moisture or burned appearance. It would be well to give the winding a DC test of about 20 milliamperes to make sure that it can carry the full signal. This should be done with a high voltage 200 to 450 volts, using an ammeter and a resistor as in Fig. 3. Turn on the current and adjust the potentiometer until the meter reads 20 milliamperes. Let it remain for a minute or so to insure that the current is perfectly constant. If the current varies, the coil must be

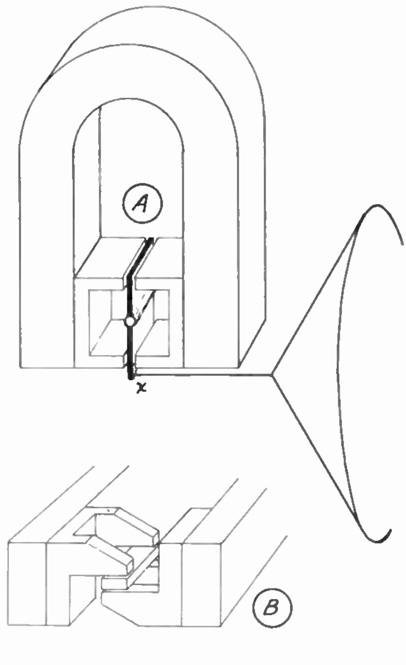


FIG. 4

replaced. Because of the work involved and the relatively low cost of a new speaker, it usually does not pay to replace a coil, but rather you should replace the entire speaker.

The probability is that if corrosion has taken place, the speaker cone has also stiffened due to age and these two defects alone would make complete replacement worthwhile. Servicemen differ in this work. However, you will soon learn which repairs are expedient and which are not. Your location may affect this. If you have to send away for all replacement parts and take a chance on a misfit together with delay, it may be more expedient to make certain minor speaker repairs.

There are many forms of magnetic speaker construction, but common to all of them is an armature mounted between two permanent magnet field poles. Two types are shown in Fig. 4. The less expensive type for small midget and portable receivers uses a thin iron vane (Fig. 4A) for an armature while the better speakers make use of a rectangular iron slug (Fig. 4B) for the armature. Usually in the better speakers an adjustment is furnished on the pivot or spring of this armature in the airgap so that it may be placed at the exact center.

First consider the type of magnetic speaker having no adjustment. Attached to this type of armature is a driving pin and a spring. The driving pin is in the cone axis and is attached to its vertex (center point) either by threading the pin and using washers and nuts on each side of the cone, or by soldering to a central bushing. The driving pin is invariably soldered to the spring support driven by the armature as in Fig. 5.

In turning about the pivot, each end of the armature must be able to swing an equal distance both up and down. Its neutral position with no signal and no DC through the coil should be in the exact center between the poles. Ordinarily this can be judged with the eye, but if desired speaker *shims* (metal or plastic spacers of varying thicknesses) may be used. Assuming that the control spring is not adjustable, simply loosen the clamping nuts at the cone from *both sides* of the cone and touch the tip of

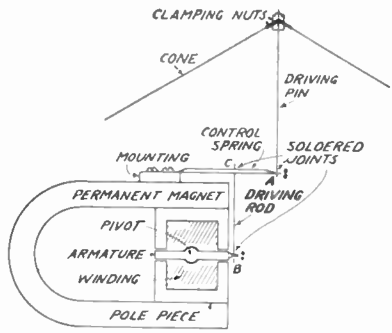


FIG. 5

Here are shown three different sizes of speakers specially designed for outdoor use. They are of the dynamic reflex type. *Courtesy of Atlas Sound.*

a hot soldering iron momentarily to either joint A or B of Fig. 5. while holding the armature in the exact center. Best results are obtained by using speaker shims of the proper thickness, on each side of the armature to insure that it is in the center. As soon as the solder melts the spring will recover to its natural unsprung position. When this happens remove the soldering iron immediately and allow the joint to harden. Now tighten the cone clamping nuts as tight as possible without bending the spring or cone. Then touch the tip of the iron to joint C in Fig. 5. where the cone driving pin attaches to the control spring. As soon as the solder melts remove the soldering iron and the natural position of the cone and spring will be assumed. The shims may now be removed from the airgaps and the speaker alignment is finished.

In some magnetic speakers, the armature control spring tension may be adjusted by means of the mounting screws. Various arrangements are made so that the armature may be adjusted to the center position. Speaker shims should always be used to insure proper spacing in the airgap.

In smaller units such as Fig. 4A, when the cone driving pin is attached directly to the armature a hot soldering iron may be held at X while the armature is held in the center with shims.

If the armature has a tendency to *stick* to either pole piece, this indicates a defective armature control mechanism. either the spring or other mounting has lost temper or is broken.

In some rare cases where the permanent magnet has been jarred severely or poorly made, it will lose magnetism. There is no accurate method of measuring magnetomotive force at the disposal of the serviceman and it will usually not pay him to attempt remagnetising these magnets, because of the equipment needed and time required to disassemble and reassemble and adjust the speaker. However, care should be taken not to hammer or drop the magnet or leave it without the pole piece and armature as these things will all reduce its magnetism.

After the proper adjustments have been made, it is important to clean all four airgaps of all dust particles and iron particles which frequently are found after working on a magnetic speaker.

This should be done by inserting the folded edge of a clean cloth in the airgap and pulling it back and forth several times, wiping off the end sections with each stroke. Iron particles will readily come out to the edge of the airgap but will usually remain here unless wiped off. A thin coating of grease will often pick up the filings, but great care must be taken to remove all of the grease possible when the job is done. Sometimes the airgaps may be *blown out* with a bicycle or auto pump, but this is not recommended as good practice for a thorough job. Be sure that the driving pin is straight. In this way it will most faithfully transmit mechanical motion to the cone.

In many cases warping of the insulating cover or stiffening of this material will cause the entire winding to be loose in its mountings. While making sure that the winding does not touch the armature it should be wedged or otherwise secured to the pole piece so that it cannot move independently. This may be neatly done with paper or wood.

The point where the speaker driving pin attaches to the driving mechanism such as at C of Fig. 5, as well as the entire driving pin should be on the axis of the cone, that is on its extended center line. Here again, you cannot make accurate measurements, but if the cone center is very much out of line it may be put back in line

This view shows four different styled auto speakers which are commonly used in present automobile receivers. *Courtesy Utah.*

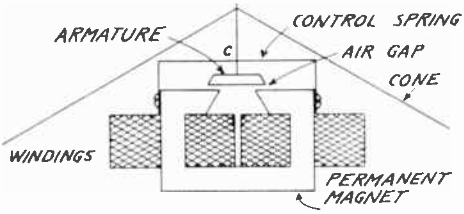


FIG. 6

by remounting the cone at its edge. The last operation of any cone adjustment should always be the soldering of point C in Fig. 5, as this permits the cone to recover to its normal position with no force or tension on the pin. For example, if the cone were remounted, it may have been twisted a little to make the holes at its edge come in line with those of the frame. This would put a twisting tension on the driving pin and assembly which would very likely cause distortion when used. Moreover, the cone may bend when a signal is applied to it in this condition due to this twisting tension. This would cause distortion.

If there is a small hole in the cone, it is usually not harmful but if it is torn anywhere or split or loose at its seams it should be replaced. Methods of repairing and replacing cones will be described further on in the lesson. Among the less common types of speakers are the *cantilever drive and the reed drive units.* The cantilever drive is shown in Fig. 6. Here, there are only two airgaps, but they must be exactly equal. They also must be wide enough so that the armature never touches them. At this position there should be no spring tension with the exception that the permanent magnet exerts a constant pull on the armature. The armature should, therefore, be set about .5 millimeter from the poles when the point C is soldered. In some models, this armature is mounted at one edge and operates as a *hinge* instead of a plunger. The same cautions should be observed.

An adaption of this form of drive is called the reed drive and is shown in a simplified form in Fig. 7. Adjustment of the screw nearest the driving rod will change the airgap. It may even be adjusted while the speaker is in operation when the position of the cone will permit. The other screw solidly holds the end of the armature. The cone is equalized as to stress by touching a hot soldering iron to C as explained. Note that the permanent magnet pull on the armature is automatically compensated for, by the tension of the armature.

The inductor type drive, many models of which are in fairly wide spread use, is shown in simplified cross-section in Fig. 8. In this assembly there are four wedge shaped airgaps and two sections to the armature. It is driven longitudinally and hence its proper center position in spite of the pull of the permanent magnets is in the center of both poles and equidistant from each airgap. This position of the armature can be obtained by the proper adjustment of the control springs and cone driving rod as mentioned for the other units. When properly in place there is no magnetic spring, or cone tension on the armature, and it is suspended freely and symmetrically in the two airgaps shown. The armature segments are shown in their shortest dimension in cross-section as they are actually .5 to .75 inch long. Be sure that they are

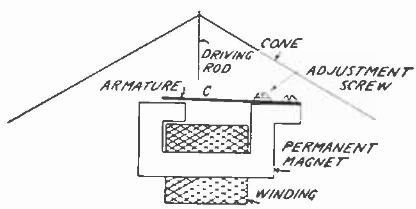


FIG. 7

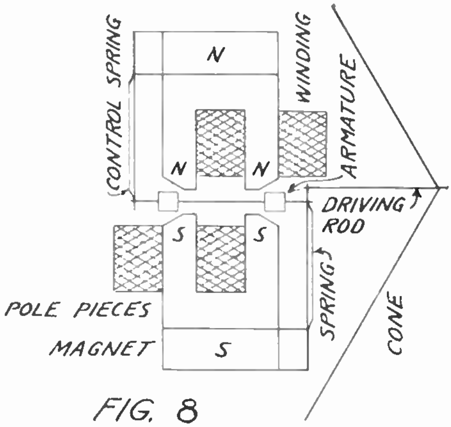


FIG. 8

parallel with the edge of the holes for best operation as well as symmetrical in cross-section as shown.

In all of these magnetic speaker structures it will be noticed that DC flowing through the coils will deflect the armature and the cone. The deflection will be proportional to the DC approximately and the cone may be held in a deflected position with DC flowing.

This study has stressed the fact that all of the armature and cone adjustments s h o u l d result in leaving them exactly in their central or non-deflated positions so that they may swing one way as easily as the other.

In early speaker design it was customary to wire the magnetic speaker in series with the output plate circuit so that it would act not only as the AC load on the output tube, but also would carry its DC p l a t e current. This wiring is shown in Fig. 9.

As soon as the receiver is turned on, plate current of the output tube flows through the speaker winding and deflects the armature and cone. A maximum signal to the tube can only vary its plate current from approximately zero to double this a m o u n t. This means that the cone will be operated only on one side of its total range of swing. When connected it will be deflected half way in one direction and as the current increases or decreases from this average *no signal value,* the cone will deflect from its neutral position to its maximum deflection in only one direction.

In e a r l y practice the serviceman would adjust the armature and cone to their neutral positions *while the speaker was in the circuit and its windings were carrying the average no-signal plate current of the output tube.* This made the speaker adjustment change with the age of the output tube and had other serious disadvantages such as reducing the magnetism of the permanent magnets.

The ordinary permanent magnet of the horseshoe type may be remagnetized if this is needed. Because there is no practical way to measure the amount of magnetism, the loss of magnetism must be determined by the judgment of the serviceman. If the magnetism is so weak that it can hardly be detected by the pull on a metal screw driver or nail, the magnet needs to be remagnetized.

To do t h i s work a coil must be made which will carry the current of a storage battery. Prepare a winding form consisting of a central round piece 1 to 1.25 inches in diameter and

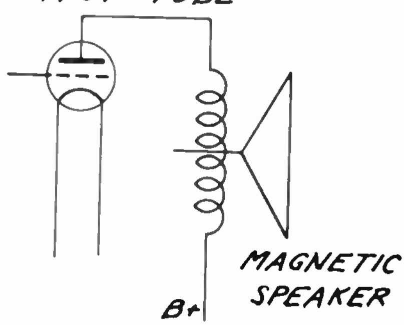


FIG. 9

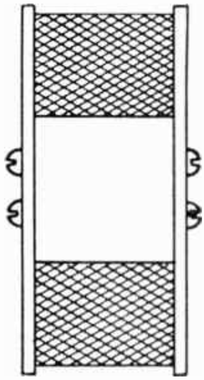


FIG. 10

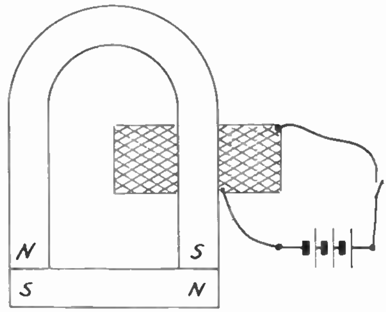


FIG. 11

.875 to 1 inch long as in Fig. 10. Place ends of at least 3 inches diameter on each end of the center core and place 3 or 4 pieces of narrow adhesive tape (adhesive side out toward winding) on the center core. Now wind 200 turns of No. 16 DCC wire on the form and fold the adhesive tape over the winding. String or ribbon may be used here, although this is less convenient. The ends are then removed and the winding slipped off of the core. It may be heavily painted with glue or shellac so that it will remain in shape during use.

The magnet to be remagnetized is inserted in the winding as in Fig. 11, and a *keeper* (iron or steel slug) must be placed across its open poles. This keeper should have the same cross-section as the magnet.

For the greatest magnetism, the former magnetic polarity of the magnet should be maintained. Figure 12 shows the proper battery polarity to be used for coils wound in either direction.

Close the switch of the battery circuit of Fig. 11 (use a 6 volt storage battery) for just a few seconds during which time, tap the magnet sharply several times with a hammer. This completes the magnetizing process.

Later, receivers were designed using an output transformer or coupling

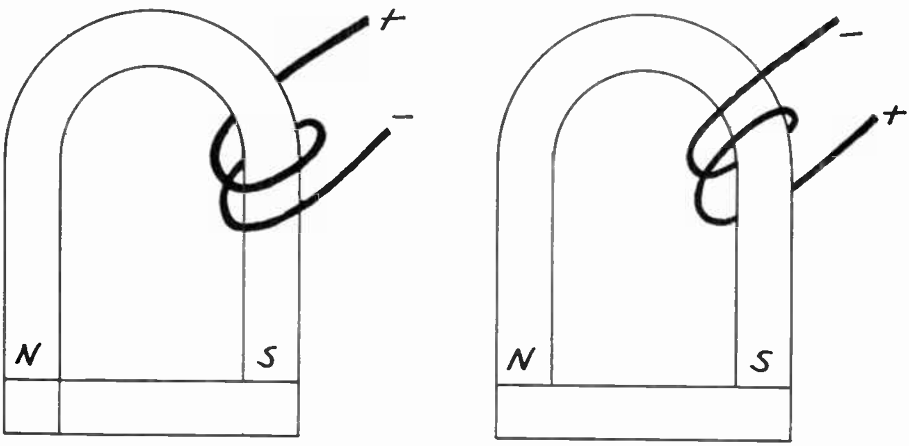


FIG. 12

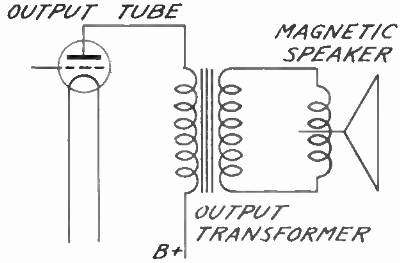


FIG. 13

unit as in Figs. 13 and 14. In addition to preventing the flow of DC in the speaker coil this transformer, Fig. 13, can exactly match the speaker and tube in impedance. An exact match was rarely possible with the other method.

The other method also widely used, but less exact, was that shown in Fig. 14, where a coil and condenser serve to couple the speaker to the tube. For this coupling, as well as for the transformer type, no DC flows through the speaker winding. Its total latitude of movement of the armature and cone is just twice that of one carrying DC. Moreover, no additional adjustment need be made when matching to any output tube or stage. Incidentally, the transformer method is preferred and should be used in all cases where possible.

When you have a speaker adjustment, repair or replacement to make and the speaker originally carried the DC plate current of the output tube, always use a transformer or a choke and condenser coupler as in Figs. 13

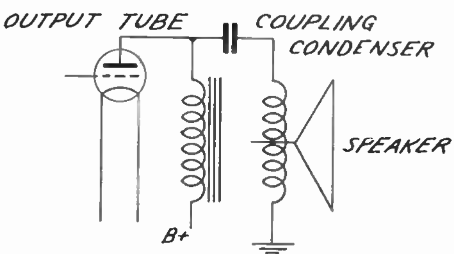


FIG. 14

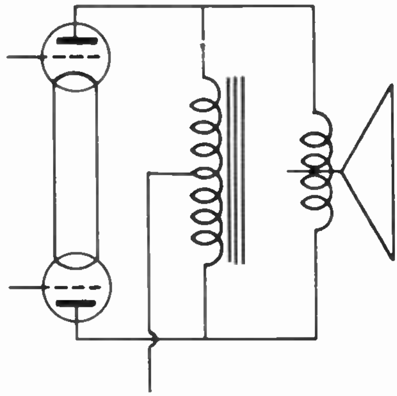


FIG. 15

and 14. The results will be well worth it from every point of view.

Where you have a push-pull output with which to deal you can place the speaker connection from plate to plate provided a choke coil carries the DC load as in Figs. 15 and 16. Here two plate output coupling methods are indicated. In Fig. 15 there is a choke coil while in Fig. 16 there is a transformer, the secondary of which may go to another speaker or otherwise is left open.

In some instances you can obtain a very close or exact impedance match of tubes to speaker as magnetic

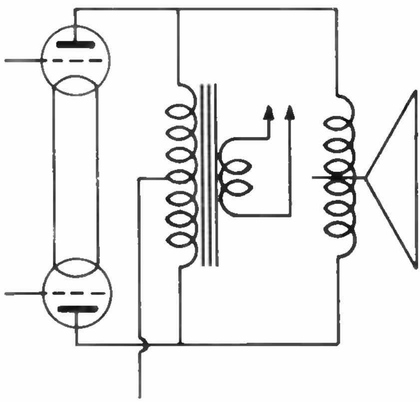


FIG. 16

speakers are usually of high impedance. Many of them have an impedance value of around 4000 ohms. Obviously the impedances should be matched as closely as possible. Note that when connected directly from plate to plate there is no DC flow through the speaker winding unless the tubes draw different amounts of current. The tubes can be somewhat unbalanced in this way before any appreciable current will flow through the speaker. A condenser (.1 to .5 mfd.) may be used in each speaker lead to remove the high DC voltage from the speaker windings to prevent arcing to the grounded frame if desired but usually this is not necessary.

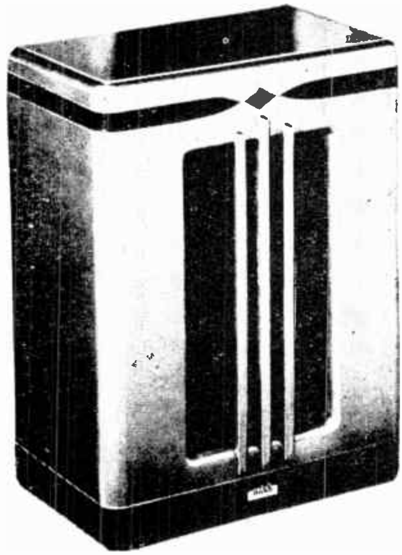
The Dynamic Speaker

Under the classification of the dynamic speaker is the type with the electromagnetic field and also the type with the permanent magnet field. With the exception of the field structure, they are basically the same.

The Cone or Voice Coil

The electrical continuity of the cone or voice coil is of first importance. This should be tested with the lowest possible range ohmmeter.

Its resistance will usually be a small fraction of an ohm to a few ohms and the exact value is not important as long as it is constant. Test from the terminals both directly at the cone (where possible) and at the speaker or output transformer terminal board. Vibration of the voice coil in driving the cone may eventually break the wires connecting it to the terminal board or strip. To prevent noise due to the cone striking the voice coil leads, they are either bent away from the cone or cemented to it. The cone will respond with a *click* when the ohmmeter circuit is closed or opened, if the speaker has no basic defect.



Above is shown a baflex reproducer made by Utah. This type speaker is especially adaptable for use with television and FM receivers which require a wide audio frequency range. *Courtesy Utah.*

A burn-out of the voice coil is practically impossible whereas opening or shorting of it are among the common speaker defects. The voice coil form is usually made of several laminated sections of special paper helically wound and with each lamination with a reverse pitch. In this way, considerable strength is obtained with very little weight. Each layer is glued and pressed in shape and the coil is wound in one or two layers on this form. The entire coil and form are made as thin as practicable, so that the magnetic gap in which it is placed can be as small as possible.

Due to age, moisture, and vibration the winding as a unit may come loose from the voice coil form. The reproduction will then be completely unintelligible and the trouble may be identified with complete loss of low frequency response. Use of the speaker will sound as though you were sandpapering the cone.

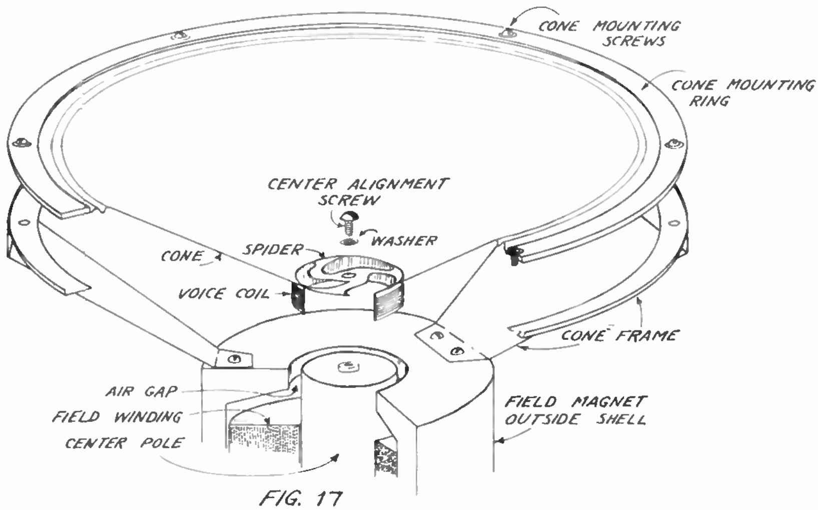


FIG. 17

While it is possible usually to remove the cone and reglue the coil onto the form, it may not pay to do this, especially if the windings have become separated. If available at a reasonable cost, a new cone should be installed. The voice coil form may have loosened, in which case, repair is nearly impossible. A new cone should be used in this case.

To remove the cone, first remove the center screw in the center pole piece which holds the cone coil in true alignment in the airgap. A web-like paper or composition framework mechanically connects the cone coil to the pole piece either at the center or at three places around the outer edge. This frame is called a *spider*. A cone being removed is shown in Fig. 17. This is a typical procedure for a dynamic speaker.

In some speakers, the cone is simply cemented or glued to the metal frame, in which case, it will be necessary to cut it from the frame ring with a knife. After this is done, the mounting ring should be thoroughly cleaned of all traces of paper, glue or cement. In other speakers, a metal mounting ring as shown in Fig. 17 with four, six, or eight mounting screws are used to hold the cone edge to the frame. Where the cone is already provided with a cardboard rim, this metal ring is often not used. In either case, there is a soft cardboard cushion ring between the cone and frame to hold the cone edge tightly without damaging it.

The voice coil leads must be removed from their lugs before the cone can be removed from the speaker frame. In replacing a new cone. sometimes it is necessary to connect the voice coil leads before the cone is inserted. On other models, the cone must be fitted in place first. This depends on whether the voice coil lugs are on the inside of the speaker framework or not. Obviously, since the voice coil leads are short, the cone should be turned so that the leads are adjacent to the lugs.

To operate properly the new voice coil must be exactly concentric with the airgap of the field. The first thing to do after the new cone is set in place is to align the voice coil so that when the cone edge is clamped down it will be under no tension.

To align the voice coil use speaker shims of proper thickness—these usually are made in the following sizes: .0035, .006, .008 and .01 inch. At least three are provided of each size. Place three of the shims in three equally spaced positions around the cone coil either on the inside or outside of it as in Fig. 18 at A or B. The end of each shim forms a *spacer gauge* to hold the cone coil concentrically within the airgap. In some cones, the spider is made of a solid material instead of 3 separate fingers and hence the placing of the shims as in Fig. 18B cannot be used as the inside pole is completely covered. Here the method of Fig. 18A must be used.

If the shims allow the cone to be loose, another thickness should be used. It is not likely that it will be too tight, but if it is, the obvious remedy is to use thinner shims. Do not spring or bend the voice coil in placing it in the airgap. It should slide in easily with just about enough friction produced by the spacer shims to hold the weight of the cone.

The center screw of the spider is now inserted with a slip washer and a lock washer. Sometimes the lock washer serves both purposes, but it is better to have a washer between the spider and lock washer, so that the lock washer may turn with the screw head without damaging the spider.

Before this center screw is tightened, place at least three of the cone edge screws in their proper places. All of them may be inserted, but none of them should be securely tightened. When this has been done, tighten the center cone screw allowing the cone to seat itself as it will and making sure that the tightening screw is not twisting the spider with its motion. The slip-washer mentioned should be used to prevent this.

When this screw is securely tightened, tighten all of the cone edge clamping screws. Then remove the voice coil shims. If the voice coil leads have not already been soldered to the proper lugs, attend to this next.

The operation is essentially the same for a cone which is glued to the frame except that glue is applied before the cone is put into position. The speaker can usually be placed face downward on the bench while the glue dries.

Voice Coil Adjustment

While you have this type of assembly in mind, it would be well to discuss the adjustment of the voice coil. It differs in no major particular from the adjustments just discussed for replacement. However, it is usually not necessary to loosen the screws holding the edge of the cone in order to *center the voice coil.* Simply loosen the center spider screw and insert the shims as described. If the spider is of the *outside type* it will be necessary to loosen

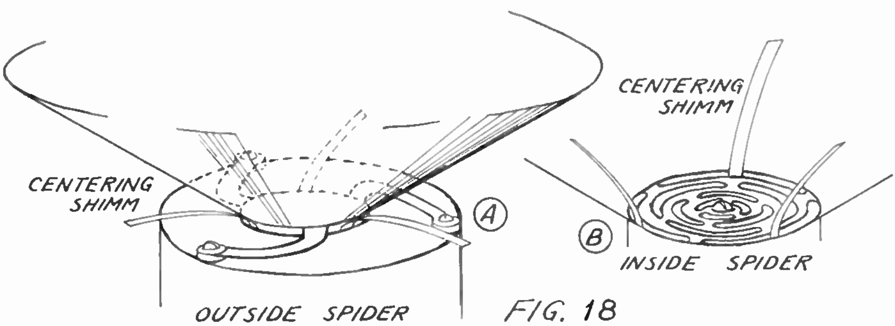
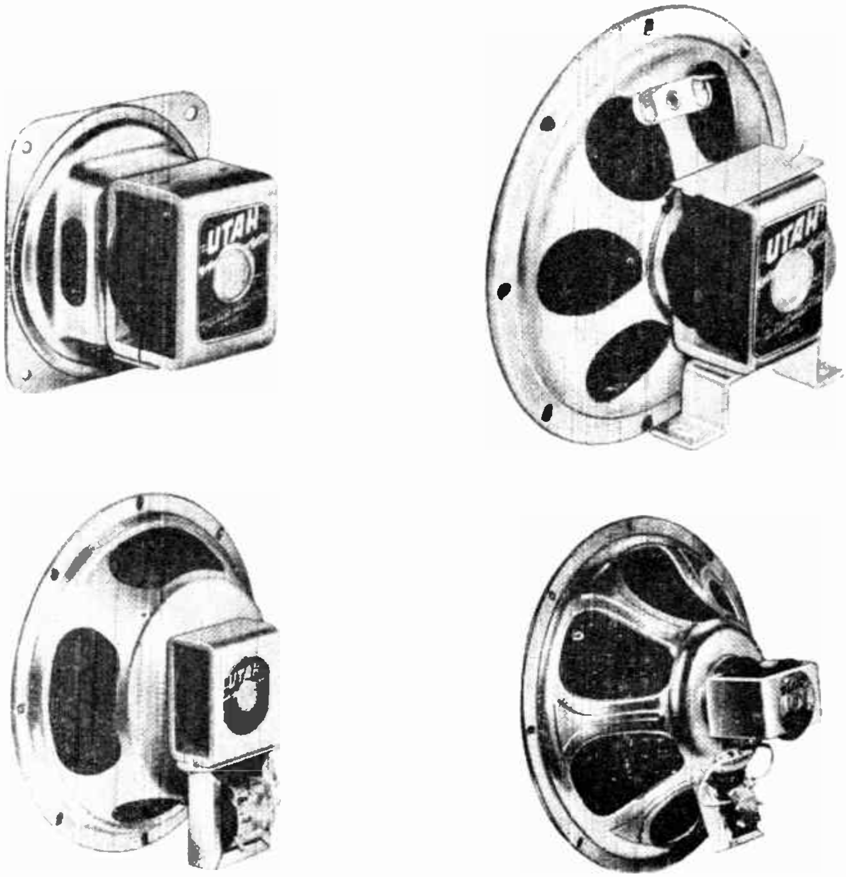


FIG. 18



The above grouping of speakers show four different types used in modern home receivers *Courtesy Utah.*

the three screws holding the ends of the spider fingers. The holes in each are somewhat larger than the screws to allow for adjustment. The center hole in the inside type of spider is also larger than the screw to allow for adjustment.

When the voice coil is forced to the center by means of the shims the central screw is tightened and the shims are removed. This job can be done by ear but the results are not as accurate as with shims. However, the ear method will be described because it will be of great value in the diagnosis of this fault.

While the speaker is operating in response to a medium volume signal (experience only will determine how much volume to use), loosen the spider as described just enough so that the voice coil can be moved by the pressure of a finger on it. Move it in all directions and note that when it is off center, the low frequencies will be seriously attenuated, many of them completely absent. As the voice coil is moved to its right position the tone will become the most mellow and natural. When the most mellow and natural tone is obtained, tighten the spider screw.

If it is impossible to align properly the voice coil because of the mounting of the edge of the cone, loosen all of the screws at the edge of the cone and readjust the voice coil. Either a received signal from a station or a signal generator coupled to the receiver may be used. Retighten the spider after the proper centering has been done. Then retighten the screws at the edge of the cone.

Sometimes you will find that one of the spider fingers is broken, in which case to prevent *paper rattle* you should cement a small piece of chamois or thin leather over the break. It is possible to replace the spider with another from another cone but this is not recommended except where a new cone cannot be obtained.

Cut the old spider out with a razor blade and cement another one obtained from a discarded cone, in place, leaving enough of the old spider for a good strong cemented joint. When such a repair is made, insert the voice coil in the airgap of the speaker with the proper shims and tighten the spider adjusting screw. When the cement is dry the shims may be removed and the voice coil will be properly centered.

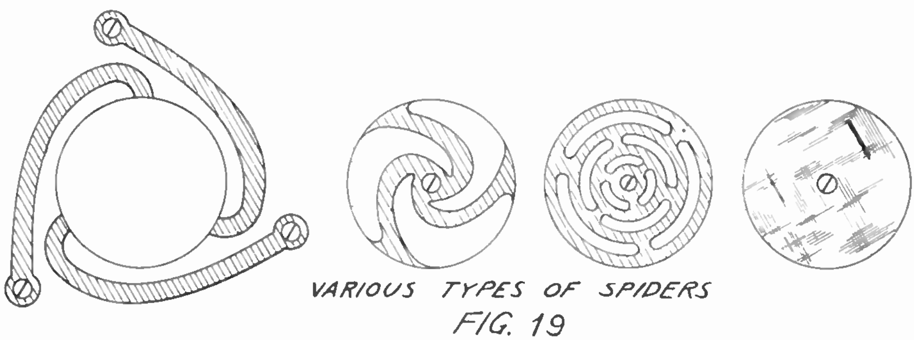
Although unusual, the voice coil may warp so that it is not perfectly round. In this case, insert a tapered cork in it and apply alcohol or a good cement solvent to the voice coil. When dry apply cement collodion, shellac, or airplane dope, making sure that it spreads evenly over the surface and is thin. Allow this to dry for at least an hour before removing the cork and replacing in the speaker.

A few spider and cone assemblies of the inside and outside types are shown in Fig. 19. Study these in order that you may become familiar with the various types in use.

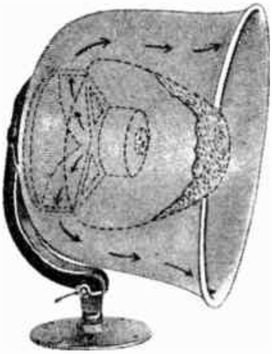
Repairing the Cone

The first cones were made of flat material, by cutting out a wedge shaped piece of paper of the proper angle and cementing the two free edges together after curving the cone. Due to constant vibration and the action of moisture the seam will, in many cases, open and the free edges will alternately touch each other causing a *rustling sound* from the speaker when in use. It is possible to glue or cement this seam again, but this job is neither a permanent cure nor a practical repair. Such a cone should be replaced with a one-piece seamless cone. Practically all of the cones made today are of the one piece seamless variety. They are pressed in shape and have no seam to open.

Opening of the seam of a cone is usually attended by warping of its surface in which case, cementing it again will not correct the matter. Moreover, the cement will make the



VARIOUS TYPES OF SPIDERS
FIG. 19



This view shows a marine type horn speaker which can be used for indoor or outdoor installations. The figure on the left shows the internal construction of the speaker. *Courtesy Atlas Sound.*

cone more rigid along one *element* (seam) than in other places, making it unbalanced in operation.

In working on a cone in connection with adjustment, it often happens that a screw driver or pliers will slip and tear or pierce the cone. A small tear, not longer than an inch or a hole no bigger than this can usually be effectively repaired by cementing a piece of 20 lb. 50 to 100% *rag bond paper* (any stationery store can supply this) over the tear with a half-inch margin all around it. Ambroid cement is recommended for this work. If the tear is near the voice coil or near the cone edge, the cone should be replaced.

A good cone is usually made of porous material and in time will harden. There is no way to satisfactorily soften such a cone again, and in this condition, it will have a more and more *metallic* sound characteristic. This is because it will tend to set up vibrations of its own as its internal stresses are provided with an elastic medium which is self acting and will resonate to one or more impulses. Practically the only remedy known for this is to replace the cone. You will find replacement quite justifiable in improved reproduction.

For the purpose of correct analysis of the defect, it should be observed that there are many different methods of mounting the edge of a cone. Various skins such as chamois, leather, kid, etc. have been used. The cone edge is cemented to a .5 inch wide ring of the skin material and its outer edge is secured to the cone frame.

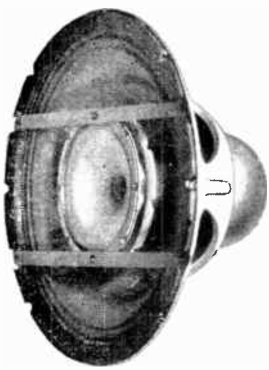
Obviously a cone of material is used for the sound producing diaphragm so that it may move as a unit without bending as a flat area would do. It is the most rigid structure for its weight that is known. The edge of the cone must, therefore, be just as free to move as the voice coil section. It is, therefore, provided with some form of flexible mounting such as soft leather.

A spider system would serve from a strictly mechanical viewpoint, but the cone edge support must also be air-tight or as sound-proof as possible. The supporting material for the bulk of the less expensive cones consists of simply an extension of the same material of which the cone is made with circular corrugations in it for the greatest possible flexibility. When these cones stiffen with age, the flexible edge becomes somewhat stiff, thus restricting the low frequency motion of the cone which is the high amplitude motion. A high grade oil or neatsfoot oil can be rubbed into this edge material of either construction, in many cases restoring proper reproduction.

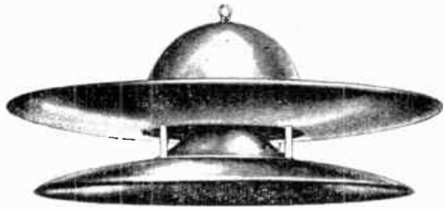
Cleaning the Airgap

The soft iron or steel of which the field magnet is made is relatively soft and will scrape or chip off in very small particles in normal working on the voice coil or field. The strong magnetic flux across the airgap will hold such particles and when the voice coil is inserted and operation restored, a rasping or static-like noise will accompany reproduction. This can only be distinguished from scraping of the voice coil on the field poles by the fact that in the former case, the low frequencies will not be lost. Dust and iron filings may accumulate in the airgap while the speaker is in operation.

To clean the airgap, remove the cone and thoroughly clean the voice coil with a cloth having no lint on it. A very slight amount of vaseline rubbed into the cloth will often serve to aid in cleaning of the voice coil of all fine dust and iron particles. Cleaning of the airgap is somewhat more



Here is shown a specially constructed high fidelity type speaker using a small tweeter speaker in the center of a large speaker cone, giving an audio frequency range from a few cycles up to as high as 15,000 cycles. *Courtesy Utah.*



This speaker is of the Chandelier type which is suspended from the ceiling in a manner similar to that of a chandelier. This type of speaker is popular in many indoor public address installations. *Courtesy Atlas Sound.*

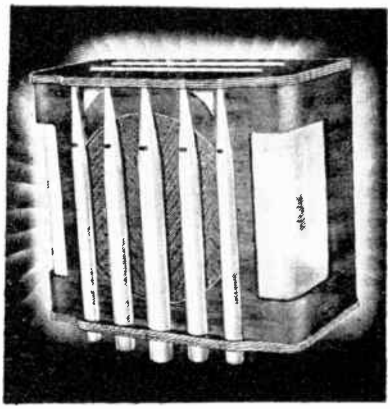
difficult, due to the magnetism present. The magnetism cannot be eliminated by any practical means. While it is much less when the speaker is not in operation, it still presents difficulties.

With a lintless cloth, folded and only slightly oily or with a slight amount of vaseline rubbed in, insert the folded edge in the airgap and turn it around several times. Select another section of the cloth and repeat until the cloth turns very smoothly and there is no visable sign of any loose material in the airgap. Inspect the airgap with an intense light directed into the airgap. After this operation, wipe the airgap in much the same manner with a clean, dry cloth and replace the cone recentering the voice coil and cone edge as described.

The Field

In most respects, testing of the field coil winding and its correction of defects is similar to any transformer winding. In general, the same things will be found at fault.

To each end of any field coil and infrequently to an intermediate point, there must be attached leads. The same wire of which the field coil is wound is rarely, if ever, used for connecting it to the circuit, because it is either not sufficiently flexible, not properly insulated or cabled or more often, too small a wire to use in this way.



The Organette type of speaker shown above has a special audio resonating chamber for increasing the bass response of the speaker. These speakers are commonly used in amusement centers in conjunction with a juke box amplifier. *Courtesy Atlas Sound.*

The leads which serve as external connecting points are soldered to the field coil and the entire unit is covered and usually impregnated with a resin compound. In most cases, such packing does not exclude moisture which becomes locked in the windings. At the soldered connections *contact potentials* are built up due to the joining of dissimilar metals and with the condensed moisture *electrolysis* or chemical action is set up. A small copper wire is easily corroded all the way through in this manner, thus breaking the connection.

For a long period in radio this action was thought to be due to acids used in soldering, but with the elimination of acids it continued. Most soldered connections in a receiver remain dry and do not act in this way, but where these connections are kept enclosed, moisture will become locked in, causing this trouble. The action is very similar to that of one storage battery terminal which will accumulate a green corrosion if not kept greased. With the exception of one unit principally for laboratory use which is a transformer packed dry in a steel tube which is evacuated, there is no known cure for this trouble.

It does not pay, as a rule, to attempt to make a repair of a field coil in this condition. To determine if this action has advanced too far, give the winding a current overload test with a high-voltage DC source and ammeter. If the current remains steady for one or two minutes at 100% overload, it is not likely that this defect is serious. This, of course, is preceded by an ohmmeter test to be sure that the circuit is not open or shorted. A high voltage field, one used as a filter in the positive DC line of a receiver's power supply, will have a resistance of from 150 to 7500 ohms. Most of them are around 500 to 1000 ohms.

Automotive speaker fields will check from 4 to 15 ohms and those used with dry rectifiers about 4 or 5 ohms. For 32 volt systems, 50 to 150 ohms may be expected. It is always a good idea to compare the test value with the proper value as indicated by the manufacturer in his circuit specifications. A 10% tolerance in value, either above or below the rated value, is permitted on the basis of temperature and original construction variations.

If an open occurs, it is probably very unusual that a repair may be made to the coil, but if a short occurs, a thorough inspection of the coil must be made. In its mounting position it is probably too well insulated to make a thorough visual inspection, so it should be removed.

To determine if the magnetism is being built up in the field, bring an iron or steel screw driver close to the center pole piece. If its attraction is noticeably increased when put into operation you may be sure that the field is magnetized.

There are several methods of field construction used, a few of which are shown in Fig. 20. The field magnet at A is simply an iron or steel rectangle fitted with a center pole piece. It is attached to the base of the field structure with a threaded shaft and nut. To remove the field winding, remove the nut and take out the center pole piece, and the field coil will simply drop out. If it cannot be repaired, another similar coil can be put in its place. At B the center pole piece is part of a solid back cover, held in place with 4 to 6 screws. The cover is circular as shown and the coil is entirely enclosed, except for the airgap. In this case to inspect the coil, the back plate with the center hole is removed.

Where the center pole piece is *spot welded* or shrunk or riveted onto the outside pole as in Fig. 20, the entire speaker must be discarded as the center pole piece cannot be detached and replaced satisfactorily. There are many variations of this basic construction, but a little thought on inspecting the unit will disclose how it may be disassembled.

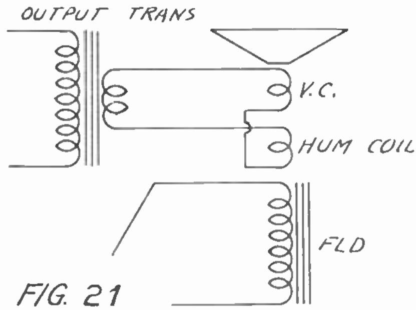


FIG. 21

Some dynamic speakers are provided with a small winding in addition to the field coil known as a *hum bucking* or *hum cancelling coil.* This is wired in series with the voice coil as in Fig. 21, and must be considered when testing the latter. It has negligible resistance as it consists of only a few turns of large wire, rarely more than 50 turns. Burn-out of this winding is not likely, but shorting of it to the magnet frame or shorting of itself is possible. Opening of the coil is also possible at its terminal leads. A simple low resistance continuity test is all that is needed here. However, if the leads to the hum coil are detached or if the coil is removed,

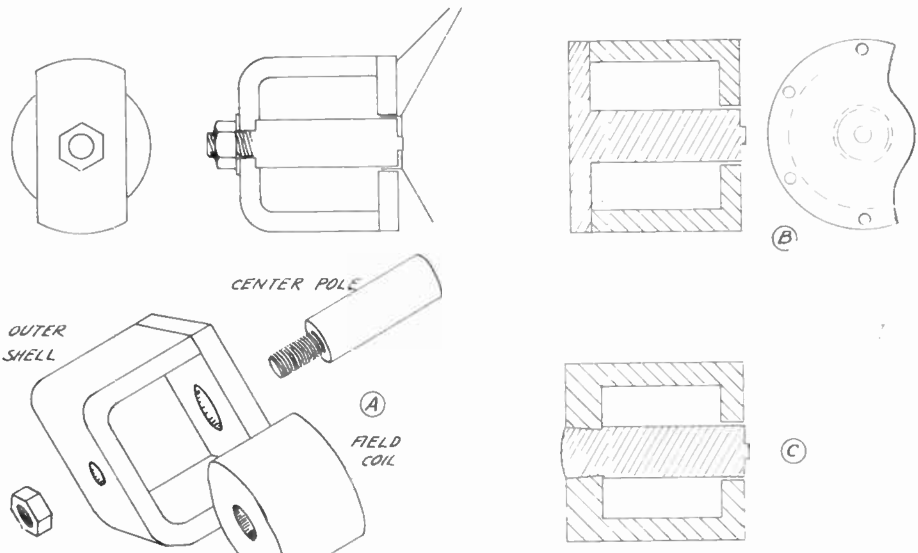


FIG. 20

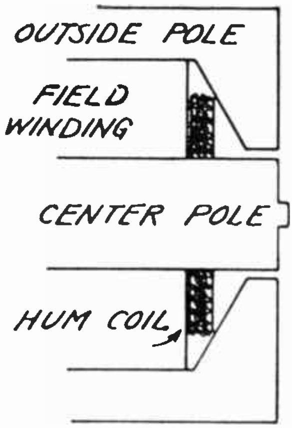


FIG. 22

care should be taken to put it back just as it was before, as it may result in increased hum if this is not done. Figure 22 shows the usual position of the hum coil. It is a flat coil of large radius often called a *pie* (π) wound coil.

Such a coil may be added to any speaker not having one, but to avoid a laborious cut and try method of design, you can use the method of hum control shown in Fig. 23. Place a 20 ohm potentiometer across any 2.5 to 6.3 volt filament winding that is already center-tapped to ground and while the speaker is operating, adjust for minimum hum.

Occasionally you will find a copper disc in the field structure which serves to eliminate hum due to the

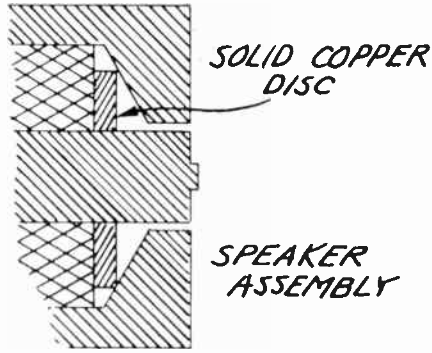


FIG. 24

ripple current of the field but this disc needs no attention except to be placed back in the field as it was found (see Fig. 24).

It should be noticed that in the majority of speakers, the field and voice coils have no common electrical connections. Therefore, any test between the voice coil and field circuits should test open. The exception to this is where the voice coil is grounded intentionally and the field is in the negative DC power lead and hence is also grounded as shown in Fig. 25.

In the latter case to make sure that there is no short of the field it is a good idea to detach all ground connections and test the two circuits independently. The connections are shown in Fig. 25.

The Output Transformer

Because of the necessity for the shortest possible leads connecting the

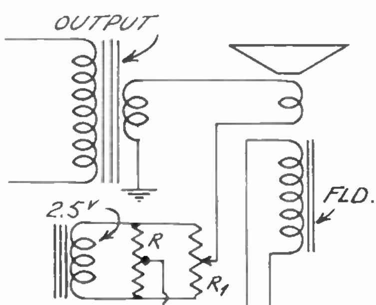


FIG. 23

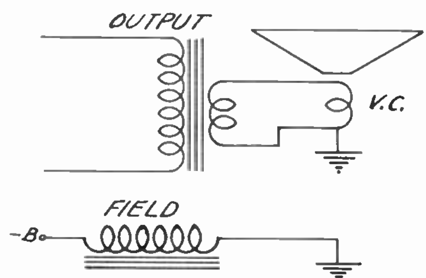


FIG. 25

output winding of the transformer to the voice coil, the output transformer is usually mounted on the speaker frame. The entire assembly is connected to the receiver by means of a multicable (or short leads) fitted with a plug or contact strip. A four terminal plug with speaker assembly is shown in Fig. 26.

The transformer primary is tested between terminals 1 and 2; 2 and 3; and 1 and 3. A test from 1 to 2 should read from 100 to about 500 ohms. That between 2 and 3 should read about the same. Because of one half of the winding usually being wound over the other half, the resistance of one half of the winding will not be the same as that of the other half. The field may be tested at leads 2 and 4 in Fig. 26.

A test from terminal 1 to 4 will show continuity of the field with the transformer tap and will, of course, read the sum of the field and one half of the transformer resistance. A test of terminals 3 and 4 will read approximately the same value. The terminals may be identified by the color of their insulation, or if the cable is entirely covered so that the plug terminal connections are not accessible, they may be identified by the tests indicated. If there is an open, of course, these test values will not be good for identifying the circuit except by the elimination method.

For example, if you get two practically equal readings and a point shows

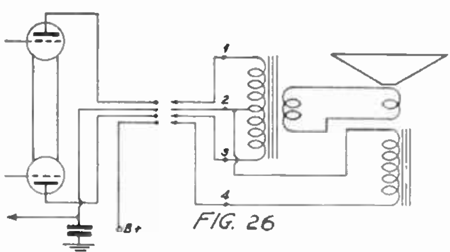


FIG. 26

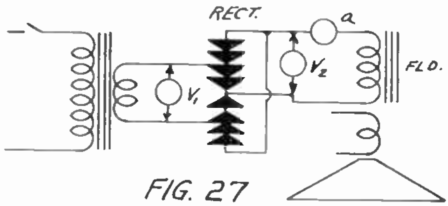


FIG. 27

open from every other pin, you may know that it is terminal 4 to the field. There are quite a number of methods of connecting the speaker and output transformer. They will differ with the type of power supply used, the output stage, whether it is single or push-pull, or uses triode or pentodes, etc. However, this method of identifying and testing the various parts while referring to the schematic circuit is suitable for all cases. Always refer to a diagram of the circuit under test and note values if any, marked on the various parts.

In connection with a low voltage field supply for externally excited fields, the usual method is to use a low voltage copper oxide bridge rectifier with a step-down transformer. A typical circuit is shown in Fig. 27. Properly loaded, the secondary of the power transformer should read about 10 to 15 volts at V1. At the output due to loss in the rectifier the voltage at V2 will be 5 to 8 volts. A DC ammeter may be placed in the field circuit as shown if there is any doubt as to the field carrying current. The meter should have a range of from .5 to 2.5 amperes. Some low voltage fields draw up to 2 amperes.

The rectifier may be tested with an ohmmeter, but if there is no output or if it is insufficient, it is impractical to replace any part of the rectifier. A new one must be used in its place. The transformer, of course, may be given a continuity test. If a high voltage exciter supply is used for the field it must be tested in accordance with conventional methods for power supply units treated elsewhere in your SAR course.

The Tweeter Speaker

To cover the upper register of audio response, many of the more expensive receivers use more than one speaker. The high frequency speakers are commonly called *tweeters* and may be of the dynamic or crystal type. Repairs for the dynamic type are just like those already described. The construction is similar to the large dynamic speaker except that the cone is smaller and lighter.

New designed speakers use a large 12 or 15 inch speaker with a small tweeter speaker mounted inside the cone of the large speaker. This allows for a wide frequency response—some of these have a frequency range from 15 to 12,000 cycles.

This type of speaker is found in the more elaborate and expensive receivers only. The service problems of this type speaker are similar to the problems of other receivers except there are two speaker systems to check.

The Crystal Speaker

You may have no occasion to repair a crystal speaker as they are not in very common use. There is not much about a crystal speaker that can be repaired except the cone and cantilever action. If the crystals crack, they must be replaced simply by detaching them from their mounting and care should be taken as with the magnetic speaker, not to allow the cone to impress any tension on the crystals. Adjustments for releasing tension are made with a soldering iron as described for the magnetic speaker.

The Condenser Speaker

The once popular condenser speaker has been obsolete for some years now. If you ever have an occasion to work on such a speaker, it should be discarded and substituted with a good magnetic or dynamic speaker. Repair is very impractical and the speaker operation is quite inefficient. Moreover, there are no more parts or complete units on the market.

The Permanent Magnet or PM Dynamic Speaker

The repair of a permanent magnet dynamic speaker is identical to that of the other type speakers with the exception of the field. The field is constructed very much like that of a dynamic type except that it has no winding. It is permanently magnetized when made and this magnetism remains up to 70 or 80% of that supplied by electromagnetic methods.

The cone and voice coil are serviced as described for dynamic speakers while the magnet needs no attention.

Coupling of Speakers to Output Stages

Manufacturers have exercised considerable individually in the design of dynamic speakers. Voice coils, fields and the magnetic structure are by no means standardized. Each speaker is made specifically for the receiver in which it is installed.

Because of its use in the filter circuit, a speaker field affects many voltages—vital to the correct operation of the receiver. It may control the plate voltage, screen voltage, bias, bleeder current and filtering efficiency. Hence it must be replaced with an equivalent value if defective.

While this is easily possible, there are so many different voice coil impedance values that it is rarely possible to find a speaker which will be exactly suitable in field resistance and voice coil impedance value.

The problem is not easy, as it is difficult to measure exact impedance

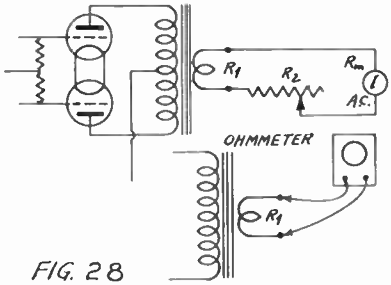


FIG. 28

values with the inexpensive means at the disposal of the serviceman. Since the voice coil winding of the output transformer must match in impedance both the output stage and the speaker voice coil, a similar problem arises for this transformer.

Methods have been suggested using the DC resistance of the voice coil winding as an index to the voice coil impedance but this is unsatisfactory, as it may be 1000% off in ordinary routine measurements. The two—DC resistance and impedance—actually have no fixed relation with each other.

A simple way of finding the output impedance of any voice coil winding is described in the following: See Fig. 28.

Measure the DC resistance of the voice coil winding Rl. Then connect a rheostat and ammeter in series across the voice coil winding of the output transformer as in Fig. 28. Add to this the ammeter resistance Rm for the range you intend to use. Call this total of Rl + Rm, Rt.

Next feed any signal (constant amplitude) as from an audio signal generator, 400 to 1000 cycles, into the receiver either from the RF input modulated RF or feed AF to one of the audio grids.

Adjust the signal generator or set the volume control for a large output with R2 of Fig. 28 at its zero setting, shorted or with no resistance in the circuit. Now without making any other changes adjust R2 so that the the meter reads 70.7% of its former value (70% is close enough). If the former value is some even multiple of 10, the latter value will be simplified.

Now measure the amount of R2 in the circuit. The value of $Z = \sqrt{2RtR2 + R2^2}$. As an example, suppose RT measured .5 ohm, being the sum of Rl at .375 ohm and Rm at .125 ohm and R2 was exactly 6 ohms when the current is reduced to 70% of its original value.

Then—

$$\begin{aligned} Z &= \sqrt{2 \times .5 \times 6 + 36} \\ &= \sqrt{6 + 36} = \sqrt{42} \\ &= 6.48 \text{ ohms.} \end{aligned}$$

The larger the original signal current without distortion the more accurate will be the value. Below about 50 ohms the accuracy will be considerably better than that of the best AC meter reading. The results will, therefore, be as good as those obtained for the average factory built receiver. The accuracy will be quite good up to 500 ohms for practical work.

Very often the voice coil winding of the output transformer will be tapped at various points to provide three or four or more impedances. For example, as in Fig. 29 it may be tapped at 2, 4, 8, 16, 200 and 500 ohms for

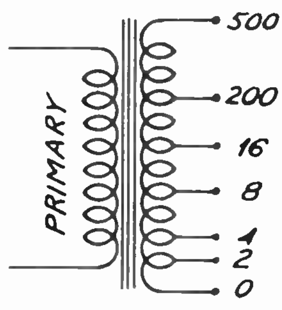


FIG. 29

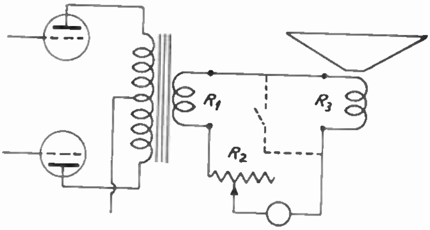


FIG. 30

a fairly universal connection. Usually the speaker or line may be connected to one common terminal and one of these marked values. However, there are quite a number of intermediate impedance values between each two terminals which, if known, may form exact values of odd speaker values. The impedance value between any two terminals may be found as stated or may be computed from known values. This is done as follows:

$$Zo = Z1 \left(\sqrt{\frac{Z2}{Z1}} - 1 \right)^2$$

If—

Z1 is any terminal impedance.
Z2 is any higher terminal impendance.
Zo is the value actually obtained between the two.

For example, if you want to know what value of impedance you can get by connecting between terminals marked 2 ohms and 4 ohms substitute these values in the preceding equation. (See Fig. 29).

$$\begin{aligned} Zo &= 2\ (\sqrt{4/2} - 1)^2 \\ &= 2\ (\sqrt{2} - 1)^2 \\ &= 2 \times (1.414 - 1)^2 \\ &= 2 \times (.414)^2 \\ &= 2 \times .1714 \\ &= .343 \text{ ohm approximately.} \end{aligned}$$

Thus it is obvious that a great number of impedances are available by this means. The impedance value of the voice coil should match that of the transformer winding within 5% for best results.

To find the voice coil impedance of a speaker the more accurate method consists of a measurement of the voice coil winding of the transformer as in Fig. 28 and then a similar measurement of both windings in series as in Fig. 30 and subtracting the impedance of the transformer winding from the total. Simply add the DC resistance R3 of the speaker voice coil to Rl and Rm for the new value of Rt in the computation. Be sure that the normal speaker field current is flowing while this test is being made.

As a final check on the proper matching of the speaker to the receiver, you may adjust R2 of Fig. 30 to zero at the same time lowering the signal so that the meter reading will not go above half scale, and short R3 as symbolized by the switch shown in dotted lines. With this short the meter reading should approximately double. If it is considerably less than double (1.5 for example), the speaker voice coil has too low an impedance, while if it more than doubles its reading, the speaker voice coil impedance is too high. This is a good rapid test for determining the proper matching. Here again, the highest possible signal will produce the most accurate results.

There are, of course, many bridge tests possible but due to the require-

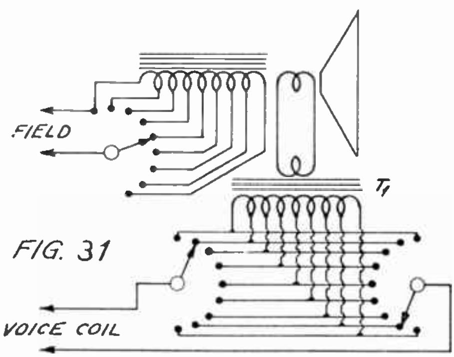


FIG. 31

ments of a standard and the expense of the equipment for this one job, they are not recommended for the serviceman. They are impractical.

Test Speakers

Very often a universal test speaker may be found advantageous in determining the source of a defect. For this purpose there are universal speakers available having taps on their field so that they may be substituted for any field value in common use and a transformer coupling to its voice coil having a multiple tap primary. The circuit is shown in Fig. 31. A number of field resistances are available. They can be used to approximate the usual speaker field within 10%. The signal transformer (T1) primary is tapped for many standard values, and values may be obtained between any two taps by means of the switch shown. The speaker may be adjusted to match practically all output transformers and output tubes as well.

With this device practically any receiver may be temporarily fitted with a speaker of the correct value. It may easily identify any defect as being in the receiver or speaker. Further it permits the proper testing of the output transformer where there is any doubt as to a perfect match.

If you suspect part of any winding of a field coil, a voice coil transformer winding, etc. to be shorted, you may know that shorting it again will make no change in the receiver operation. If any change is noticed on shorting part of any winding, it was not shorted at the start.

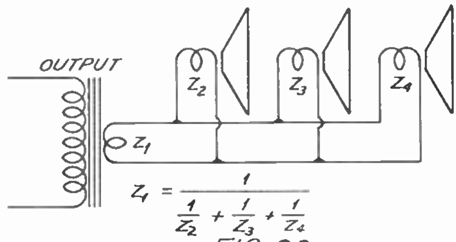


FIG. 33

Multiple Speakers

The present day serviceman will have jobs in which there may be two or three speakers rather than only one. He must, therefore, observe certain points in connection with multiple speaker installations.

One way of connecting voice coils is in series as in Fig. 32. In this method, the sum of the voice coil impedances must equal the transformer impedance. On other occasions the speaker voice coils will be wired in parallel as in Fig. 33. In still other instances will be found a series parallel connection as in Fig. 34.

In every case the two other speakers used must be wired so that each cone is moving in the same direction at the same time for the same signal impulse.

The best way to determine which way a signal impulse drives a cone is to place a battery (4.5v) in series with the voice coil and transformer circuits as in Fig. 35. and close the circuit momentarily, holding your hand on each cone or watching both cones. If one of the cones moves out while the other moves in, reverse the terminals to one of the voice coils. If they both move in or both move out,

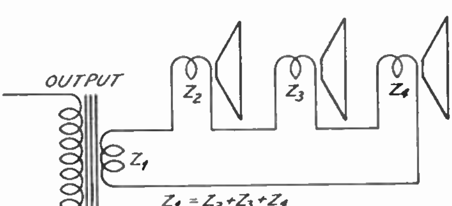


FIG. 32

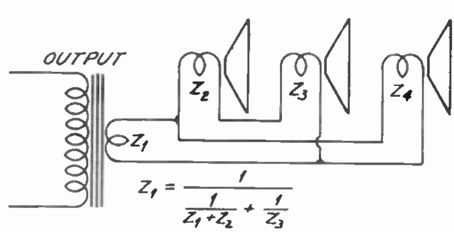


FIG. 34

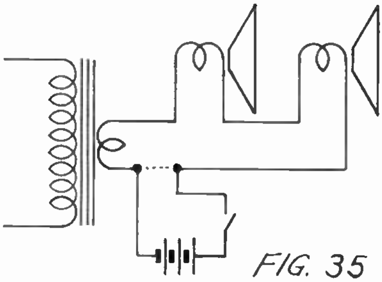


FIG. 35

they are correctly phased.

In a three speaker arrangement if two cones move one way while the third moves the other way, reverse the voice coil leads to the odd cone only.

The principle symptoms of cones which are in reverse phase is loss of low frequency response.

Cabinet Structure

There are some things that the serviceman can do in the way of mounting a speaker so that the best results for the installation is obtained. If there are any loose screws, shield pieces, braces or insulating cardboard about the chassis they should all be tightened so that they cannot vibrate. This is true also of sections of veneer which may have come loose from the cabinet, as they will produce a rustling noise when they vibrate due to sound waves.

The edge of the cone frame should be mounted securely against the edge of the speaker coil. If there is any appreciable airspace between the edge of the speaker and the cabinet, low frequencies will be lost.

Many of the circuits of early design did not satisfactorily handle the sound waves produced by the back of the cone. If the owner of the receiver wishes to have the resulting *booming* corrected you can fit the inside of the cabinet with *ribbed celotex* for sound vibration.

The cabinet is first completely lined with porous celotex (.5 inch thick stock) and over this is placed two or three inch strips as far apart as their width throughout the entire enclosure as in Fig. 36.

The cost of this work is mainly in the time required and should not be done unless the customer thinks that this cost will be justified. Many people may not notice sufficient improvement to justify this cost, but there will be a definite improvement in quality none the less. The celotex is attached with finishing nails and glue.

Cabinets of more recent design are provided with various means of acoustic control, such as a padded *labyrinth* for absorbing the sound in back of the speaker, steel tubes for equalizing the air pressure at low frequencies and by still other methods. Such things do not require repair but may come loose, in which case, they should be secured to prevent vibration.

The speaker of a receiver is the determining limiting factor of the response expected from a receiver. It doesn't matter how well the audio amplifier is designed that drives this

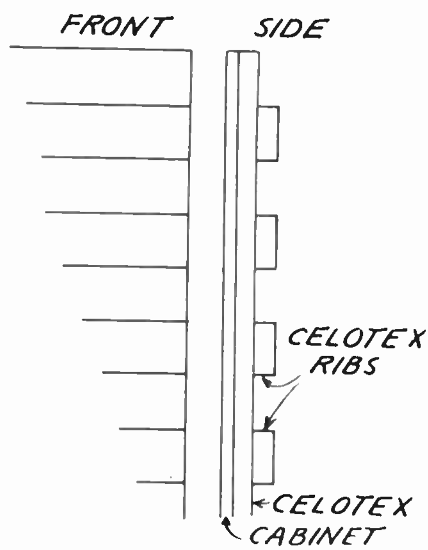


FIG. 36

speaker if the speaker will not respond to the frequencies fed to it. One of the biggest improvements in receiver design in the past few years is in the design of the speaker. Today the entire receiver is built around the speaker. Thus, the importance of the proper operation of the speaker is evident.

Many of the audio amplifiers associated with a speaker are designed to improve the characteristic of the speaker used with the amplifier. Thus, undesirable results are often encountered when a substitute speaker is used to replace the original speaker.

It is not only important that the speaker itself be properly replaced but the circuit components within the amplifier which drives the speaker. The speaker is sometimes blamed for faulty receiver operation when in reality some other receiver part is at fault. Because of this, it is important to isolate the defect, making sure which component is at fault and then correct the fault.

As the speaker is an electromechanical transducer (changes the electrical impulses to audible sounds) it is first to be accused of being faulty when distortion and noise is emanating from it.

The placement of the receiver or speaker, if one is used separate from the receiver, is very important to the operation of the speaker. Receivers where the back of the cabinet is open should be located such that a spacing of at least 3 to 4 inches is left between the wall and the cabinet if it is to be operated against a wall. This will allow the air to equalize as the speaker is operating, eliminating excess boom of the low tones. Where speakers are used in large auditoriums, the placement problems are magnified.

Synthetic Bass

The smaller cabinet model radio has always had the problem of poor bass response due to the small speaker which it must use. Recently a receiver was designed which tends to improve the bass response by introducing a synthetic bass circuit. This circuit operates upon the principle that the ear does not respond to the actual low tones but responds to the harmonics of these tones which are created by the nonlinearity of the ear when the low tones are impressed upon the ear. Thus, if these harmonics which are found to be made up of the odd harmonics are produced at the speaker before they reach the ear, they will appear to the ear to be the low frequency fundamentals and the impression of a low bass will result.

The system used to develop this synthetic bass is shown in Fig. 37. The network R5, R6 and C5 furnishes a positive feed back. This feed back is essentially low frequencies. due to the presence of C5 which bypasses the high frequencies to ground. Tube V1 in Fig. 37 is biased with a small bias so that it will create more harmonic distortion and as V1 is a pentode, this distortion will be mainly odd harmonics which is what is needed. C4 furnishes negative feed back from the output. By doing this, cabinet resonance can be avoided—and it also improves the stability of the circuit. C3 serves as a hum reducing circuit by applying a hum voltage in the opposite phase from that ordinarily developed in the tube. thus. cancelling out the hum. C6 being the coupling condenser from the plate of V1 to the grid of V2 determines the frequency of maximum feedback through R5, R6, and C5. R3 serves to increase the bias on V1 in the presence of a strong signal. thus reducing the bass at the high signal level automatically compensating for the bass response.

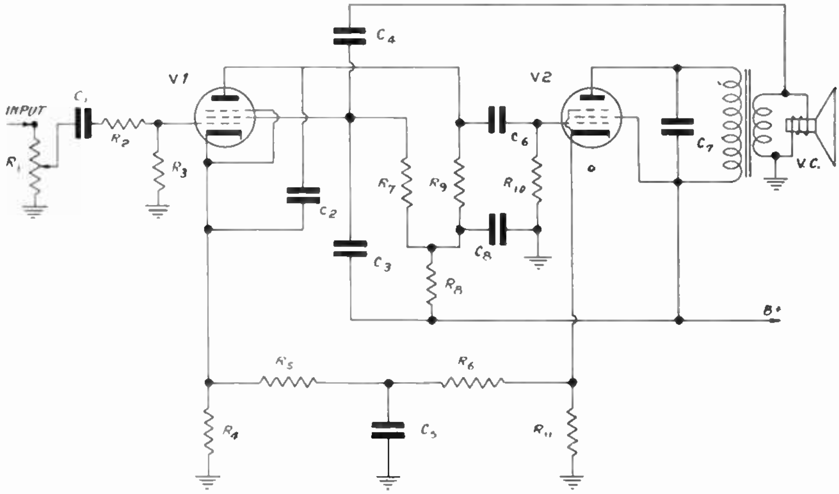


FIG. 37

The maintenance problem with this type circuit is, of course, different from other speaker systems. As you can see from the circuit, the value of each part is determined from the design. Therefore, when a replacement becomes necessary, a part of the same value and characteristics must be used.

Many circuits of this type will be confusing to servicemen not familiar with them. Some of the service difficulties that arise with circuits of this type are loss of the bass. This may be due to the stiffening of the speaker cone due to age.

By finding the resonant point of the speaker you can tell whether the speaker is too stiff. This can be done by applying a variable frequency audio oscillator to the audio amplifier of the receiver noting what frequency the cone is displaced the greatest distance. This is the resonant frequency and it should be as low as 120 cycles per second for small receivers and 60 cycles for larger receivers. If the speaker cone resonant point is not at or below this value, either the speaker will have to be replaced or the old speaker repaired.

When replacing these units, the phase of the speaker must be correct if feedback is to be expected. To check if the phase is correct when installing a new speaker in a receiver employing a circuit such as that of Fig. 37, disconnect R6 from the cathode of tube V2 and feed an audio signal to the audio amplifier, noting the effect on the output of the signal.

C4 is connected and then disconnected from the circuit. If an increase in the output is observed when it is disconnected, the phase is correct. If the signal decreases when it is disconnected, the phase is wrong and the leads of the speaker voice coil will have to be reversed.

Many times the speaker can be repaired by painting the outside of the cone with acetone or finger nail polish. In this way the cone will be softened and the resonant frequency reduced. The correct amount of softening can be determined by checking the resonant frequency each time the softener is applied and when the correct resonant frequency is reached the speaker is repaired.

Speakers are very easy to replace and in most cases when the speaker is in need of considerable repairs it is better to replace it than to attempt a repair.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 How may unnecessary work on speakers be avoided?

No. 2 Why should a speaker armature be in the exact center of its range of motion when no signal is applied?

No. 3 What method of coupling a magnetic speaker to an output tube is preferred and why is this true?

No. 4 Describe the two general types of spider construction used in dynamic speakers.

No. 5 Is the voice coil centering done entirely by the spider adjustment?

No. 6 Name three cone defects for any one of which a cone should be replaced.

No. 7 Where would field coil opens most likely be found and why is this true?

No. 8 Is a grounded field coil or voice coil necessarily an indication of a defect in the speaker?

No. 9 Would a DC resistance test be satisfactory for determining the voice coil impedance of a speaker or a transformer for matching purposes?

No. 10 State the procedure for checking the phase of two speakers which are connected to the same output transformer.

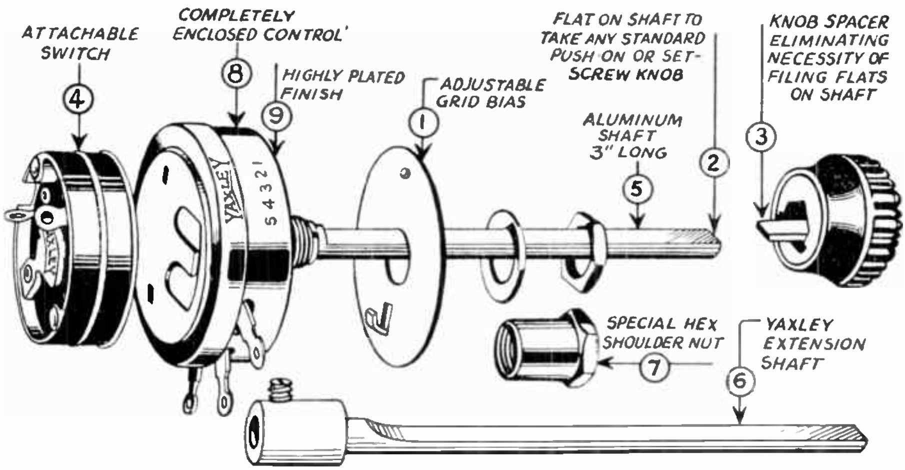
HOW TO MAKE VOLUME CONTROL REPLACEMENTS

LESSON NO. TV-16

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K2552M



The above drawing shows a complete Mallory-Yaxley replacement volume control unit with all the attachments including the attachable switch. *Courtesy of Mallory-Yaxley.*

HOW TO MAKE VOLUME CONTROL REPLACEMENTS

Lesson No. TV-16

While a volume control is nothing more than a variable resistance, the facts from experience with them indicate that their servicing, repair and replacement, becomes a special servicing problem. Therefore, it will be found profitable for you to investigate the various methods of controlling volume, the design of the circuits used for this control and the diagnosis of defects in controls with methods for their replacement.

Every part of any radio receiver carrying any current while in operation is vital to its operation. Furthermore, if any such current is changed it will have some effect on the output of the receiver. From this it is found that there is no restriction on the place in the circuit where the volume control may be connected. In fact, as a complete survey of receiver development will show, practically every conceivable method has been used for the control of volume. Some methods actually hamper the normal operation of the receiver, some are quite inefficient, while still others are so critical in operation as to be undesirable.

Now, starting with those factors which are most desirable in a volume control, it is easy to see which control must be chosen for a particular circuit. And this control must have a design which best fits the requirements of that circuit.

For this study it is necessary to refer to sound and the characteristics of the ear. It has been found that a barely noticeable change in sound intensity at any volume level is always a percentage change rather than a numerical or linear change. The amount of this percentage change necessary to cause a barely noticeable increase in volume is 12.2% and for a decrease in the sound level the ear will detect a change as low as 10.88%

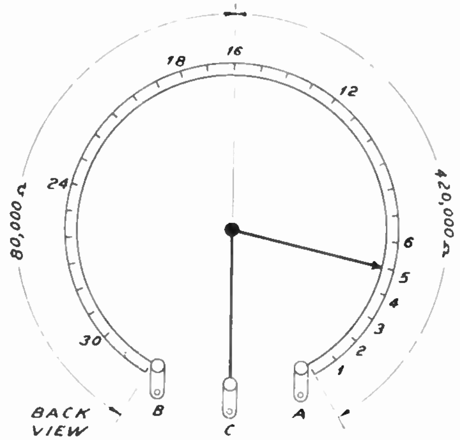


FIG. 1

but will not notice a change of less than this amount. If a sound either increases or decreases 10% the change will not be noticed, but if increased 12.2% or decreased 10.88% it will be noticed. Now what does this mean in terms of resistance values of a common type of volume control? It must be recalled that the voltage of the speaker is proportional to the voltage output of the volume control and this in turn varies as the square root of the output sound energy.

To understand this better you may divide the total angular range of a volume control into, for example, 32 equal parts. Figure 1 shows a typical range of motion of about 300 degrees divided in this manner. It is connected as in Fig. 2, with the total signal applied across it. One end is connected to the signal coupling condenser from the second detector output while the other end is connected to ground. The movable element of the volume control connects to the first audio grid. The letters A, B and C correspond in Figs. 1 and 2.

Assuming that the signal voltage is constant at 20 volts as represented by (V) of Fig. 2, if the moving arm C is at position A, the total signal will be supplied to the grid. In Fig. 1 thirty-two points have arbitrarily been marked on the scale although there may be 10, 50, or 100 if desired. Starting with 32 divisions the first thing to do is to determine the resistance between each point or the way in which the resistance must change with the angle of motion of C so that the signal will be reduced 10.88% of its value at every division. At point A the signal will be 20 volts, but at point 1 of Fig. 1 it must be less by 10.88%. Therefore 100 − 10.88% = 89.12% and 89.12% of 20 volts is approximately 17.83 volts at point 1 of Fig. 1. Other values are found as follows:

VALUE				VOLTS
A				20
1	.8912	× 20	=	17.83
2	.8912	× 17.83	=	15.9
3	.8912	× 15.9	=	14.2
4	.8912	× 14.2	=	12.65
5	.8912	× 12.65	=	11.28
6	.8912	× 11.28	=	10.05
12	.5	× 10.05	=	5.
18	.5	× 5	=	2.5
24	.5	× 2.5	=	1.25
30	.5	× 1.25	=	.625

In the table the first seven values are shown continuously and then every 6th value from there on. Thus at every sixth position the resistance is reduced by one-half (.5) and therefore the multiplying factor becomes .5 instead of .8912. All possible voltage values for each position

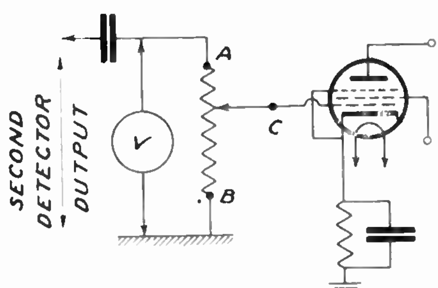


FIG. 2

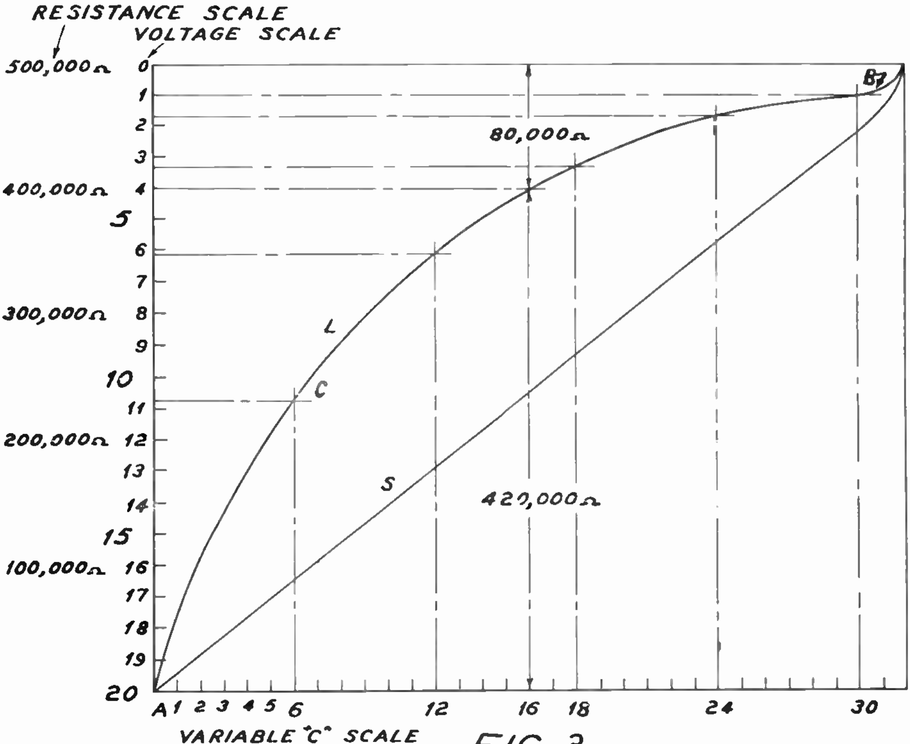
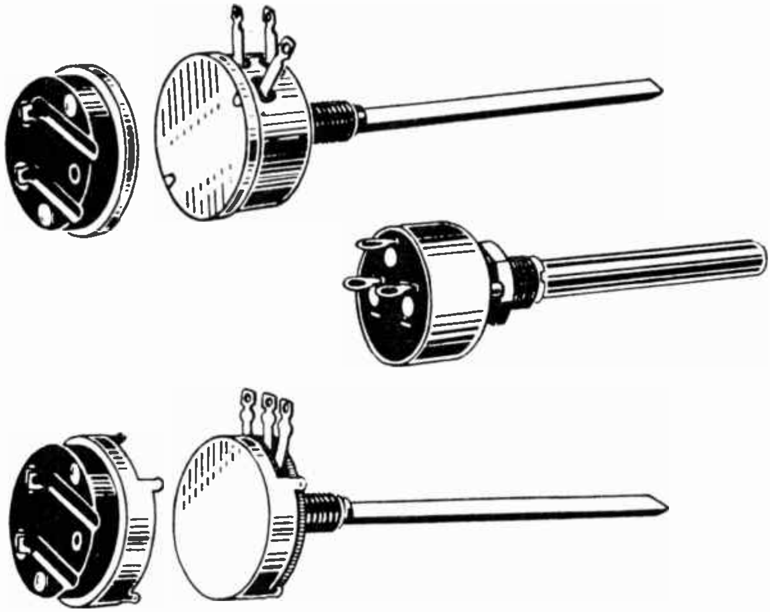


FIG. 3

of C may be found by continuing the mathematical work shown by the table.

To bring out the value of these figures, it is necessary to plot these voltages with reference to rotation of the control so you may visualize just what relation the resistance has to the circuit. A graph as a result of this plotting is shown in Fig. 3. See curve L. Note that as the movable element of C of Fig. 1 is moved along from A to B the voltage from C to A of Fig. 3 at first reduces very rapidly and then as it approaches B, the voltage reduces more gradually. Note in this type of control at point 2 of Fig. 3 the voltage reduces more than 4 volts, while from point 14 all the way to B the total decrease in voltage is less than 4 volts. *The signal voltage must change in this way so that the sound level will decrease and increase in proportion to the amount of rotation of the volume control. The volume changes evenly or is evenly distributed about the control range*— the resistance change on the other hand is inverse to this.

If the resistance were uniform as indicated by the straight line in Fig. 3 at first in moving the arm C from A toward B the volume would decrease quite gradually. And then at about point 12 it would suddenly decrease very fast—so that it would actually be difficult to set the volume control at any desired point. Only a slight motion toward B would produce almost silence. Practically all of the useful volume control range would be between points 10 and 18, and the value of the unit as a volume control would be almost useless.



This view shows three different type volume controls. The top control is of the wire wound type with an end type removable switch which is also operated by the control shaft. The center control is of the midget carbon type, and the lower control is an improved carbon type. *Courtesy of Utah.*

In any circuit where there is a constant voltage impressed (signal voltage in this case, which can be assumed constant), the voltage drop will be proportional to the resistance. The resistance is therefore shown in the left column of Fig. 3 with the voltage increasing between A and C (the movable element) as C is moved toward B. Note that in moving C just 2 points (from A to 2) the resistance left between A and C (at L) is more than 100,000 ohms. At C in the center of its motion between A and B (at 16), there is 420,000 ohms from A to C (16) and only 80,000 ohms from C (16) to B. Thus 80,000/500,000 gives .16 or 16% of the total resistance is contained from the end B to the center while the other 84% is between A and the center. This is also shown in Fig. 1.

Now when point 30 is reached in Fig. 1, two spaces from B a signal voltage of .625 volt appears which on the basis of 5 watts for 20 volts produces an output power of .004875 watts or 4.875 milliwatts which would be scarcely audible from a speaker. When terminal C is at point B it is, of course, grounded and the signal is dead or at no voltage. Since the volume is almost zero at point 30 and 31 it is not objectionable for the signal to be sharply cut off at B.

You can easily see from all this information that the resistance along the path of C is not uniform—that is, it varies not in relation to the angle through which C is turned. The resistance changes practically uniformly at first, then *tapers* off rapidly. The resistance is therefore referred to as a *tapered* resistance, a tapered potentiometer or a tapered volume control.

Now a more rapid or more gradual control of volume can be obtained by

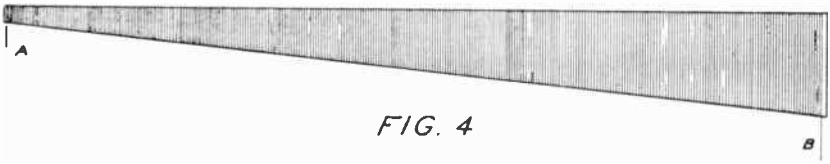


FIG. 4

choosing more or less equally divided points as may be necessary. So many radio circuits require this type of volume control taper that a standard design has been chosen with only 10% of the resistance from B to the center and 90% of it from the center to A. The resistance is rapidly tapered on the *left* side of the control and hence the term *left-hand taper* has been adopted to identify it. The actual resistance value may vary from 1000 to 10,000,000 ohms total for a single unit.

The majority of the tapered volume controls are of the carbon type. They are made by applying a carbon compound to a strip of insulating composition. It is applied in greater density toward one end than the other, so that the tapered property will be acquired. The strip is in cylindrical form in some makes of controls and of disc shape in others. Contact scraping is avoided through the use of an indirect metal compression arrangement. As the contact slides on the metal it presses it at the point where it touches the metal to the carbon surface. Excess wear between the carbon strip and the moving contact is thus avoided.

One form of a tapered wire wound resistor is made by winding resistance wire in equally spaced grooves around a strip of insulating material that is cut in a tapered form. This unit is shown in Fig. 4, before it is bent in a circular form to fit the shape of the circular casing and moving terminal of the control. It is then bent into a circle arc as shown in Fig. 5. This drawing shows how the moving arm and terminals are applied. Because there is a much greater length of wire between turns near end B than at end A, the resistance change here is more rapid for a given angular motion of the moving arm. The moving arm contacts the wire on the straight top edge at every turn. It is not practical in a standard sized unit to use a wire of high enough resistance to produce more than about 50,000 to 100,000 ohms in a wire wound unit.

You cannot compare the carbon type of control with the wire wound control on a basis of merit for the same use. because they rarely if ever are used for the same purpose. Each has definite advantages in their respective applications.

It would be well to examine all of the circuits wherein this left-hand taper potentiometer is used as a control of volume. In Fig. 6 is shown an early type of volume control used before the development of AVC. As long as you are dealing with the entire signal voltage you need not consider whether it is in the form of RF, IF, or AF. In this circuit the entire available signal is impressed across

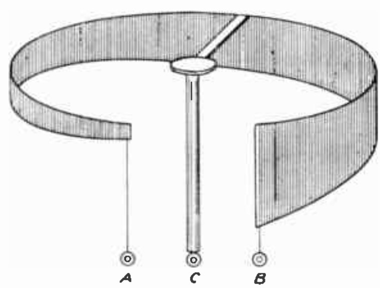


FIG. 5

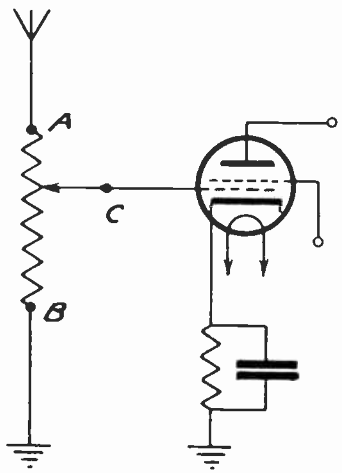


FIG. 6

the potentiometer terminals. The same left-hand taper is required here. *In every case where the resistance is shunted across the signal source, the left-hand taper is used.*

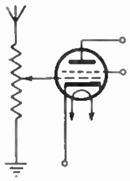
Now this control is not required to carry any appreciable current. What current it does carry is RF. It may, therefore, be of the carbon type if desired. Its total resistance value does not usually exceed 10,000 ohms although it may be as low as 500 ohms in many cases.

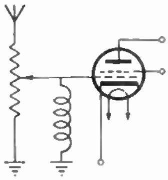
The carbon element volume control is not adapted for carrying any appreciable current while the wire wound type may carry considerable current. Its resistance is much more precise or definite whereas resistance values for carbon units are controllable only to a certain percentage. On the other hand, the resistance change of the carbon type is perfectly smooth while that of the wire wound type is varied in small steps—not continuous from one value to another. This is due to the resistance reduction from one turn to the next. No intermediate values are available between turns. There are, of course, a great enough number of turns to make the individual resistance changes sufficiently gradual to be practical.

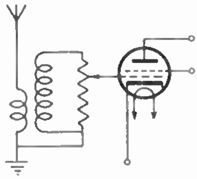
The wire wound feature, however, gives the unit an inductance property which makes it unsuitable for use in some types of antenna or other high frequency RF or IF control circuits.

In Figs. 7 through 15 the preferred forms of all of the shunt types of volume control circuits are shown. These all require the *left-hand taper* type of volume control. Figure 11 is very undesirable and should be changed to conform to Figs. 7 or 10 if a receiver is found using it. As shown in Fig. 11 the circuit used seriously impairs sensitivity and selectivity. The resistance values for the RF group (Figs. 7 to 10) are not critical ranging from 50 ohms to 10,000 ohms. The greatest value which will permit circuit stability should be used. However, in Fig. 11, the resistance value must be as large as the shunt resistance of the tuned circuit or larger. Values ranging from 125,000 ohms to 500,000 ohms should be used.

The diode detector output and power detector output volume control circuits shown in Figs. 12 and 13 respectively are of high value as they shunt circuits of high value. The circuit of Fig. 12 usually has a value of 500,000 ohms while Fig. 13 usually uses a value from 250.000 to 500.000 ohms. The circuit of Fig. 14 usually uses a value of 500,000 ohms and may be placed anywhere in the audio system. It is usually used at the audio input as in Fig. 12. The circuit of Fig. 15 uses a lower value, comparable in resistance value with the impedance of the transformer winding. A value of 100,000 ohms is a good average for this type of circuit.







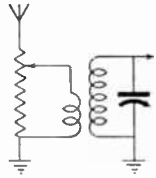


FIG. 7 FIG. 8 FIG. 9 FIG. 10

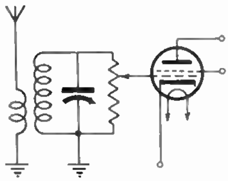


FIG. 11

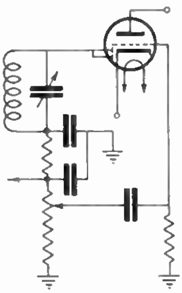


FIG. 12

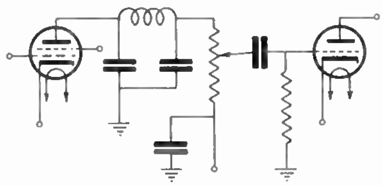


FIG. 13

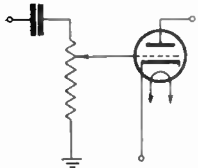


FIG. 14

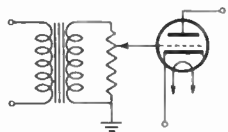


FIG. 15

Diode Detector Output Controls

There are three basic points in a receiver where a volume control may be used. Figure 16 shows a block diagram of a receiver illustrating these three points. Point A is in the RF or antenna circuit. Point B is the audio input or second detector and point C the audio amplifier. Of these three points, point B is most commonly used. This is due to the simplicity of the control circuit and also because of the smoothness of operation of the control in this circuit. Practically all of the modern type receivers are designed with the volume control in the second detector circuit. Figures 17 and 18 show two very common methods of employing a volume control in the diode detector circuit. These two methods of control are more practical than many control circuits because no RF or DC currents flow through the volume control unit. Volume controls of the carbon variety become noisy much quicker if heavy currents

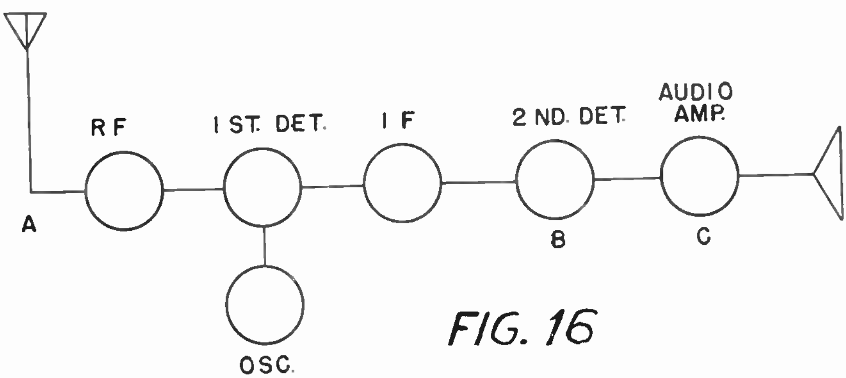


FIG. 16

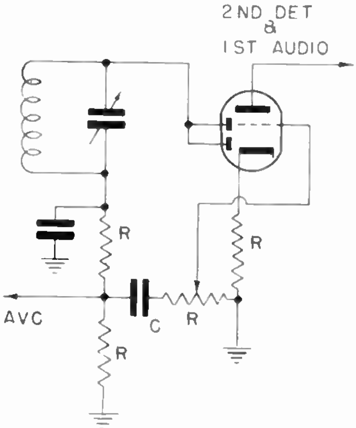


FIG. 17

ACTUAL CIRCUIT

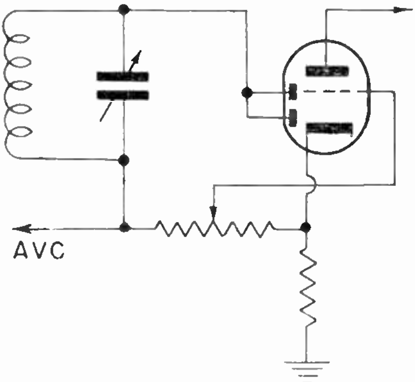


FIG. 19

are allowed to pass through them. Thus, by keeping the RF and DC out of the control, it is less likely to develope into a noisy control.

Figure 19 shows a volume control circuit where DC and RF are allowed to pass through the volume control and many times a noisy volume control results. It may be advantageous, when encountering a volume control circuit of this type, to rewire the circuit such that there is a minimum of current passing through the control unit. Figure 20 shows a method of correcting this difficulty and will, no doubt, prove more desirable, increasing the life of the volume control by eliminating the flow of DC current through it. It isn't advisable to make this change unless trouble with the volume control has occurred.

There are many volume controls that use a tap other than the two end terminals. Figures 21 and 22 show two circuits which use a tapped vol-

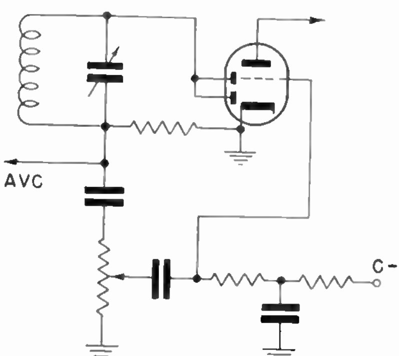


FIG. 18

REWIRED CIRCUIT

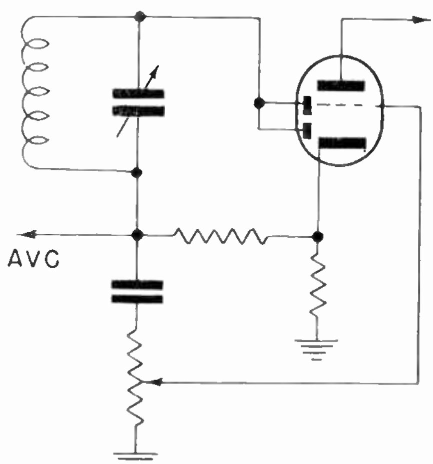


FIG. 20

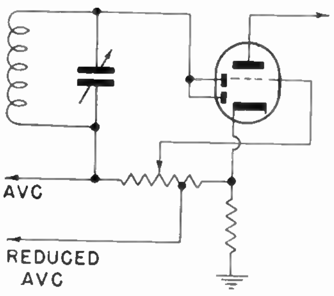


FIG. 21

ume control. Figure 21 shows a control used in such a way that a reduced AVC voltage can be secured. The reduced AVC voltage is used for controlling part of the RF or IF tubes, such that complete plate current cut off is prevented, giving a smoother operating AVC action.

As has been brought out at the beginning of the lesson, the human ear responds rather peculiarly to sound energy. It is found that at low sound intensity that the ear is not as sensitive to low tones as it is to the higher AF frequencies. For this reason if the frequency response of a receiver remains the same, as the volume of the receiver is reduced, the low tones of the original program will appear to be lost. This can be corrected by the use of a tone control that will reduce the high frequencies in proportion to the characteristics of the ear such that all frequencies appear to the ear in the same proportion regardless of the volume control adjustment. By a simple yet efficient tone compensator circuit connected to the volume control in a special way, this compensation can be done automatically.

Figure 22 shows such a circuit. The volume control unit is tapped at a predetermined point, and a condenser and a resistor are placed from this tap to ground. The value of the resistor and condenser are selected so as to by-pass the high frequencies more readily than the low frequencies when the volume control is turned to low volume, thus automatically changing the response of the audio amplifier to correct the characteristics of the human ear.

Some receivers use more than one tap. By connecting different condenser-resistor networks to each tap, a smoother, more effective, tone compensation can be obtained.

The Bias Type Control

An entirely different method of volume control based on the change in characteristics of tubes for carrying signals and amplifying them will now be considered. As before the simple idea that the volume must be reduced by a given percentage or ratio for equal degrees of rotation of the control will be assumed.

Since tube and circuit designs are not the object of this lesson, certain facts from circuits which are already in use will be used. The RF bias type of control had its greatest importance with the 35 or 51 type tube so this is the logical place to start this study. This is a super-control tube or remote cut-off type. When this type of tube is used as an amplifier with a bias meth-

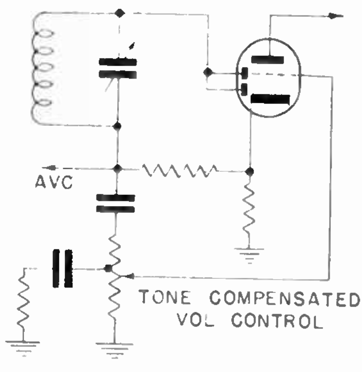


FIG. 22

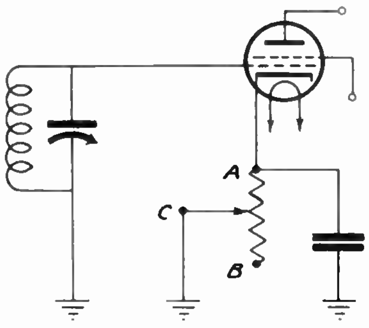


FIG. 23

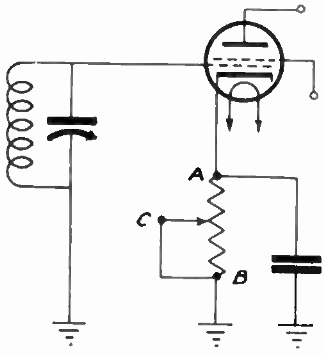


FIG. 24

od of control the potentiometer is placed in series with the cathode as in Figs. 23 and 24. It makes very little difference whether the lower end of the resistor is connected to the ground or not.

First take note of the fact that the amplifying power of the tube or its gain is related to its bias. In a typical circuit the gain and the bias will be about as given by the following table. This assumes a maximum gain of the stage at — 3V bias to be 85.

BIAS	GAIN
— 3V	85
— 10V	70.5
— 20V	57.4
— 30V	42.
— 40V	23.7
— 50V	1.5

Assume this in general to be either in an RF or an IF stage. Now as before, it is desired that for a given angle of rotation of the volume control that the gain will be reduced by a given percentage and that for every section of the volume control this relationship must be true. The most convenient way to determine these figures is to assume a constant input of 1 volt and simply regard the figures for gain as the output voltage values. Without regard to the number of steps needed, the voltage is listed in the following table in steps of 89.12% (1 db) of each value successively starting with 85 volts for a maximum signal.

TABLE

VALUE A		85	VOLTS	
1	.8912 × 85	=	75.7	Steps of 1 db.
2	.8912 × 75.7	=	67.4	
3	.8912 × 67.4	=	60.0	
4	.8912 × 60.0	=	53.5	
5	.8912 × 53.5	=	47.65	
6	.8912 × 47.65	=	42.5	
12	.502 × 42.5	=	21.125	Steps of 6 db.
18	.502 × 21.125	=	10.56	
24	.502 × 10.56	=	5.29	
30	.502 × 5.29	=	2.65	

TABLE		
VALUE	VOLTS OUTPUT	BIAS
1	75.7 × .575 = 43.6	— 50 = — 6.4
2	67.4 × .575 = 38.8	— 50 = — 11.2
3	60.0 × .575 = 34.5	— 50 = — 15.5
4	53.5 × .575 = 30.8	— 50 = — 19.2
5	47.65 × .575 = 27.4	— 50 = — 22.6
6	42.5 × .575 = 24.4	— 50 = — 25.4
12	21.12 × .575 = 12.15	— 50 = — 37.85
18	10.56 × .575 = 6.07	— 50 = — 44
24	5.29 × .575 = 3.04	— 50 = — 47
30	2.65 × .575 = 1.53	— 50 = — 48.5

Next it is desired to know what grid bias voltages will produce these output voltages. For a bias of — 3 volts an output voltage of 85 volts is obtained while for — 50 volts bias an output voltage of only 1.5 volts is obtained. Then for a total grid range of 50 — 3 or 47 volts a total output change of 85 — 1.5 or 83.5 volts is obtained or an output *per bias volt* of 83.5/47 = 1.74 volts output change for 1 volt bias change. Or you may consider it in an other way, 1/1.74 = .575 *volt bias change for each output volt change.* Then for each of the foregoing tabulated voltage values simply multiply by .575 and subtract from 50 to get the bias values. The tabulation of this work is shown in the above table.

All values in this table are, of course, approximate. They simply show the general nature of the design problems of the bias form of volume control and are not intended as actual values to use in any circuit.

The remainder of this problem is to find just what resistance is required in the cathode to produce the required bias voltage values. It must be remembered that as the resistance is increased the current is reduced through it tending to off-set the effect of the increasing voltage drop across it. This is the main feature which so materially determines the nature of the resistor used. Without actually setting up a circuit or using advanced mathematics it is easy to determine the plate current for several fixed values of grid voltage and then plot the results along with the required values to get the resistance values.

The plate current values for various grid voltage values are very nearly as indicated in the table below for this type tube (35 or 51) under the conditions outlined.

TABLE		
Grid Volts	Plate current Milliamperes.	Total Cathode Current or Plate Current Plus Screen Current
— 3	6.5	9
— 10	4.25	5.87
— 20	2.25	3.11
— 30	1.	1.38
— 40	.3	.414
— 50	.0	.0

		TABLE		
VOLTS		AMPERES		OHMS
3	Divided by	.009	=	333
10	Divided by	.00587	=	1,700
20	Divided by	.00311	=	6,430
30	Divided by	.00138	=	21,700
40	Divided by	.000414	=	96,500

With this information you may simply divide the bias voltage by the total cathode current in amperes to find the resistance value necessary for each of the required bias voltage values. The screen current which must be included in the total cathode current is proportional to the plate current and is at every point practically 38% more. Each value of plate current is therefore multiplied by (1.38) raising it 38% as shown in the 3rd column in the above table.

These values are plotted in Fig.25. Note that at the center of the total control range of the volume control between A and B (approximately 28 volts) there is about 15,000 ohms from the starting end A. Although only a few volts from the maximum needed for plate current cut-off, actual plate current cut-off cannot be attained because current flow is required through the cathode resistor to give the bias voltage. The various voltage reductions which are required for a

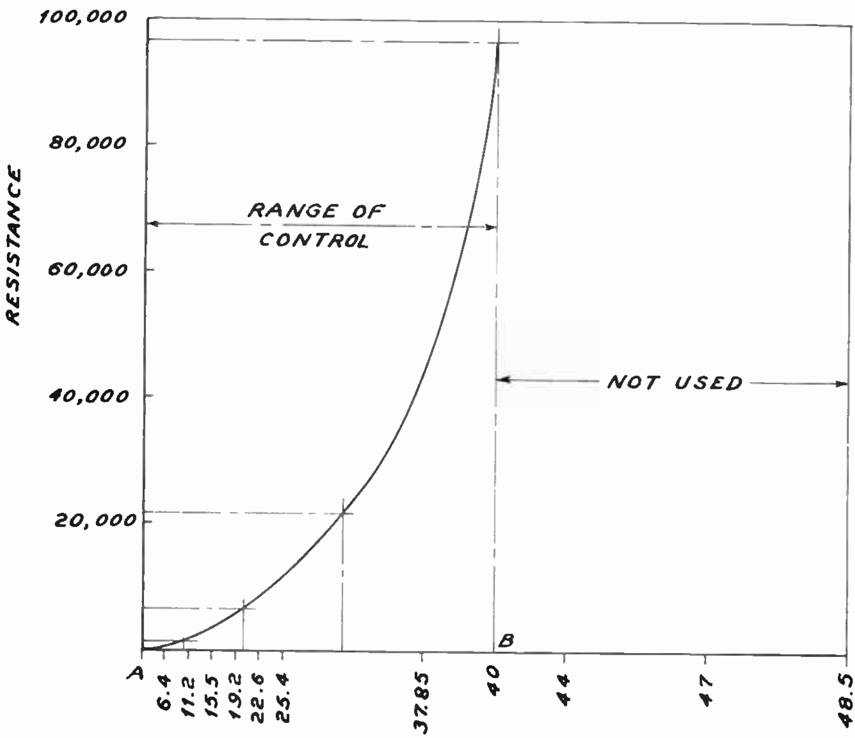


FIG. 25

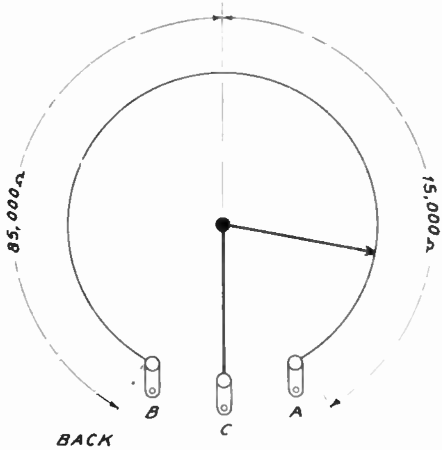


FIG. 26

smooth control of gain are evenly divided along the circumference of the control unit. Its total value is 100,000 ohms, and it allows approximately — 40 volts bias for a type 35 tube, as indicated in Fig. 25. The actual control resistance extends only from A to B in Fig. 25—the balance of the graph showing why it is useless to consider a cut-off value.

The taper of this type of volume control is on the right side. It is therefore, called a *right-hand taper control.* The distribution of its total 100,000 ohms is clearly indicated in Fig. 26, where only 15,000 ohms are between A and the center, leaving 85,000 ohms from C to end B. Again if the resistance varied directly with the angle of rotation the entire control of volume would be largely confined to the A end of the control.

The practical application of this type of control involves several variations from this original model. For example, it is not practical to control only one tube and when two or more tubes are under control with one resistance, the current is doubled and the resistance values are, therefore, all divided in half. Likewise, if three tubes are controlled in this way, only one third of this resistance value is used, or about 30,000 ohms.

Because of the large current flow required at high volume levels the volume control resistor must be wire wound. It has been shown that for — 3 volts minimum bias a resistance of 333 ohms (350 ohms in actual practice) for each tube must be in the circuit at all times. This may be in the form of a wire wound resistor as a separate unit or as a part of the volume control which is not subject to variation.

Figure 27 shows a conventional bias type of control with an external series resistance for maintaining *minimum bias* on the control tube or tubes. For controlling three tubes simultaneously the arrangement would be set up as in Fig. 28. Resistor R1 is the volume control unit while the fixed resistor R2 provides the minimum bias value for all three of the tubes. This arrangement is necessary so that when the volume control resistance is reduced to zero or minimum, resistor R2 will continue to maintain minimum bias voltage on

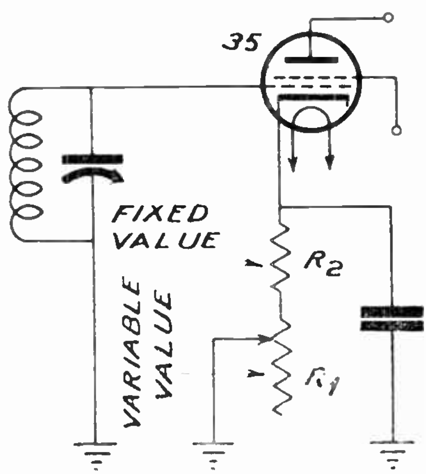


FIG. 27

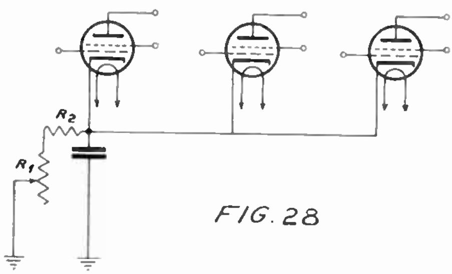


FIG. 28

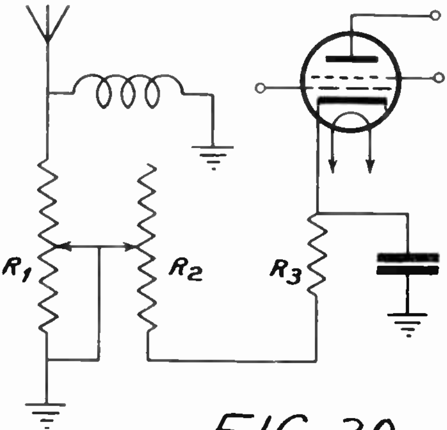


FIG. 30

the grids of the controlled tubes.

For the purpose of minimizing cross modulation as much as possible such circuits are improved materially by a combination of bias and input sensitivity control as in Fig. 29. Resistor R1 in this case is the usual *left-hand taper control* with its (A) end connected to two minimum bias resistors R2 and R3 in the cathode circuits of two controlled tubes. Its remote or (B) end is connected to the antenna so that when the volume control unit is set near minimum the signal at the antenna is practically shorted to ground. This increases the effectiveness of the volume control but has a more important function of reducing cross modulation in the receiver. The taper is the same as for the bias type of control and as you have learned the resistance value is not at all critical from the viewpoint of antenna control. It is completely determined by the characteristics of the tube or tubes being controlled. It is called the *antenna bias* method of control. Near the A end of the control in Fig. 29 the major effect is upon the gain of the tubes while near the B end the major effect is upon the signal input from the antenna.

Sometimes the same service is accomplished with two controls as in Fig. 30. This provides that a left-hand taper may be used for R1 (across the signal source) while a right-hand taper is used for R2. Ordinarily the slight improvement in control over the circuit of Fig. 29 does not justify the cost of a dual control as in Fig. 30.

Now the failure of the straight bias system as in Figs. 28 and 29 to bring the controlled tubes all the way to plate current cut-off has been corrected through the use of a high voltage bleeder resistor which serves the purpose of always maintaining some current flow through the volume control unit so that absolute plate current cut-off may be reached. Figure 31

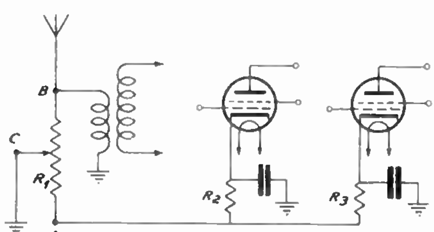


FIG. 29

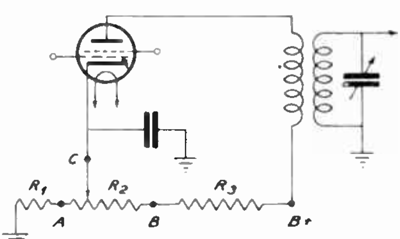


FIG. 31

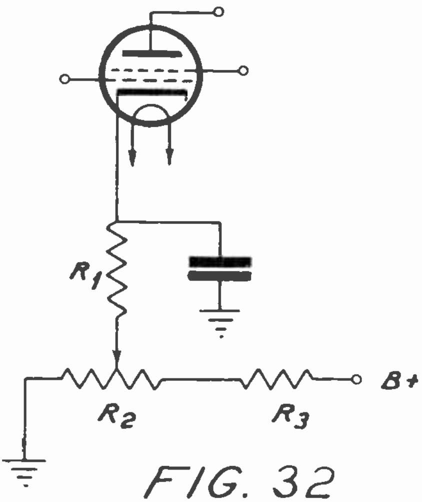


FIG. 32

illustrates one common method of this character. As usual the minimum bias resistor R1 is either a part of the volume control R2 or it is a separate wire wound resistor. In series with these is another resistor R3 of fairly high value connecting the group to a positive voltage.

Now as the arm C in Fig. 31 is rotated toward B of R2, the cathode current reduces but some bleeder current remains, making the point B positive even at plate current cut-off value of the bias. The total bias is, of course, that voltage between C and ground. Because of this bleeder connection the taper of the control used in the circuit need not be as severe as otherwise. The resistance is more evenly divided throughout the control.

A slight variation in the application of this idea is shown in Fig. 32. It will be recognized as almost electrically identical to the circuit of Fig. 31.

As a further convenience, the screen grid bleeder resistance may be made to terminate at the cathode as in Fig. 33, forming somewhat the same circuit as for Figs. 31 and 32. The taper for this service is the usual *right-hand taper* of less curvature (more gradual taper than the straight bias type). An additional operating characteristic is worth noting in connection with this circuit. As the volume is increased the screen grid voltage is reduced and this offsets the effect of the volume increase to a certain extent. For some circuits the effect is great enough to require a control with a special *right-hand* taper. With this as well as with some plate circuit bleeder arrangements the taper is made so slight that the resistance is practically *linear* or evenly distributed throughout the control range. Because they carry more current than if connected to the cathode alone, their resistance values are much lower, rarely exceeding 15,000 to 20,000 ohms. Controls of this kind are usually of the wire wound type.

In Fig. 34 is shown a rarely used circuit showing still another use of the bleeder current idea. More or less current is introduced into a fixed cathode resistor by the setting of volume control R1. Because of the relatively large current flowing in the resistance it is a linear or nearly linear wire wound unit of fairly low resistance value—10,000 ohms or less.

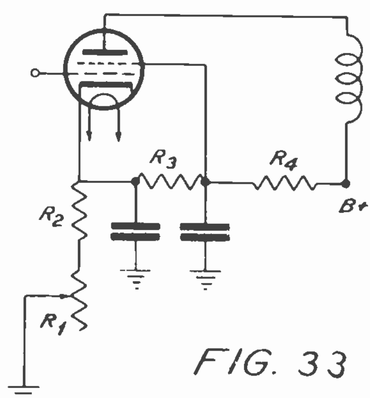


FIG. 33

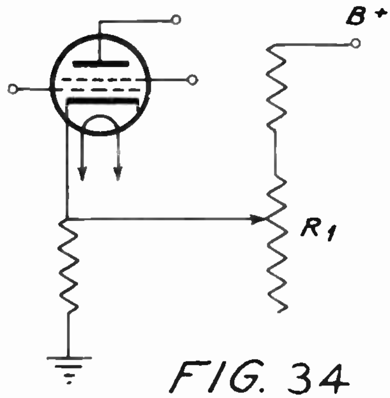


FIG. 34

No Current Bias Control

The most universally used type of bias control for battery operated receivers where filament type tubes are used is the straight potentiometer type. One practical and widely used arrangement is shown in Fig. 35. Since no grid current is drawn, both of the resistances in Fig. 35 may have quite a high value. They must not be high enough however, to prevent the natural leakage current of the grid. Values from 250,000 to 500,000 ohms will be satisfactory for the fixed grid resistor, while the potentiometer may have about 10,000 ohms per volt of the C battery. A switch is pro-

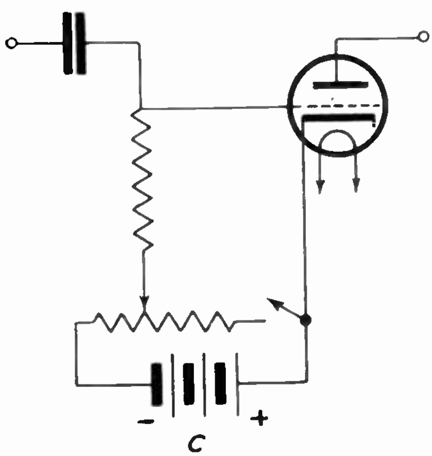


FIG. 35

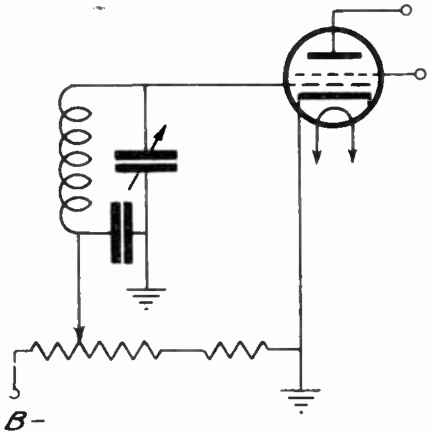


FIG. 36

vided so that the battery may be disconnected when not in use. Having 10,000 ohms per volt, only .1 milliampere will flow when the switch is closed.

It was mentioned in connection with the control of volume by means of grid bias that the volume was somewhere nearly inversely proportional to the bias—that is, for equal increases of bias there will be correspondingly equal reductions of volume. This is only partially true with super-control tubes. Therefore, where such a circuit is employed a control without any taper is used. This is one in which the resistance is proportional to the angle of rotation. No exact type or degree of taper can be specified for all of these *no-current bias circuits* nor can the resistance values be exactly set except by trial.

The AVC application of this method is shown in Fig. 36. A voltage divider in the section of the B supply below the cathode or ground potential is used instead of a battery. The value here is much lower, wire wound and is usually linear. Another application of this method of volume con-

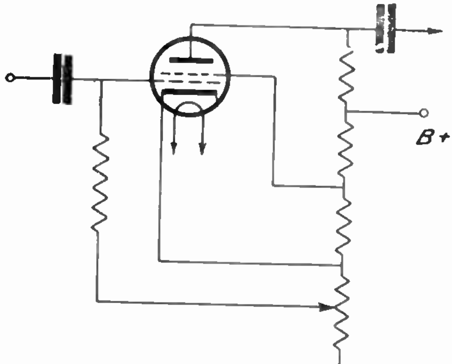


FIG. 37

trol is shown in Fig. 37. This is used extensively in connection with separate AVC tubes and muter systems. Volume is indirectly controlled by adjusting the amount of AVC action. The resistance value used here is usually quite low—200 to 1000 ohms. The unit is wire wound and has no taper.

Shunt Controls

Under this classification is placed the type of control which simply shorts proportionally the resistance across which the signal voltage is impressed. There are several ways that these circuits are wired in practice. One of these is the antenna type of shunt circuit as shown in Fig. 38. Such circuits use wire wound resistors

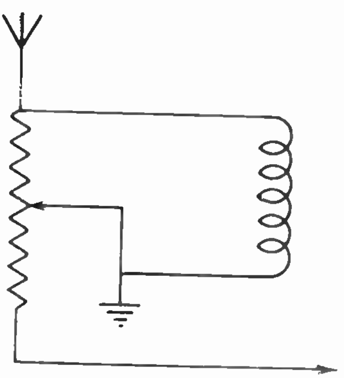


FIG. 38

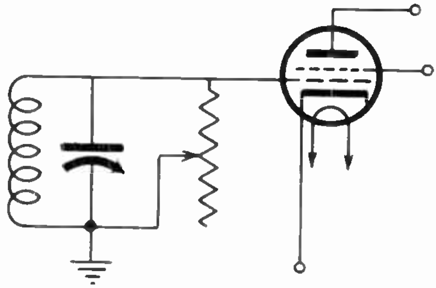


FIG. 39

of the linear or slightly left-hand taper type. They are low in value, ranging from 2000 ohms to about 10,000 ohms.

In a few RF or IF stages the circuit of Fig. 39 is infrequently used. For many reasons, this circuit is very undesirable. It r e d u c e s selectivity, changes the load on the preceding tube as well as the input admittance of the tube shown. Distortion will result if operated under modern receiving conditions.

This is true also of Fig. 40. These volume control circuits can be changed readily to other types. Figure 41 shows a very unusual type of control. It combines the bias and shunt types in a single unit. Obviously it has the same limitation as any shunt type of control and should be replaced with

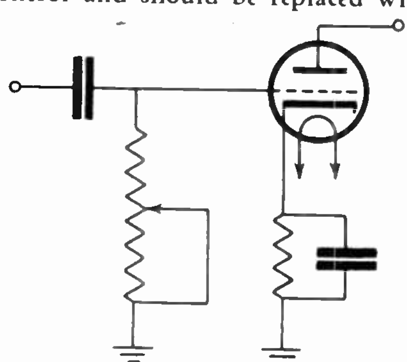


FIG. 40

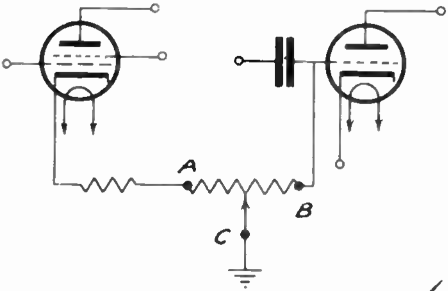


FIG. 41

another type. The grid which is shunted to ground should be provided with a fixed resistor suitable for the tube and the end (B) of the bias control should either be left free or connected to the antenna. It has the usual right-hand taper suitable for all bias circuits. In Fig. 42 is shown the shunt type of control as applied to an RF or IF plate circuit rather than a grid circuit as in Fig. 39. It has essentially the same limitations as the grid type.

Power Supply Control Circuits

Within definite limits the power supply type of volume control is very efficient and quite practical. The disadvantage of this and other types of voltage controls is that the electrical characteristics of the unit being controlled very rarely remains uniform for the range necessary for complete control of the signal.

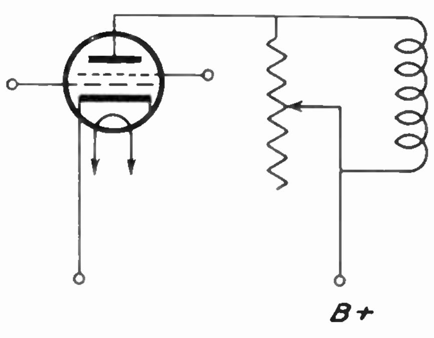


FIG. 42

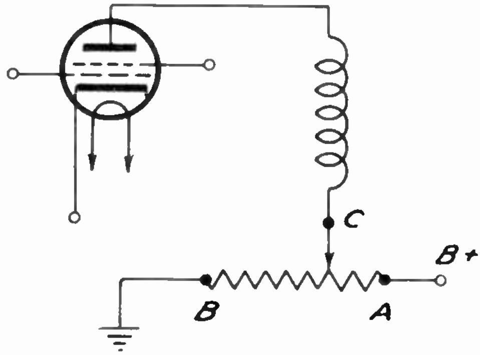


FIG. 43

These circuits may be classified into two groups—the shunt type and the series type. Figure 43 is typical of the shunt type of plate supply control. Because the characteristics of the tube changes very little in the high plate voltage range the control is of the left-hand taper type. Its value must be high, because of the high plate voltage. Values of 50,000 to 500,000 ohms are used in the carbon type of control as a rule, although wire wound units are also found in this type of circuit. The series plate supply control is shown in Fig. 44. This circuit requires a right-hand tapered control because it is somewhat equivalent to the bias in its action.

Generally speaking, the current for this type of circuit is too high for the carbon type of control while the resistance values and taper required make the design of a wire wound unit

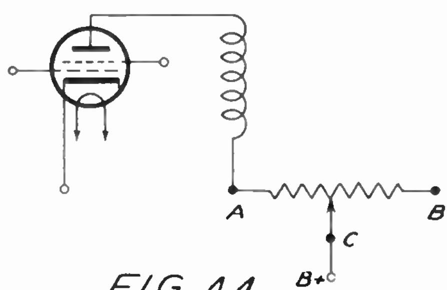


FIG. 44

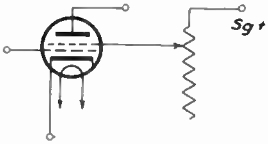


FIG. 46

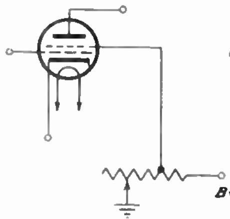


FIG. 47

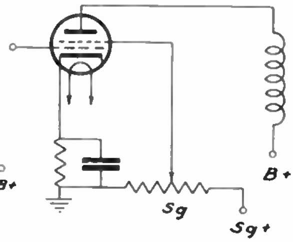


FIG. 45

impracticable. It is not satisfactory for modern applications and should be changed to the bias type or some other type more suitable.

The action of the equivalent type of screen grid voltage control is substantially the same as for the plate supply type. Shunt and series types are shown in Figs. 45 and 46 and a special shunt t y p e is shown in Fig. 47. Being a combination of series and shunt it may be a linear control with a reasonable high value, 100,000 ohms average. A carbon type of control will be suitable.

The filament control is, of course, obsolete and should not be used if it can be avoided. It is shown in Fig. 48 and was one of the first types of controls to be used.

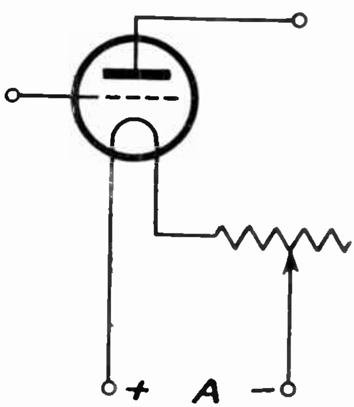


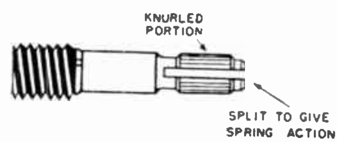
FIG. 48

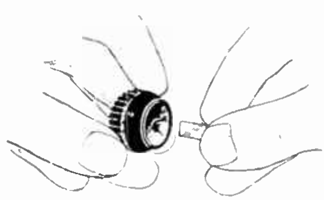
Other Uses of Controls

The volume control is only one major use of resistor controls. In addition to this, resistor controls are used for hum control, tone control, neutralization control, threshold signal control, sensitivity control, signal balancing control, circuit impedance control, fidelity control and other purposes.

There are, of course, other methods of controlling all of these things but the interest here is only in the use of variable resistors in this connection. Control of circuits may be accomplished by variable coupling, either inductive or capacitive or by variable core material of a transformer.

In Figs. 49 through 53 various methods of hum control are shown.





The top view shows a split knurled type shaft which requires no set screw or spring for holding the control knob. The bottom view illustrates how to insert a flat spring in the push-on type knob.

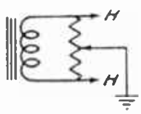


FIG. 49

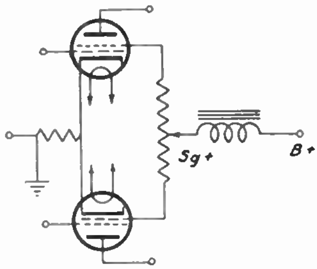


FIG. 50

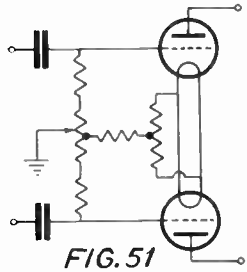


FIG. 51

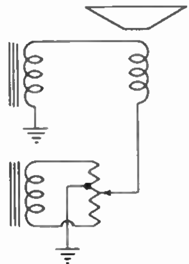


FIG. 52

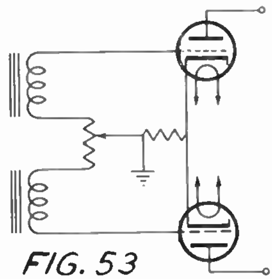


FIG. 53

In Fig. 49 is the filament type consisting of a linear 20 to 400 ohm, wire wound type of potentiometer. In Fig. 50 the screen grid supply type is shown which is also a linear and wire wound type. Its value is rarely over 1000 ohms. The control grid type is shown in Fig. 51. This is also a linear type, wire wound control having a tap in the center of the wire for the fixed connection shown. In Fig. 52 the type used for speakers is shown. It also has a tap. All of these make use of the cancellation type of action. Equal and opposite voltages are introduced into each side of the circuit with the proper adjustment. Values of the controls in Figs. 51 and 52 are low, ranging from 20 to 100 ohms. The circuit of Fig. 53 is equivalent to the circuit of Fig. 51 in its action.

A grid circuit tone control is shown in Fig. 54. The DC voltage across the control is negligible and the impedance of the grid circuit is high, averaging around 100,000 ohms. The resistor for any grid type tone control may, therefore, be a high value from 100,000 to 500,000 ohms carbon, left-hand taper type. This provides that the left or counter-clockwise position of its control knob produces maximum bass response while the *treble* or *high frequency* part of the signal is successively increased as the knob is turned to the right. If the reverse situation is desired, of course, a right-hand tapered control must be used.

The tone control capacity should be eight or ten times larger than the coupling condenser capacity while the total resistance should be this much larger than the capacitive reactance in ohms of the tone control condenser at the lowest frequency handled by the amplifier. Practically the same holds true for the circuit of Fig. 55, which is also of the grid circuit type. The identifications A, B, and C in these figures refer to the starting end (A) finishing end (B) and moving arm (C) of a potentiometer.

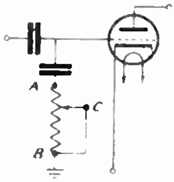


FIG. 54

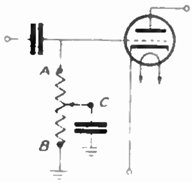


FIG. 55

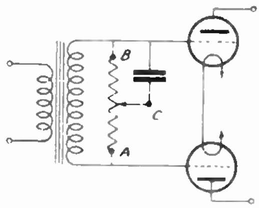


FIG. 56

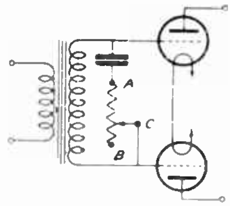


FIG. 57

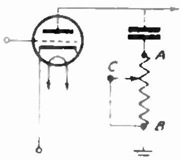


FIG. 58

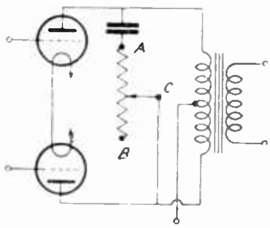


FIG. 59

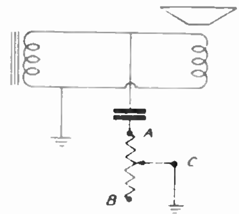


FIG. 60

In contrast to these values for grid circuits (such as Figs. 54, 55, 56, and 57) are the plate circuit types shown in Figs. 58 and 59. The plate circuit impedance is much lower than the grid impedance and there is not only high voltage but considerable power in the plate circuit. Therefore, a paper condenser of high value .5 to 2 mfd. is used and a wire wound resistor having a rating of 2 or more watts. Its resistance value is much lower, 25,000 to 10,000 ohms and a left-hand taper is desirable. As usual the taper is to even out the distribution of tone change, over the range of the control.

For a voice coil circuit as in Fig. 60 a very large capacity 10 to 25 mfd. and a very low resistance 1000 ohms or less will be necessary. As this circuit wastes considerable power it should not be used except in extreme cases.

Two control circuits for neutralization or for the suppression of self-oscillation are shown in Figs. 61 and 62. In Fig. 61 is shown a filament type and in Fig. 62 is shown a plate type. They are both obsolete and are not satisfactory for modern receiving conditions.

Fidelity controls are increasing in popularity and hence deserve detailed study. In Fig. 63 an ordinary shunt type fidelity control in the audio sys-

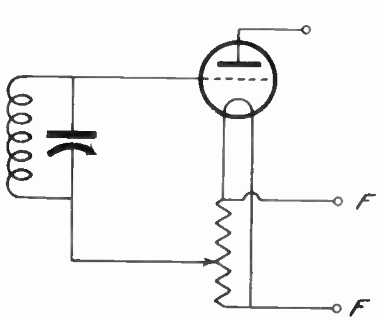


FIG. 61

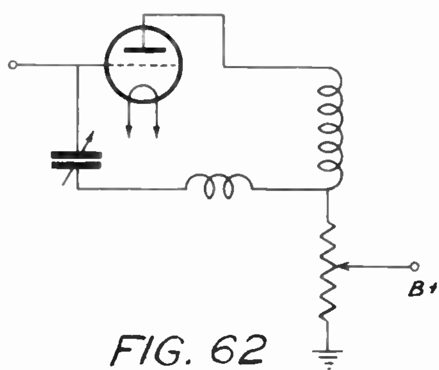


FIG. 62

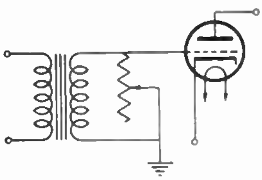


FIG. 63

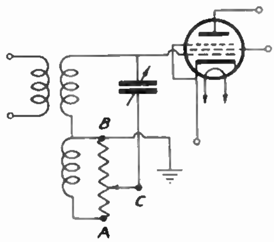


FIG. 64

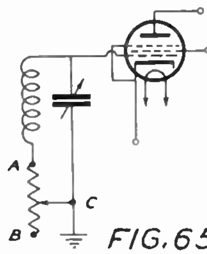


FIG. 65

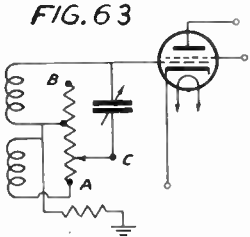


FIG. 66

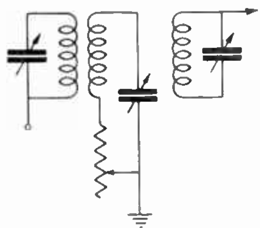


FIG. 67

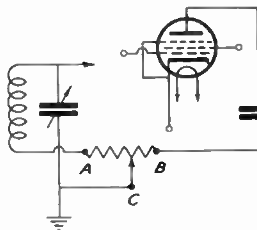


FIG. 68

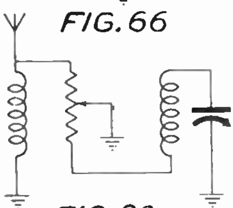


FIG. 69

tem is shown. In many cases this is a a fixed resistor to prevent the gain of the circuit rising steadily with frequency. It may be used as a volume control, but is intended to regulate the audio response to a certain extent, the volume being controlled elsewhere. In Fig. 64 there is shown an IF fidelity control. Coupling of the primary and secondary is varied in accordance with the position of the movable arm of the control. It is maximum at A and becomes minimum as the arm is moved to B. In Fig. 65 at position A, maximum selectivity is obtained because the sharpness of resonance (Q) of the tuned circuit is highest while at B the moving arm introduces enough resistance (1000 ohms average) to materially broaden the tuning characteristics of the amplifier. The circuit of Fig. 66 is an improvement over Fig. 64 as it includes (Q) circuit alteration with coupling variation. For the position of C from A to the tap, the coupling reduces and Q increases while from the tap to B, the Q only reduces. The circuit of Fig. 67 is similar to Fig. 65 but with a separate winding. In Fig. 68 a *constant band* fidelity control is shown which compensates for the tendency of reduced gain with a high fidelity adjustment. At position A the selectivity and gain is maximum while at B as the broadening tendency of the circuit is increased, the high frequencies are attenuated. In Fig. 69 is shown an RF fidelity control similar to those in Figs. 65 and 67.

In general it may be said that all of these resistors are of quite low value and are usually of wire wound type. However, recent improvements in carbon resistance elements permits their use in many of these circuits. The desired taper varies considerably and as this type of control is set to a desired point rather than adjusted frequently, the taper may usually be eliminated. This is true for many low valued controls.

Mechanics of Controls

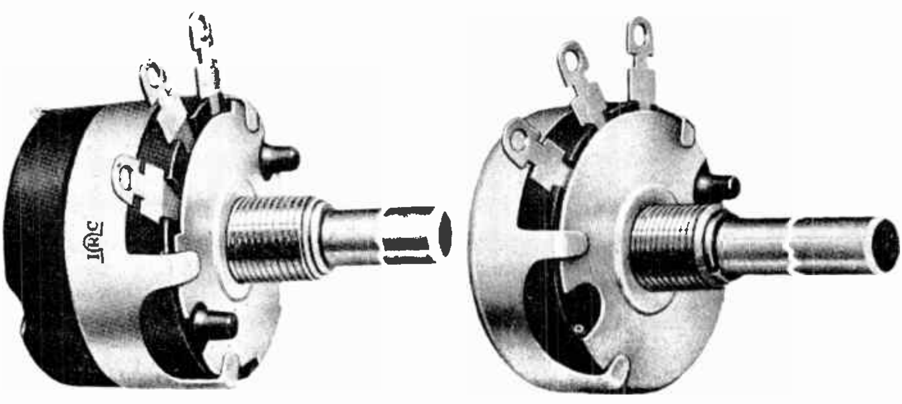
Controls are made in two sizes, the standard and the midget sizes. The former should be used where the power dissipated is large or where the space available for replacement is confined, use the midget control.

To avoid the use of a separate switch, the power line switch is very often mounted along with the volume or tone control. Practically all controls are now made with a removable dust back plate so that a switch may be added. If the switch is not used. however. the control is protected from foreign material such as dust or dirt by means of the back plate. The switch lever is designed so that the switch will close during the very first part of the turning of the control in a clockwise direction. It is attached in some designs by cleats and in others by metallic straps.

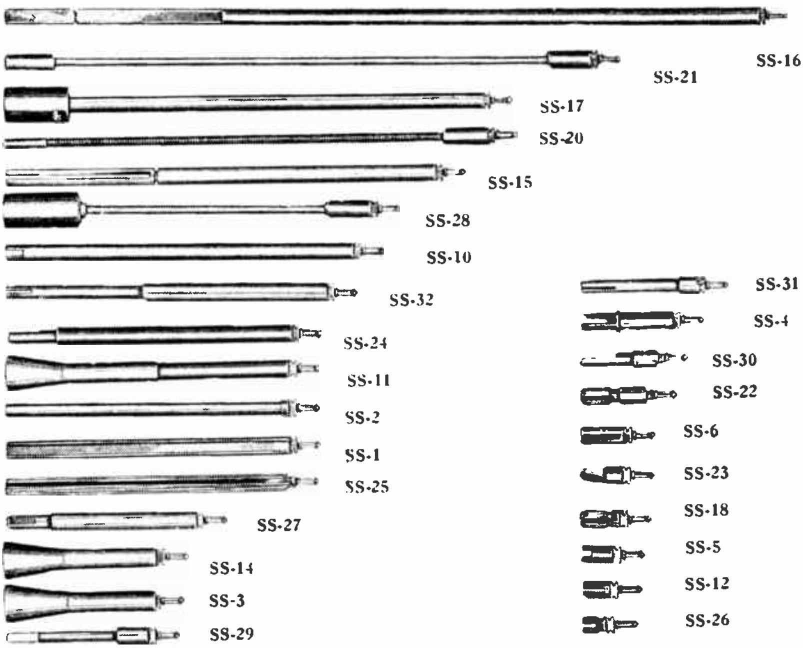
The shafts of modern controls are made sufficiently long for any average purpose and are made from aluminum or other soft material so that they may be easily cut to the proper length. After measurement for the right length as determined by the length of the shaft of the old control, the shaft may be notched with a knife or hacksaw and bent with pliers until it breaks. It may easily be sawed off with a hacksaw and trimmed at the end with a file.

Some models of controls have a movable front plate which may be set for a minimum fixed resistance at its (A) end ranging up to 500 ohms. This is for the minimum bias purposes as described before.

Invariably volume and tone controls are *single hole* mounted by means of a shaft threaded bushing and hex nut. They should be detached and attached with a wrench preferably or by use of pliers. Pliers may mar the escutcheon or panel. In modern controls the shaft is never electrically connected with the center terminal or moving arm as were many early type controls. They can, therefore, be mounted on the metal chassis or a metal brace attached to the chassis with no fear of their shorting to the chassis. The three terminals are tinned soldering lugs and the (A) and (B) ends may be identified by placing the volume control in front



This photo shows two modern type volume controls made by IRC. The control on the left has an off-on switch attached. *Courtesy IRC.*



The above photo shows a kit of plug-in shafts designed to meet most type and length requirements for home and auto receiver volume and tone control replacements. *Courtesy Mallory.*

of you with the shaft pointing toward you, with the terminals up. The right-hand terminal is the (A) or start end of the control and the left lug is the (B) end. The center terminal is always the moving arm connection.

The shaft is ¼ inch in diameter and the mounting hole should be at least ⅜ inch in diameter but not more than ½ inch in diameter. Supplied with the volume control there is a flat metal piece used for certain knobs which cannot be fitted onto a shaft with too large a flat area on the shaft. This metal piece is placed on the flat section of the shaft and the knob is placed on both. Shaft extensions and flexible connections are available for special installations from the various volume and tone control manufacturers. Also mounting brackets, insulating washers and shaft contact terminals are available when needed.

Common Volume Control Defects

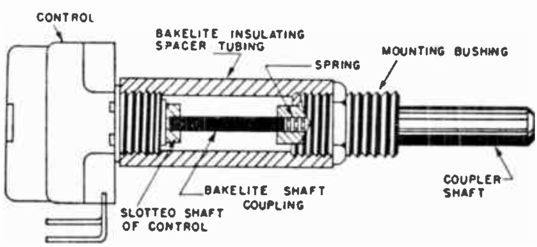
(1) Change in resistance: The wearing away of the resistance element often causes the control to increase in resistance. This increase is not usually enough to cause the receiver to stop operating. A 20% increase or decrease has little effect upon the operation of the unit unless the volume control is in some tricky circuit such as the voltage dividing network. With these close tolerance circuits, it may be necessary to replace the unit, if the resistance value has shown an appreciable change.

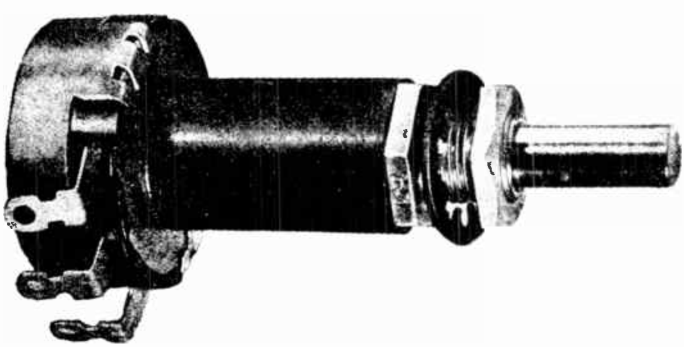
(2) Noisy controls: This is by far the most common volume control defect. The wear on the resistance element, loose spring tensions, and dirt getting in between the contacts of the control, are the main causes of this trouble.

This noise is usually revealed by the operation of the control and it may be intermittent, operating erratically on part of the rotation of the control knob only. Regardless of the cause of such noise, it is very annoying to the radio listener. This type of receiver complaint is very common. Where the volume control is in the diode detector stage and the DC current from the tube is allowed to pass through the control, noise may develope due to a faulty tube and not the control. The tube in this case should be changed to make sure that the f a u l t is due to the control and where this fault continues to occur, it may become necessary to change the circuit so that the DC doesn't flow through the control.

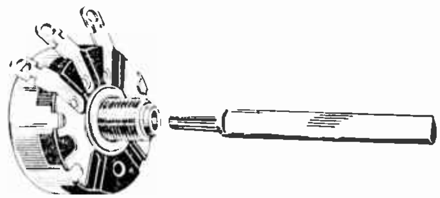
(3) Open: This is a fault usually caused by wearing of the resistance element. A control will usually become excessively noisy before it becomes open. As the wear on the element increases the increase in resistance causes more heat to develope and as the heat conducting surface is reduced, the element soon burns out causing it to become open. Opens are also caused by loose terminals or a poor contact on the resistance element.

(4) Shorts: Because of the construction of volume and tone controls an internal short does not often occur. However, where all of the terminals coming from the unit are above ground potential, a short to the case of the control which is usually grounded may occur. A quick visual observation will usually reveal this difficulty. If not by disconnecting the control and checking continuity.





It is necessary to use an insulated coupler on controls where high voltages are involved. The control illustrated above shows a type of high voltage control for use in high voltage circuits such as used in television and oscilloscope circuits. *Courtesy Clarostat Mfg. Company.*



This view illustrates the construction of a volume control unit employing the plug-in type shaft.

with an ohmmeter, you can find the cause of the defect.

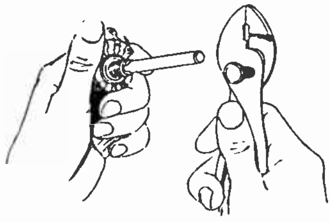
Replacement Hints

In most cases it is cheaper and much better to replace a faulty control. However, there are instances where a repair may prove satisfactory.

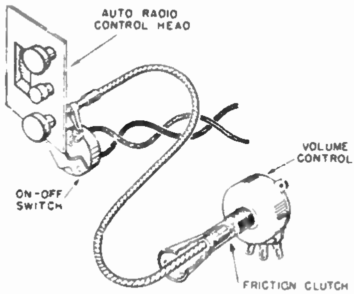
Volume control failure comprises a fairly large percentage of receiver defects. Thus, it is important to know how to replace faulty volume or tone control units.

The first thing to consider, assuming the control is at fault, is to obtain a control to replace the faulty unit. Manufacturers of volume controls put out in booklet form, volume and tone control guides. In these booklets there is a fairly complete list of all models of receivers with the type volume or tone control used by these receivers. There are usually two controls listed—one the exact duplicate and the other a possible substitution. The exact duplicate may not be available due to several reasons, making it necessary to order a substitute control. Control guides will usually aid the serviceman in this respect. Some of of the control manufacturers have developed volume controls which are almost universal in order to aid the serviceman in making volume control substitutions. Some of these companies have developed controls such that five different types of controls will replace approximately 95% of all the controls used in receivers. This reduces the number of controls necessary for the serviceman to have in stock.

The manufacturers of volume and tone controls are always developing better and more useful types of controls. One type that has just recently been developed is a type that the shaft comes separate from the control itself. In this way, where the control being replaced is in a position making it impossible to remove and replace without removing several parts from the chassis, the control can be fastened in place without the shaft and then the shaft inserted in place. This is done by placing the proper end of the shaft in the hole provided for it in the control and giving it a slight tap on the other end. It then automatically slips into place. It can be removed just as easily. (When the control to be replaced is not of the plug-in shaft type, it can be removed without moving other parts by cutting off the shaft as close to the panel as possible—by means of a hack saw). The plug-in shaft type controls are supplied with a variety of shafts. Almost any length or shape is available.



To insert the shaft in the plug-in type volume control just give the end of the shaft a sharp tap with a solid instrument as illustrated above. *Courtesy Mallory.*



This view illustrates how the friction clutch type control is used. *Courtesy Mallory.*

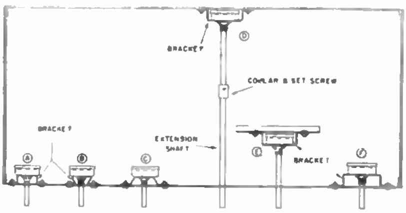
Another special type shaft is the clutch type. This shaft is especially designed for use in automobile receivers where the volume control and off-on switch are controlled by the same knob, as it is necessary to have the control knob in the correct position to indicate when the receiver is turned off and unless a slipping clutch shaft is used, it is a difficult job to align the control properly. With the slipping clutch, all that is necessary is to attach the flexible shaft to the receiver control. Then rotate the control knob on the panel to the left until the receiver is turned off and the knob is in the position to indicate *off*. This is possible because the shaft is made to slip when it is forced, allowing the shaft to turn until the correct position is reached. There are other type controls which are supplied with extra long shafts. This type control can be used for several different installations and when it is properly installed the shaft can be cut off to the correct length. To make it easy to cut, the shaft of some controls are made with a deep slot in the center and can be broken at any point desired. A slot filed in the shaft at the point it is to be broken will aid in breaking the shaft at the proper point.

Other type controls provide several deep impressions at even intervals along the extended shaft and all that is necessary to break off the shaft at the proper point is to apply pressure to the shaft on each side of the impression nearest the correct length.

In automobile controls, a knurled type shaft is popular. As in other shafts, it is made of a soft material and with the universal controls, it is made long with a deep slot in the side for ease in cutting to the proper length. These knurled shafts are usually provided with a split in the center so that the spring in the metal shaft aids in holding the knob in place when it is forced on.

It is desirable that the servicemen obtain the various control guides which are available. They will aid him in making all types of volume and tone control replacements. These guides are reasonable in price and are available from any radio parts jobber.

There are several things to consider when making a tone or volume control replacement. The first of which is to secure a control that will be correct for the installation involved. If the receiver needing the new control is of a standard make and model, an exact replacement can usually be secured. However, if the receiver is an old or odd make (not a



The above drawing illustrates the use of brackets for mounting volume and tone controls to the front panel of a receiver. Also the use of extension shafts where extra long shafts are required. *Courtesy Mallory.*

standard make), you will have no means other than the control itself and the circuit in which it is used to secure information concerning the control. This problem is made more difficult when the original control has been replaced with a substitute control which may or may not be the correct type of control for the circuit.

When making a volume control replacement where there is no identification and the receiver is an odd model, the first step is to check the circuit in which the volume control is employed. From the circuit of the receiver, and by a careful study of the circuits given in this lesson, you can, no doubt, determine the electrical characteristics necessary for the replacement control. After the approximate resistance and taper of the control has been determined, the physical dimensions of the unit must be given special consideration. The size and shape of the shaft must be chosen to fit the hole in the panel and also to fit the knob which is to operate it. Not only must the resistance value be considered, but also the power rating. The tapered control has a much smaller power rating than a linear control of the same physical dimensions. The number and placement of taps, if any are used on the control, must also be determined. The off-on switch that is often attached to the rear of the control must be considered in the replacement. The physical size of the unit itself is often critical due to the small space available for these units.

The circuit can be traced and drawn (if a schematic of the circuit is not available) and from the sketch made, the best type of control for this circuit can usually be determined. The diameter of the shaft and the length of the shaft should be determined. This can easily be secured directly from the old unit. The resistance value of the unit itself may be secured from the old unit, but in case it is completely destroyed or a substitute of the original has been made, the resistance value will have to be determined from the information secured from the circuit in which it is used.

The type taper can often be determined direct from the old control if it isn't badly damaged. The method for securing the taper was discussed in a previous lesson on resistance units. Refer back to this lesson for a complete description of the method for determining the taper of a control unit. Where there are taps on the control it may not be easy to determine the exact position for these taps. Often the manufacturer can aid you in this respect by sending the old control to them. They often determine the correct replacement for the control.

When removing the wire leads from a control it is very important that they be put back in the same positions. If this is not done, controls having a taper will operate in the reverse manner causing the volume adjustment to become critical, making it hard to adjust properly.

In most volume and tone control replacement jobs, the procedure is quite simple. As already mentioned, there are only a relatively few receivers that are not listed in the volume control guides and it is these few that will require special attention. In general, volume control replacements prove to be quite profitable and are easy to make.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 What type of resistance taper is used for a volume control which is shunted across a signal source?

No. 2 If you were asked to install a new volume control in a receiver employing a diode detector, in what part of the circuit would you connect the control unit?

No. 3 In what two ways does the volume control in Fig. 29 affect the signal?

No. 4 What is the purpose of a small fixed resistor in series with a cathode or bias type of control?

No. 5 Is it possible to obtain complete plate current cut-off with the type of control shown in Fig. 31?

No. 6 Will adjustment of volume affect the selectivity of the circuit in Fig. 39?

No. 7 Name three circuits in which hum controls may be placed.

No. 8 In which tone control circuit would you find the highest resistance value, Fig. 54 or Fig. 58?

No. 9 What is the chief disadvantage of the tone control of Fig. 60?

No. 10 Why is the taper of a fidelity control of little or no importance?

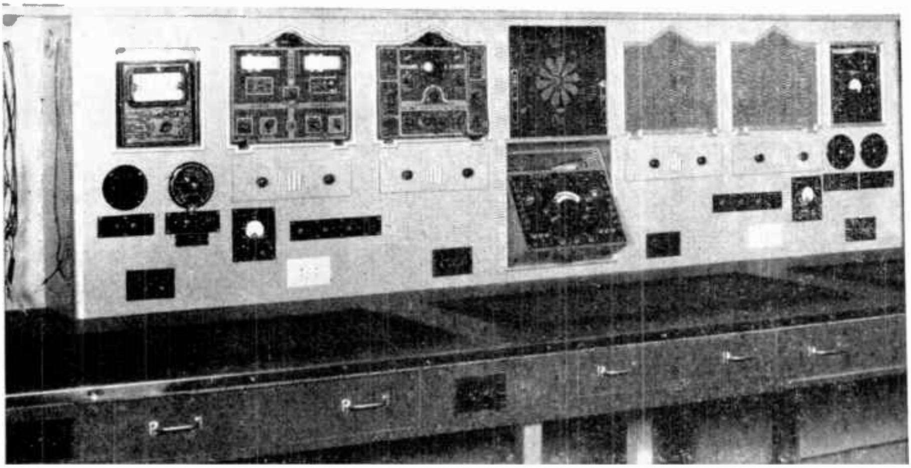
HOW TO CORRECT DEFECTS WHICH CAUSE INTERMITTENT RECEPTION

LESSON TV-17

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K2552M



Adequate space in which to work is of prime importance in radio repair work. This view shows a well arranged work bench with plenty of space and the necessary instruments in which to get the work done. Such a layout makes complex problems such as intermittent reception fairly easy to correct.

HOW TO CORRECT DEFECTS WHICH CAUSE INTERMITTENT RECEPTION

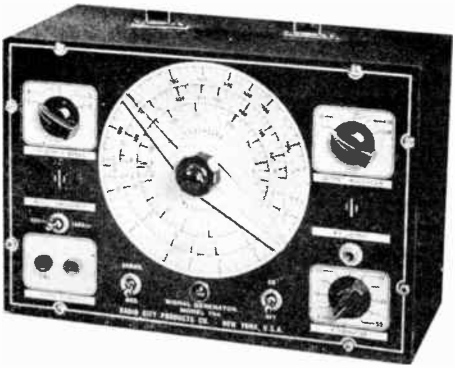
Lesson TV-17

Complaints of intermittent reception usually cause the serviceman more worry and trouble than all other receiver defects combined. Any serviceman with experience will substantiate this statement. The successful repair of a receiver that has developed a *case* of intermittent reception is *not easy*. Such a repair is not only difficult, but it takes time and effort to correct the fault—sometimes days. The reason for this is that you have to make a test or substitution and then wait, perhaps several hours, to see if the test you have made has corrected the defect.

This does not mean that you must continually have the receiver under observation. You may have the receiver operating all day, yet your actual work time on the receiver may not amount to more than one hour. Correcting defects which cause intermittent reception often consists of making substitution tests, and if after several hours of operation, the receiver does not fade or act intermittently, then you can assume you have corrected the defect.

The automatic changing of receiver volume or the cutting-in of an unwanted noise or signal, either periodic or non-periodic is defined as intermittent receiver operation. The receiver output volume may reduce considerably or it may cut off completely. In other cases, a sudden change in volume occurs. A condition sometimes exists where an increase in noise level along with considerable increase in hum occurs which may or may not be periodic. Intermittent oscillation causing an audio howl is also a common receiver complaint. All of these conditions are, in general, termed intermittent operation.

The receiver may be operating satisfactorily on local stations and then



This view shows an up-to-date signal generator as made by the Radio City Products Company. Such an instrument as this can be very useful in the correction of intermittent reception problems. By feeding a signal to different stages, a suspected part can be checked alone or in combination with other parts.

all of a sudden the signal will reduce, increase or distort. The volume may drop to a low level and may remain at this level several minutes or hours and then come back to the original level.

A peculiar fact about this type of defect is that after the receiver has become inoperative, normal reception may be often temporarily restored by turning the receiver switch on and off several times or by switching a light on and off somewhere in the house. It is also sometimes possible to restore normal operation by jarring the cabinet or even touching the receiver chassis with a screw driver or other metal tool.

This action makes testing for this type of defect very difficult. In many cases a receiver is very stubborn about *cutting off in* the shop, or if it does cut off and you attempt to make tests, it immediately starts operating normally. Oftentimes the slightest jar or touch with the test leads will be sufficient to start the receiver working properly.

For these reasons, you must be at your best on intermittent jobs—you must keep a clear head, test systematically and be on the lookout for any unusual effects accompanying the defect.

The first thing to do on any intermittent job is to question the customer about the receiver. Find out if the receiver fades gradually or quickly. Ask if a click is heard at the time of fading, if there is noise, and ask what is done to restore operation and if the action appears with regularity.

The answer to these questions may give you a clue to the type of defect and you may be able to correct it on the spot. To convince yourself of the nature of the defect, you should try to make the receiver fade or cut off. This may be done by jarring the chassis or shaking the antenna and ground leads. If a window strip is used, it should be examined. Also the lead-in from the antenna to the window strip should be shaken. The lightning arrestor should also be checked with a high resistance range ohmmeter (it should show infinite resistance). Then the antenna and ground leads should be disconnected from the receiver and an ohmmeter

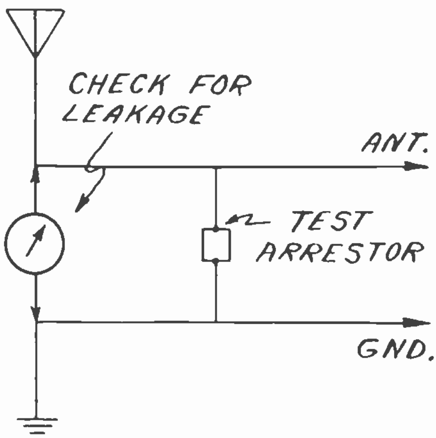


FIG. 1

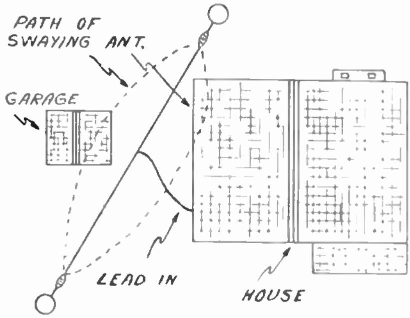


FIG. 2

connected between these two free leads. See Fig. 1. If your ohmmeter shows a reading, the entire antenna (this includes the lead-in) should be checked carefully, because a reading in this case is an absolute indication that the antenna circuit is grounded.

While you are examining the antenna and lead-in, note if there is a possibility of the wind swaying either the antenna or lead-in. Experience has proven that many complaints on intermittent reception have been due to nothing more than a swaying antenna. This refers, of course, to the outside type of antenna. That is, when the wind is from a certain direction, the antenna or lead-in may be caused to sway back and forth, and in doing so, it will intermittently touch a tree, chimney, ventilator or iron pipe. Each time there is a contact of this kind, the volume of the receiver will drop to a low level, and a peculiar scratching noise will be heard. This type of defect is easily recognized after you have observed the effects once or twice. When the antenna or lead-in hits an object, it sounds as though you were rubbing a wire across the antenna and ground connections of the receiver. If you have ever done this, you will know just how a swaying antenna causes intermittent reception when it hits an object. See Fig. 2.

After making sure the antenna is not the cause of the intermittent operation. proceed to examine the power line cord and plug. Be sure the wires are fastened to the plug so that good electrical contact is made. Then examine the line plug contacts. If you are not sure good contact is being made, dismantle the receptacle so that you may examine the contacts. If these look w o r n or out of line, replace the receptacle. Before doing this, however, operate the receiver from another receptacle so as to get a check on your observation. Be on the lookout for *spliced joints in the cord* made by the receiver owner. See Fig. 3. The chassis itself should then be examined carefully, looking for such obvious defects as loose shields, tubes not pushed down in their sockets, poor connections or control grid caps loose or out of place. Also, examine any other mechanical contacts which are visible. If the receiver fades while you are making this examination, observe the tubes carefully—see if one or more of them dim in brilliancy or go out. If so, replace that tube or tubes with others and wait for the receiver to fade again, in order to observe if the tubes are really the cause of the intermittent action. When an examination of this kind does not show up the defect, the receiver must be removed to the shop for more extensive tests.

The customer's home is no place to trace down the cause of intermittent reception. Explain to your customer the exact nature of the defect, and why you m u s t have the receiver at

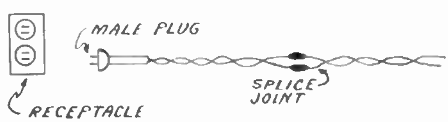


FIG. 3

Here is shown a unique type of multimeter. It has AC and DC voltage ranges, ohmmeter and milliammeter ranges. The face of the meter is covered so that only the printed scale shows which results in a linear scale all the way across the meter face. The selector switch to the right is used in choosing the different meter ranges. Otherwise this multimeter is very much like others in common use. This one is made by Simpson.

your shop. Point out that in your shop you can make a certain test and while waiting for the results of this test you can be at other work. Also explain that on the other hand, if you have to make the repair in the home, it may take several hours, and consequently, there will be a larger repair bill. If you expect to be more than a day on the job, it would be good psychology to offer to lend the customer a receiver until you have repaired his.

Once you get the receiver in the shop, the search for the defect begins. Place the receiver on your work bench with all wiring exposed to view. Then turn on the receiver and tune it to a station. Next with an orange stick or other piece of insulation, pull and pry on all exposed wire contacts, joints, etc. Pay special attention to the wires soldered to sockets, transformers, resistors, condensers, and speaker terminals. Don't be afraid to pull on a wire, for if it comes loose, it was poorly attached in the first place. It is often worth while to apply a hot soldering iron to all suspicious appearing soldered connections, making the solder flow freely over the joint. This will often clear up a *rosin joint* or *a cold soldered joint*.

When you can get to a part to visually examine it, do so. Make your examinations as thorough as possible. Some servicemen use a magnifying glass for close examination of wiring and parts. Such a glass is particularly useful in examining wire wound volume controls and wire wound resistors for poor spacing and minute breaks in the wires or cracks which will test electrically correct, yet may open occasionally.

At the customer's home you may have made a casual check of the tubes. However, now that you have the receiver at your shop, you want to be absolutely sure that the tubes are not at fault. You can now get a check on all of the tubes by means of a tube tester or by trying a complete new set of tubes in the receiver.

If the defect is still present, you will know that the original tubes are not at fault and they may be replaced in the receiver. On the other hand, if the defect is no longer evident (allowing plenty of time for the intermittent action to take place), it is safe to assume that one or more tubes are at fault.

This brings up a very important question. Should you recommend a complete new set of tubes for the receiver, or should you determine which tubes are at fault? This, you will have to determine for yourself. If the tubes are very old, then we suggest that you recommend a new set. On the other hand, if the tubes are relatively new, it will pay to try to find those which are defective. If you do not have a tube tester, you can get a check on the tubes by reinserting one original tube at a time. In this connection, you should keep in mind that a tube tester will not always show up an intermittent action, which is one reason why an operating test on each of the tubes is highly desirable.

Once tubes have been eliminated from the list of suspects to your satisfaction, the connections between the rotors of the tuning condensers and the chassis should be inspected. A poor connection at this point often develops and is a common cause for intermittent reception, oscillation and noisy tuning. The sliding or pressure type of contact should be cleaned with cigarette lighter fluid or alcohol and sandpapered and bent so as to give a better connection. In special cases where an absolutely permanent cure is desired, it is a good idea to fasten a flexible pigtail connection between the rotor shaft and chassis. See Fig. 4. This is done by attaching one end of the pigtail to the shaft with the condenser rotor plates open and then winding the pigtail by enmeshing the condenser plates after which the other end is made fast to the chassis.

In a few instances, the defect may be generally localized by certain symtoms of the receiver. If the dial setting, for example, has any connection with the intermittent action, the defect may be definitely traced to the tuning condensers. If the intermittent action is different in any respect on one part of the band, on one station or closely related stations in frequency this will be the case.

If the action is noticeable at one volume control setting and not at others, it may lead to valuable information in connection with the control itself. Obviously, if it is free from intermittent action at certain settings. it may usually be regarded as at fault. However, this may not always be the case, as a receiver may become intermittent on one volume level while it will work perfectly at a lower volume, due to an entirely different cause. A critical value of signal voltage may cause a coupling condenser to temporarily break down and this would make it appear as though the defect were due to the volume control.

When all possible surface defects have been checked and the receiver still has an intermittent action, it is evident that the defect is electrical in nature. Some part is periodically breaking down, opening or changing in value.

Intermittent reception not due to surface defects may be classified under three general headings: Poor mechanical connections, electrical defects, resulting in an intermittent short or open and thermal connections. On any job involving any intermittent action, the solution is made easier if it is possible to identify the type of intermittent action which is occurring.

A *poor mechanical connection* is definitely known to be causing the defect if jarring the chassis either causes the received signal to cut on or to cut off. A defect of this kind may not

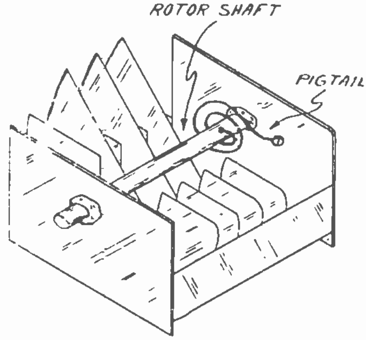
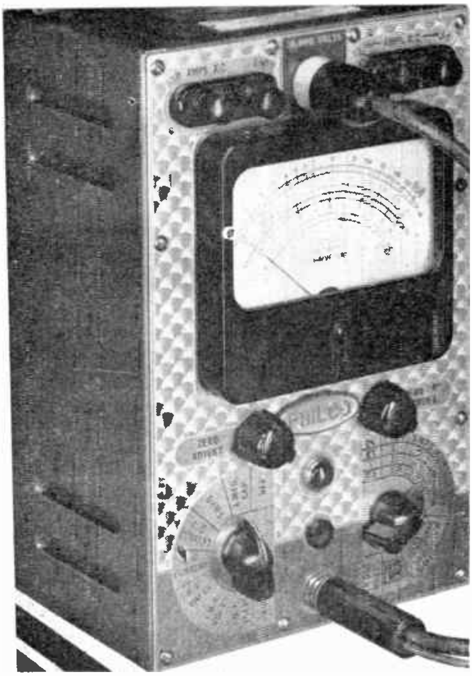


FIG. 4



In the above view is shown a Philco multimeter of the electronic type. In essence this is a vacuum tube voltmeter type instrument and can be used in high impedance circuits in which it is desired to disturb the circuit constants a minimum. Very often ordinary meters with low internal resistances will make changes in a circuit with intermittent defects. This may restore normal operation before the part causing the trouble can be found, a vacuum tube voltmeter is least likely of all meters to cause circuit disturbances.

show up regularly but may make its appearance when the speaker emits a certain sound. For instance, certain sound waves may be transmitted to the poor connection and cause a vibration. Or, again, a similar action may take place when someone walks across the floor. A street car, heavy bus or truck has also been known to jar the receiver as it passes the house causing intermittent operation. In this case, the defect may exist in the house wiring or in any part of the receiver, including the tubes.

An electrical defect will not usually make itself evident when the cabinet is shaken. However, when the intermittent action does take place, even the slightest voltage surge may restore the bad connection and cause the receiver to act normally. Very often with defects of this kind, turning on the lights, pulling out a tube and replacing it or making voltage measurements will restore the reception. Thus, you can readily see that this is the most difficult type of intermittent action to overcome.

A partial connection through which current *arcs* which is usually made evident visibly by the arc, may occur. Any voltage change whatsoever may break the arc, thereby opening the circuit. Such an electrical defect is sometimes started by a *thermal action*— the expanding and contracting effects of heat and cold.

Intermittent action due to a thermal joint is characterized by its regularity. The other two types of intermittent action do not occur with regularity. The cut-off or other effect is almost always periodic in nature. On the other hand, a thermal joint will act as a thermostat. When enough heat has been developed the joint may expand and break, thus causing the intermittent action to occur. When the heat at the joint decreases the parts come back together, thus restoring normal operation.

A defect of this type may occur in a voltage supply circuit. In the former case the defect will show up quickly as the heat is generated at the thermal contact itself, by the passage of current through it. In the latter case, it may be minutes or hours before the defect makes its appearance, as in this case the heat is absorbed from some other part. For example, a coil which carries no DC whatsoever may absorb heat from some nearby part and expand, thereby causing a break in the winding. In this case, it is necessary to turn the receiver off for sometime before the heat absorbed by the coil form will be dissipated sufficiently to allow it to shrink to normal proportions and the circuit to close. Obviously, such an open would affect none of the voltage current readings. This shows that on any intermittent job *you must be a l e r t and on your toes* all the time and must be a master of all types of testing.

Mechanical Connections

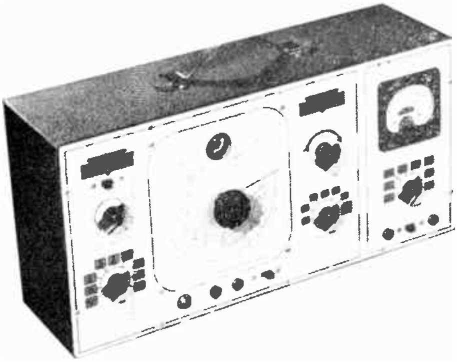
The condition which will cause wire connections or their terminals to make improper contact are generally improperly soldered connections. wire too tight, moisture or oil penetration of insulation of wire and corrosion.

It is a good plan to resolder all connections which have the obvious appearance of poor soldering. If the solder does not partially assume the outline shape of the terminal and wire end where it is attached and have a smooth glossy look, it is well to touch a hot soldering iron to it. If the solder does not adhere to the joint and stands out in globules about the connection, the electrical connection which it makes is doubtful. Very often the rosin flux when cool is sufficient to hold the wire mechanically but will allow an intermittent electrical connection to be formed on vibration.

Guard against the possibility of the wire being too tight by unsoldering and allowing just a little *slack* in the wire. If necessary splice on another short length of wire or use a new wire of proper length. If it remains too tight it may pull the terminal loose from its rivet causing an intermittent contact to the socket or chassis or other unit. No soldered joint should be made with a wire under tension as it may work loose on cooling or after the receiver is put into operation.

In many confined spaces in a receiver chassis moisture will collect due to condensation from the air when the temperature is allowed to lower. This will eventually decompose rubber insulation and will penetrate to the wire if it is not completely impregnated with oil-asphalt, rosin or wax. This is rarely the case in the older receivers and hence insulation breakdown causes moisture to form various amounts of leakage through the insul-

This instrument as made by Philco is a multimeter having an internal resistance of 1,000 ohms per volt. Such an instrument is all right to use in making all ordinary measurements where great sensitivity is not required. For greatest sensitivity a vacuum tube voltmeter is recommended such as those made by Philco and other companies.



Here is shown a modern condenser checking instrument. Such an instrument is very useful in finding condensers which have an intermittent type of defect. This particular instrument is made by Sprague and is similar to other makes of this same type of instrument using a bridge circuit for most of the condenser measurements.

ation from one wire to another or from a wire to the chassis. When this has been definitely ascertained by leakage tests with an ohmmeter, the wire should be replaced with cloth and wax insulated wire, and this should be given as much free space as possible without unduly increasing the length of the wire.

Corrosion of wire is also a condition due to moisture condensation and occurs in confined places. In fact, most of this will occur under the insulating layers of audio and power transformers, or condensers or in some few cases in certain types of resistors. It is impractical to open all such units to inspect for this condition and this can be avoided by overload tests of such units after the defect has been localized to them. With a sufficient number of well directed tests, substitution, stage-by-stage tests, load tests, etc., the source of the defect may usually be localized.

Other Mechanical Factors

While an important part of the mechanical checking is made on the wiring, the shielding is also important in this connection. The IF, RF and oscillator coil shields should make a perfect electrical connection to the chassis. Many servicemen solder pigtail connections to the shields and chassis to insure a perfect connection. However, if the shields fit their sockets snugly and they are brushed or sandpapered at the fitting surface, you can usually be sure of a good connection. An intermittent connection of any shield is likely to cause some degree of intermittent reception.

Shielded wires should be inspected for grounding of their shields and tube shields must be properly grounded. The spray shield type tubes (now obsolete) and those fitted with individual shields attached to the tube must be given special attention, as they are more frequently the cause of defects than other types.

Imperfect connections to the condenser rotors are often the cause of intermittent reception. These should be tested by continuity and if the pressure type of contact is used, they should be cleaned regardless of the test and regardless of whether there is any tuning noise or not.

Electrical Defects

Ultimately, of course, all mechanical defects result in electrical defects causing intermittent operation. Under this heading, however, the electrical defect is less easily traced to its possible mechanical beginning. You cannot draw a very definite line of distinction between the two, as each may have some of the symptoms of the other. Mechanical vibration will in many cases cause electrical disturbances. Such defects cannot even be limited to any class of units used in receivers such as resistors, condensers or transformers.

Those condensers which are associated with the signal circuits in such a way as to be affected by a signal may

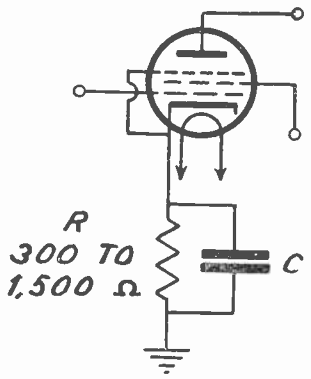


FIG. 5

cause the receiver to operate intermittently. These are cathode by-pass condensers, screen grid by-pass condensers, plate by-pass condensers and coupling condensers. If a cathode by-pass condenser develops a considerable temporary leakage, the bias will be lowered and the signal may increase a little and may be accompanied by cross modulation or other distortion. On the other hand, if a screen grid or plate by-pass condenser should develop such a leakage the signal will be reduced in relation to the amount of leakage. A by-pass condenser will sometimes develop leakage at a certain critical voltage. As long as the DC voltage applied plus the signal positive peak at the condenser is below this critical value, the reception will be normal, but when this is exceeded the leakage will start. It may last for some time, or may stop as soon as the voltage again reduces. All condensers suspected of this type of defect should be given a high voltage charging test and a leakage test at high voltage.

The leakage may be of such a nature that AC is required to bring it about. In this case (for paper condensers only) an AC test must be used.

It is interesting to notice the relative leakage for various condensers to cause the same condition, or to see what degree of leakage would be expected of a condenser in various circuits.

The cathode by-pass condenser, Fig. 5, shunts a relatively low resistance as a rule and this resistor carries a very heavy current as compared to the signal in most places in the receiver. Therefore, a considerable amount of leakage would be required to change the circuit operation. The bias may change 50 to 100% in RF or IF tubes without a noticeable change in signal strength in most cases. Therefore, a very large leakage may be tolerated in the cathode by-pass condenser. Moreover, the leakage here may change 100% or more if it is small as this will make very little change in the total resistance in the cathode circuit. Not until the leakage resistance begins to compare in value with the cathode bias resistor value does any serious trouble occur. However, if the condenser were intermittently shorting you would naturally expect trouble.

In regard to the screen grid voltage at which the usual RF or IF tube is operating, the gain of the stage is not critical to small changes in screen voltage such as plus or minus 5 volts. It is even much less critical to DC changes in applied plate voltage. The plate voltage can often be varied 50 to 100 volts plus or minus without a noticeable change in gain of the stage.

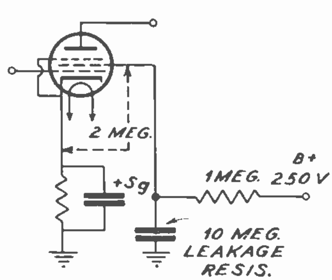


FIG. 6

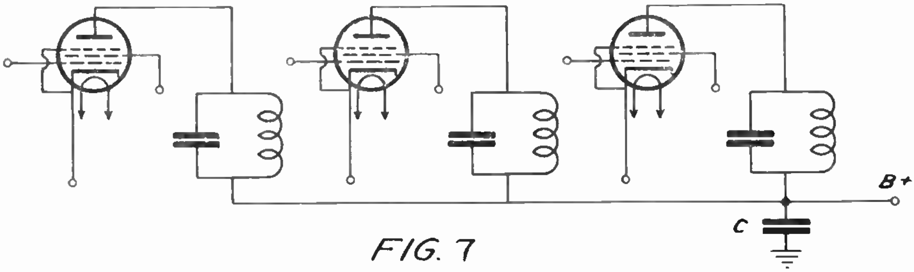


FIG. 7

Because the screen grids are usually supplied through series resistors, a low leakage resistance (large leakage current) will make a considerable change in applied screen grid voltage.

For accurate values in the case of the screen grid circuit as in Fig. 6 if the series screen grid resistor is 1 megohm and the actual screen grid to cathode resistance is 2 megohms and the leakage resistance of the screen grid by-pass condenser is 10 megohms, there will be only about 2 volts change in the applied screen voltage if the leakage reduces 10% or increases 10%. That is, if the leakage changes 1 megohm. This shows that aside from instantaneous changes which would simply cause clicks in the signal circuit, the leakage will be easily detectable if it can have any effect on the signal.

An even greater change in the plate by-pass condenser leakage must be made before the signal will be altered. Because there is no series resistance in the plate circuit as a rule, the leakage of the by-pass condenser will do no harm until it draws a considerable percentage of the current from the power supply.

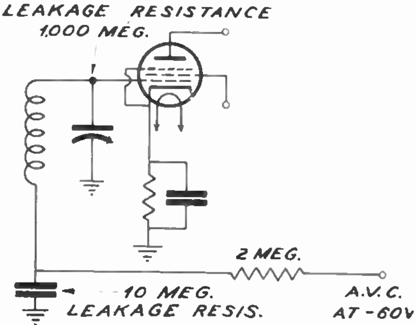


FIG. 8

It must be noted as brought out in Fig. 7, that leakage in one plate circuit by-pass condenser such as C will affect all plate circuits as they are connected as a rule in parallel.

If the condenser opens the symptom will not be intermittent reception, but most likely oscillation. However, the amount of leakage which this condenser must have to make a volume change of the signal is quite great and therefore easily detected.

This is not at all true with regard to audio coupling condensers or AVC or AFC filter condensers. Furthermore, the leakage changes of such condensers in order to cause large changes in signal strength are almost impossible to measure by the usual methods.

In the AVC filter for example, as in Fig. 8, if a leakage of 1000 megohms is assumed from control grid to the other tube elements, 10 megohms leakage of the AVC by-pass or filter condenser and a 2 megohm AVC series filter resistor there will be nearly .1 volt change in AVC voltage for each *megohm* change in leakage resistance of the filter condenser. On the other hand, if the leakage of this condenser is up to 100 megohms and that of the grid around 250 megohms with the other values the same: a change in condenser leakage of 1 *megohm* will make about a .25 volt change in the AVC voltage. Obviously, an electrolytic condenser could never be used and a paper condenser must be as free as possible from any leakage current at maximum signal strength.

For the audio coupling condenser, see Fig. 9. How many volts change will result from a change in leakage resistance of 1 megohm in condenser C? If the leakage is initially 1000 megohms which is quite possible, it may change 1 megohm and still the voltage on the grid will be changed less than 100 microvolts. However, if the leakage is down to 100 megohms with a grid coupling resistor of 2 megohms, a leakage resistance change of C of 1 megohm will cause a grid voltage change of .02 volts. This, of course, is a change in bias voltage. Now it is not uncommon for a condenser of high leakage resistance to change many megohms in value either suddenly or gradually, due to moisture getting into it. No ordinary test open to the average serviceman would enable him to distinguish a leakage of 150 megohms from for example 60 megohms. Yet a change of this nature would make a considerable difference in the operation of a receiver. The most direct method of cure in this case is substitution of parts. In order for a filter condenser to cause intermittent reception, its leakage must reduce to a few thousand ohms or become a direct short. When this happens, it will show up in the measurement of plate voltage and will be independent generally of the volume of the received signal. That is, it will act in this way at any signal level.

Thermoelectric Effects

When a receiver has operated for some time virtually everything in it is operating at a higher temperature than when not operating. Due to natural expansion pratically everything in the receiver has moved a trifle. This expansion and subsequent movement may detach one or more connections vital to the operation of the receiver. Strip resistances have been seen to buckle and touch some other part causing a short of the filament, bias, signal circuit, etc. Welds at the filament wire within the tube have been known to separate and break the filament circuit. Connections have been known to break from condensers, transformers or resistors or from shields in this way. However, these are things which cannot be seen except in the case of the open filament of a glass tube.

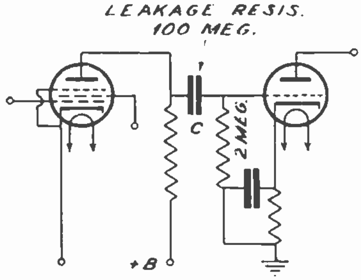


FIG. 9

The best suggestion here is to test various units which may be suspected of a defect, due to the symptoms immediately after the receiver is turned off while it is still at operating temperature. In many cases, defects may be located while the receiver is operating.

The ability to reason out the probable location or cause of the intermittent action from its effect must be developed by the individual serviceman. Be on the watch for the little effects as well as the big ones, and always call on your knowledge of parts and receiver operation.

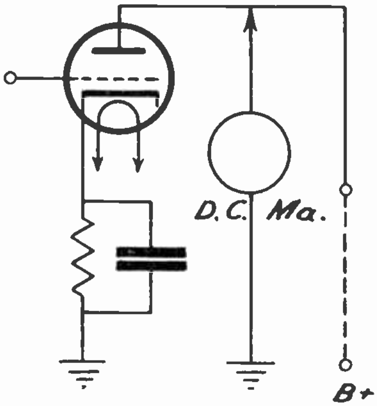


FIG. 10

For example, if when adjusting an IF trimmer condenser, you cannot get it to peak at the proper IF frequency, remove the IF transformer from the chassis and take off its shield. Examine the wiring, looking for corroded spots. Check with an ohmmeter between each condenser plate and the coil.

Acid applied to the joints of an IF transformer lead, either when the receiver was built or at a later date, can cause corrosion which in turn will more than likely cause an intermittent, if not a permanent, opening in the transformer windings.

If an IF transformer is suspected of causing trouble, it should be removed from the shield and given a thorough visual inspection for corrosion.

The primary of an IF or RF transformer or a plate resistance or any transformer load for AF may be easily given an overload test as in Fig. 10. A milliammeter may be set to a high range (100 to 150 milliamperes) and shunted from plate to ground momentarily. In this way, the entire power unit voltage will be impressed across the plate load unit. If it shows a steady flow and works after the milliammeter is removed, the plate load unit must be in good condition.

An IF transformer which acts as previously described will usually be found to have an open or short. Either defect will effectively remove the trimmer condenser from the circuit and its action on adjustment will be slight, if perceptible at all. A break between a trimmer condenser and the rest of the coil can only be detected by examination. However, its action on adjustment will give you a clue. See Fig. 11. If C1 shorts, the coil L1 is also shorted. The same applies to C2 and L2. A small amount of dust or dirt between the IF trimmer condenser plates is sufficient to cause an intermittent short.

Don't be too critical of the trimmer condenser adjustments on TRF receivers as they are not apt to be naturally sharp. Carefully note how the receiver performs when it cuts out. If the volume drops to a low level and distant signals can still be received, the trouble is not likely to be in the RF or IF sections. More than likely you will find it to be in or past the detector (second detector in a superheterodyne).

If the signals become distorted or muffled, a signal circuit supplying AC signal voltage to some of the tube elements is at fault. If the defect is in the RF or IF sections reception of distant stations will be out of question, and strong locals may come through but weakly or the receiver may become entirely inoperative.

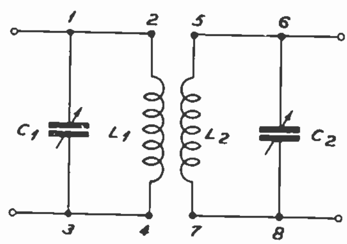


FIG. 11

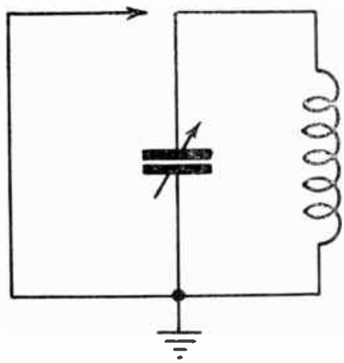


FIG. 12

If the receiver cuts out at one end of the dial and not at the other, look for dust, dirt and direct shorts between the tuning condenser plates. A full short across the tuning condenser plates is the same as connecting a wire across the coil and condenser. See Fig. 12. Thus the short effectively prevents any passage of signals in a circuit of this type. If the cut-off (intermittent action) is at the low frequency end of the dial there is probably some trouble in the oscillator padding condenser and possibly there is a poor connection between the rotors of the tuning condenser and the metal chassis. If the intermittent cut-off takes place at the high frequency end, and a combination-detector-oscillator tube is used, it is probably blocking. Decreasing the value of the bias resistor in the cathode circuit may make a permanent cure.

AVC controlled receivers, especially those with some form of visual tuning, makes the correction of an intermittent job easier. If no tuning meter is employed, insert a milliammeter capable of measuring the *no signal plate current* of all the AVC tubes (measure them individually to determine what size milliammeter to employ) in the common plate supply circuit. The meter will then function as a visual tuning indicator. When the receiver cuts off, watch the meter. If its reading does not change, the defect is past the AVC stage—in the audio system. The reading of the meter is dependent not only on the tube voltage, but also on the safe passage of the signal through the receiver to at least the output of the AVC. This little observation, simple as it seems, indicates that the preselector, first detector, oscillator, IF amplifier, AVC and the general power supply are probably in good condition. Conversely, if the meter reading reduces the defect is in some of the aforementioned sections and not in the AF stages or speaker.

As intermittent receiver operation is a difficult service problem, it will be well to consider the most common receiver parts that cause this defect. To make a list of these defects in their order of importance should prove valuable at the service bench. From this list, the tests for the most common intermittent defects can be made first. The following list is made up from service experience of the most common sources of intermittent receiver operation and they appear in their order of importance:

1. Tubes.
2. Condensers (paper).
3. IF and RF transformers (plate windings).
4. Audio transformers (plate windings).
5. Condensers (filter).
6. Corroded and dirty resistance windings or friction contacts on switch, push button, and volume controls.
7. Shrinkage of fiber insulation on controls, trimmers, tuning gangs, sockets, switches, etc.
8. Speaker field coils.
9. Antenna circuit (mechani-

cally loose or shorting wires and solder joints).
10. Tuning condensers (gang).
11. Power transformers.
12. Resistors.
13. Other miscellaneous defects—low filament voltage. speaker voice coils and leads, wax in trimmers. erratic vibrators, bias cells. contaminated oscillator coils.

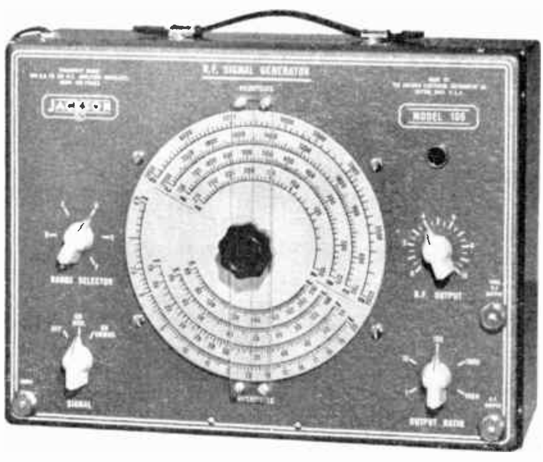
Tubes: It has already been pointed out that tubes are the most common causes of intermittent receiver operation. With AC-DC receivers a common cause of intermittent operation is the opening of the filament intermittently. The receiver may play normally for several hours then cut out all at once and then after a few minutes time cut back in and operate perfectly normal again. Inasmuch as the filaments of these AC-DC receivers are in series and in turn in series with the pilot light. any opening in the filament line will cause the pilot light to flicker or go out entirely. This is a good clue to the defect and by applying an AC voltmeter across each tube with the receiver switch turned on. will definitely identify the tubes with the open filaments, as practically full line voltage will be indicated across the tube having an open filament.

The grid cap connection to tubes is often a cause of intermittent operation. Check the grid cap connection carefully. If the grid cap is loose or if it can be moved a new tube should be used.

The pins of some tubes may be poorly soldered. Thus, they are a source of trouble and if upon inspection of the tube pins there is any indication of a poor solder joint, reheat the solder in the pin and if necessary apply more solder.

Tubes sometimes develop intermittent internal shorts or opens. These tube troubles will usually be revealed when checking with a good tube tester if the tube is *tapped gently* with a rubber mallet or your finger while testing it.

Gassy tubes can often cause an intermittent action to occur. This is especially true of the power and audio driving tubes. The gas within the



This view shows a typical signal generator for Radio testing purposes. Its frequency range is from 100 KC to 216 megacycles in six ranges and has extensive use in several kinds of radio testing. *Courtesy Jackson Electrical Instrument Co.*

tube causes grid current to flow and allows the grid to become positive and in this way overloads the tube and causes it to be blocked. Gas within a tube can be detected by measuring the voltage across the grid resistor while there is no signal being applied to the tube. If there is a noticeable voltage developed across this resistor when there is no signal applied and the voltage disappears when the tube is removed from the socket, it indicates that it is gassy. (In AC-DC receivers, a tube cannot be removed from the socket without interfering with the operation of the other tubes as their filaments are in series. To simulate this test in AC-DC receivers, disconnect the lead to the cathode of the tube under test and if the voltage across the grid resistor drops, the tube is, no doubt, gassy and should be replaced).

The AVC action of a tube may cause intermittent operation of the receiver if the AVC tube is gassy. The OZ4 cold cathode type of rectifier may become intermittent after continued use. If an OZ4 tube in a receiver is found to be old and the complaint is intermittent operation, replacing the OZ4 in many cases will restore the receiver to normal operation.

Condensers—paper: Condenser causes of intermittent reception are almost wholly restricted to AF coupling or RF by-pass condensers which open. These are, in general, best checked by shunting the condenser under test with another of about the same size known to be in good condition. A more positive check, however, would be to disconnect the suspected condenser and then connect another in its place.

Totally shorted condensers are rarely the cause of intermittent reception. When a condenser is completely shorted it generally stays shorted. Leaky condensers are another matter, and often give rise to puzzling actions. They are best checked with a high voltage for ability to hold a charge.

Condensers which are enclosed in a rigid container are more likely to develop opens than other types. Uncased condensers are usually free from this trouble. The reason that condensers which are enclosed in a container are more susceptible to this type of defect is because heat expansion causes the lead wire, fastened to a lug on the outside of the case, to tear loose from the foil, thus opening the condenser. In this case, the intermittent action can be made to occur by gently moving the wire between the outside lug and foil.

With some of the cheaper type condensers, hard wax is used to hold the connecting lead against the foil of the condenser and the lead is not soldered. This type of condenser will also cause an intermittent action as this wax may become soft upon overheating and cause poor contact to the foil. Many times the offender can be found by tuning in a station on the receiver and then giving each condenser a slight tap or pull. In automobile receivers where the vibration from the car causes a strain of the receiver parts, the condensers which are supported by their own leads are most likely to cause intermittent receiver operation. These condensers should be checked very carefully.

RF and IF transformers: Most of the defects encountered with RF and IF transformers are in the primary or plate winding where considerable current is flowing. Due to corrosion or poorly soldered connections, the winding developes a high resistance connection and as considerable current is flowing through the winding heat will be developed causing the connec-

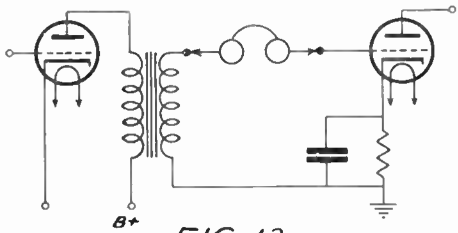


FIG. 13

tion to be unstable. It may in time weld itself or become permanently open, but before this happens an intermittent connection will, no doubt, result.

One way to test this is to momentarily short circuit the B + through this winding and if a weak connection exists, it will either be opened permanently or it may cause an arc which may weld several turns together. In either case an intermittent noise will be heard from the speaker until one of these permanent conditions is reached. If this condition is found even if the connection does seal itself, it has probably shorted out a few turns of the winding. Therefore it is best to replace the transformer.

Audio transformers: In regard to audio transformers. the turns may intermittently short or open. Noise may or may not accompany the defect, although when it does (a sharp click will be heard) it is usually associated with the opening of the transformer rather than a short between turns.

Arcing between turns, a partial short or open, would result in noise. If a meter will not show the defect, a pair of phones properly connected in the circuit while the receiver is operating will enable you to localize it.

When the headphones are connected as in Fig. 13, signals will practically cease or become very low if the winding becomes open. If the headphones are connected as in Fig. 14, signals will cease if there is a direct

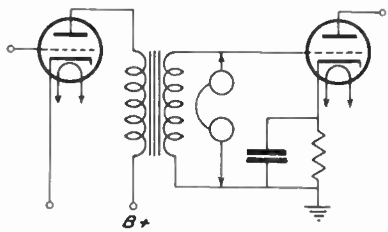


FIG. 14

short circuit in the primary or secondary. If there is a partial short, the signals will be decreased in the same proportion in the speaker output.

Shorts between the primary and secondary of a transformer are rather unusual, in case of intermittent reception, but this has been known to occur. A milliammeter inserted in series with the plate of the tube fed by the suspected transformer will show a marked increase in plate current, if there is a short between windings.

If, in Fig. 15, the primary of T shorts to the secondary or if the primary opens, the plate current of tube A will change. The current of tube B will change if the primary is shorted to the secondary. However, the greater change will be in the plate current of tube B since there will be a high positive grid voltage applied to the tube. This same test may be employed to check for a complete or partial break-down in a condenser coupled stage.

Condenser Filter: Filter condensers are more likely to be affected by corrosion because of the chemicals used

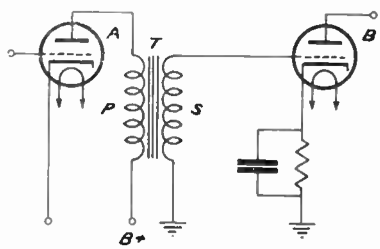


FIG. 15

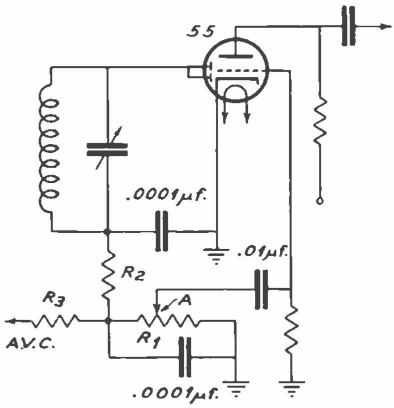


FIG. 16

in their construction. Thus they can cause the receiver to be intermittent in operation. Measuring the ripple voltage with a vacuum tube voltmeter will aid in identifying the cause of the faulty operation. If the ripple voltage is found to exceed 3 volts, the condenser should be replaced. Moving the leads of the condenser or tilting the container of the wet type electrolytic condenser will often identify the condenser or the faulty unit.

Corroded and Dirty Wiping Contacts:

Wherever there is a friction contact intermittent operation is likely to occur due to wear and also due to dirt or other foreign matter getting in between the contacts. Switches of all types are subject to this type of defect, band switches, pust buttons and selector switches are the most common switches which may cause such trouble. The terminals of these switches should be examined very carefully and if found worn badly, the switch should be replaced; but if it is just dirty a good cleaning with carbon tetrachloride and vaseline applied to the terminals will cure any such difficulty. When these units are defective, they usually will cause a scratchy noise to emanate from the speaker while they are being rotated.

Volume Controls are often the cause of intermittent reception. The best check on a volume control is to remove it entirely from the circuit and to try a new control in its place. Any control unit which is not in a voltage supply circuit can be removed without affecting the action of the rest of the circuit.

No power supply voltage will be disturbed by removing a control which is across the antenna input coil, the primary of an RF transformer or secondary of an AF transformer. The controls of more modern receivers cannot usually be removed in this fashion, as they are in most cases in a voltage supply circuit such as the cathode, the screen grid. the AVC control, or the AF grid circuit. However, when a duplicate control is not handy, it is perfectly possible to remove the suspected unit and substitute a *fixed resistor* having the same resistance value as the maximum volume position of the original variable unit. Figure 16 shows a diode circuit in which R1 is the variable volume control. To substitute a fixed resistor for the variable unit, connect the circuit as shown in Fig. 17. Note that point A is now connected to the maximum volume position. An intermittent control is generally noisy when moved and should be replaced.

When a replacement control is not available. clean the old control, tighten any loose moving contacts and rub a soft lead pencil over the resistor element. If this seems to clear

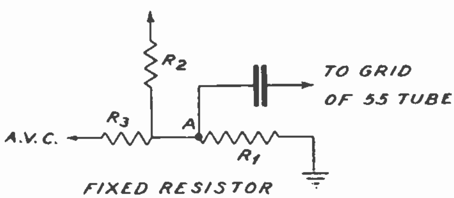


FIG. 17

up the condition which existed, order a new control as you have proven that the old one is at fault. A patched up control will not last very long and should not be considered as a permanent repair.

Shrinkage of fibre insulation: A great number of the parts of a receiver are constructed from a fibre compound such as tube sockets, insulated strips in volume and tone controls, switch housings, and switch terminal mountings, terminal strips, insulation between the sections of tuning condensers and many others. As this fibre is subject to shrinkage with age, parts constructed of this material are often a source of trouble. Where rivets are used to fasten a terminal through this fibre, when the fibre shrinks it leaves the terminal loose, causing an intermittent connection to exist which may cause considerable trouble. A vibration from the speaker or a heavy jar will cause this connection to make and break and if this loose connection is in a critical position it will cause a very annoying noise to be produced through the speaker. A close visual inspection of all fibre constructed parts should be made. This is especially true if the receiver is over two years old.

Speaker Field: The intermittent defects to be found with speaker fields is similar to those found in audio transformers. The defect may be due to an intermittent short or open. This can often be checked by placing a heavy load upon the field winding as recommended for IF and RF transformers and then measuring the DC resistance with an ohmmeter to ascertain the resulting condition.

Antenna Circuit: At the beginning of the lesson, methods of locating intermittent defects associated with the antenna were given. Thus it will not be repeated. It is a very common cause of intermittent reception and it should be thoroughly checked to make sure it isn't the cause of the intermittent operation.

Tuning Condensers: Intermittent reception is often caused by a faulty tuning condenser due to foreign objects getting lodged in between the condenser plates or due to fibre insulation shrinking, causing the plates to become shorted intermittently. The method of checking for foreign objects in between the plates of a tuning condenser is very simple. The test consists of simply placing a *high DC voltage* across the condenser in series with a .5 mfd. paper condenser and foreign objects will cause an arc which can be seen. This arrangement will only show an arc temporarily because once the series .5 mfd. condenser charges the arc will no longer be seen. So you need to watch carefully for the arc (sparking). If the room in which you are working is dark it will be much easier to see the arc.

This will in many cases burn the particles causing the short, thus removing the source of trouble. If the foreign object isn't removed by this process a pipe smokers cleaner inserted between the plates will do the job. If the fibre insulation has shrunk causing the plates to short, with a jar or vibration, this can be cured by reriveting the supports.

Power Transformers have on occasion been known to cause intermittent reception. Shorts between secondary turns will result in a lowered secondary voltage and overheating. If the AC voltmeter shows a varying voltage, you should check carefully for the short or other cause. If there is an intermittent short in a power transformer the current through the primary circuit will vary considerably. Unless you disconnect the B plus lead from the rectifier filament

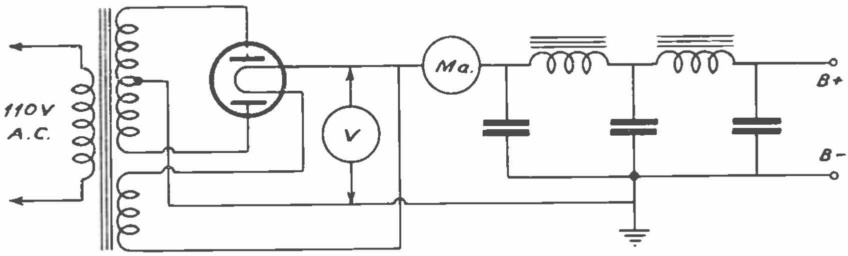


FIG. 18

and connect a resistor which will equal the regular load, a test of the primary current with an AC ammeter or a secondary voltage test is of little value in checking the power transformer.

A short in the receiver proper would increase the high voltage secondary current load and result in a greater primary current. Also the secondary voltages would be decreased. If desired, the power load on the high voltage winding may be determined by measuring (with a 1000 ohms per volt. DC voltmeter) the voltage between the filament of the rectifier tube and the center tap on the high voltage winding. See Fig. 18. Then the current to the input of the filter should be measured with a milliammeter. See the milliammeter connection in Fig. 18. The resistance load value may then be calculated by dividing the measured voltage value by the measured current value.

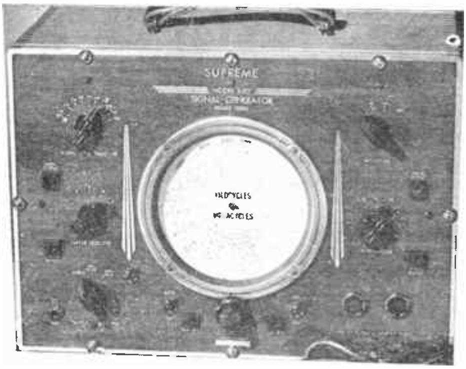
Then the AC ammeter may be inserted in the primary circuit and the receiver turned on, or an AC voltmeter may be applied to the high voltage secondary. A variation in current or voltage. indicates that a short has occurred in one of the transformer windings or in the load connected to it. It is not necessary to disconnect the low voltage secondaries as the wiring from them to the tube filaments may be visually inspected. To make sure no external shorts have occurred, you should look for charred insulation and note if the odor characteristic of burned insulation is present.

A detachable shield between the primary and secondary of the power transformer will cause considerable trouble. There is no test for it except to use a regular line filter for substitution. In many cases this will not prove the source of the trouble. The only thing to do is to dismantle the transformer and check the connections. The shield core and outside frame work of the transformer should all be connected together and grounded.

Resistors: A large amount of heat is developed in a resistor carrying a supply current. The heat may cause the winding form of a wire wound resistor to expand, breaking the wiring. or in the case of the early DC and universal receivers, the series filament wire wound resistor *form* may warp (caused by heat) and short to the chassis.

A voltage measurement will in most cases indicate the circuit in which the defect occurs. If arcing or sparking is present, the source of the defect is easy to locate. especially if the receiver is operated in a dark room.

Carbon resistors often change in value giving rise to intermittent hissing noises and less often to changes in sound output. If they deviate more than 20% plus or minus from their rated value when hot (turn receiver



Above is shown a Supreme signal generator of the all-wave or multiband type. With several ranges available on a signal generator it makes it possible to test all tuning bands of the receiver. In this way the possibility of an intermittent type of defect being in any particular tuning band can be eliminated.

off and measure them before they cool) replace the defective resistor with a metallized or wire wound unit.

The connection to the resistance element in any type of resistor is a constant source of trouble. Resistance wire cannot as a rule be soldered, and soldered or welded connections to carbon or metallized units are out of the question. A pressure contact is employed by most resistor manufacturers and such a contact is a potential source of trouble. Mechanical or thermal contacts quite often occur in these units. Reclamping the resistor terminals with a pair of pliers will often permit a cure of the trouble. However, this is a makeshift arrangement and to be sure of a permanent repair, a new resistor should be installed.

Miscellaneous Causes of Intermittent Operation

There are, of course, a considerable number of receiver defects which have caused intermittent receiver operation most of which are uncommon. Low filament voltage is often the cause of intermittent operation in portable receivers, also a low line voltage. Both of these should be checked.

When the plate or screen grid voltage on the oscillator tube reduces to a low value, it will stop oscillating, causing the receiver to be inoperative. Thus, if the voltage is fluctuating the receiver will operate intermittently. Wax from different parts of the receiver can get in between the plates of the trimmer condensers and can often cause an intermittent condition to exist. The warming up of the receiver may be sufficient to cause this wax to melt and run in between the plates of the trimmer and as this has a different dielectric constant than the mica or air between the plates of the trimmers, it will detune the receiver. If the receiver is readjusted with the wax in between the trimmer plates the trouble will still exist due to the change in the dielectric constant of the wax on warming up. A close visual observation of the trimmers should reveal such difficulty and the wax should be thoroughly cleaned from between the condenser plates if it is found. It may be necessary to warm the wax in order to remove it. Then precaution should be taken to prevent this from happening again. Some type of absorbent cloth or paper can be inserted at the point from where the wax is emanating, keeping it from dripping on the condenser.

Bias voltage cells are used in many receivers. These small units often cause an intermittent condition to exist. They should be replaced if their action is erratic. It may prove advantageous to change the type of bias to cathode bias if the bias cells continue to cause trouble or if they are not readily obtainable.

When a receiver is subjected to varied conditions such as being sprayed with water or if rain water reaches it, a number of defects may occur. Where the oscillator coil has absorbed water, it can cause untold trouble. In case of this type of defect, the customer can be of great service. If you are told under what circumstances the receiver has been operating, you will k n o w what to expect and where to l o o k for the defect or defects.

Mice often cause trouble, not only by chewing the insulation from wire causing shorts and chewing speaker cones, etc., but t h e y also can cause considerable trouble by contaminating the parts in the circuit causing high resistance shorts to ground. Watch carefully for any trace of mice for much time can be saved if you can locate the parts that have been made inoperative by them.

Speaker intermittent action is usually the result of the voice coil shorting, opening or grounding. Windings on speaker fields sometimes intermittently short or open, thus reducing magnetism. This will show up as a change in voltage across the field or a change in pull on a metal screw driver held near the pole of the speaker field.

Defects that cause intermittent action in the power supply are not common. Filter condensers which are leaky will cause trouble as will defective voltage dividers. If one of these parts is defective, a change in operating current and voltage throughout the entire receiver will be noted.

In AVC controlled receivers the resistance-capacity filtered control grid return leads should be closely checked. An open of the filter condenser in the grid return will often cause a reduction in signal strength as the condenser is part of the tuning circuit. Condenser C1 of Fig. 19 is a typical example. High value resistors associated with the AVC tube may best be checked by trying new resistors if the high range of your ohmmeter will not measure their resistance value.

Isolating the Defect to a Single Stage

When the foregoing described tests do not s h o w up in the defect and when current tests and surface tests do not result in a solution, the stage-by-stage method must be employed.

With this system you can definitely localize the trouble to one stage and once the defective stage is known, parts in that stage can be substituted until the defective one is ascertained by the process of elimination. This procedure however, is only recommended for receivers which have an intermittent defect.

For the application of this method you should have a diagram of the receiver, a test oscillator, an output meter and a DC milliammeter.

The diagram of the receiver should be carefully studied before going ahead with the tests to determine if there are any peculiarities which will warrant special attention.

As an example of how to localize defects in a receiver, the block form of diagram in Fig. 20 will be used. As shown, this receiver is a superheterodyne employing a separate oscillator and automatic volume control. The AVC is applied to the IF amplifier only.

The first thing to do is to couple the test oscillator or signal generator (tuned to the IF of the receiver) to the input of the second detector. The

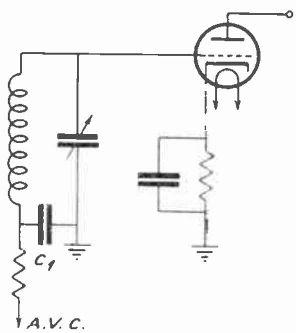


FIG. 19

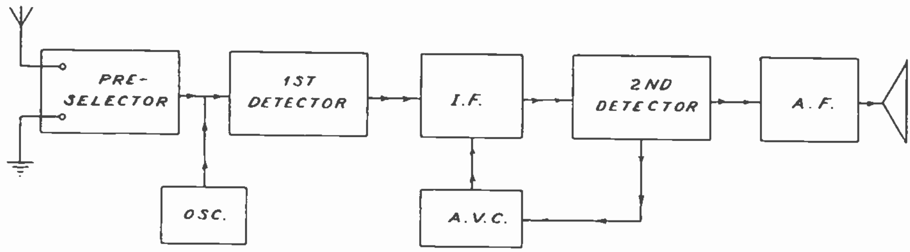


FIG. 20

output meter is connected to the output circuit of the second detector. The system is set in operation and operated for a reasonable length of time to see if the sound output of the speaker changes. If there is a noticeable change in sound, the output meter reading is noted to see if it has also changed. If so, the defect is in the second detector circuit, or in the power supply. If there is no accompanying change of the output meter, it is moved to the output of the AF amplifier and the receiver allowed to operate again. If the output meter does not now change, it indicates that the speaker or output transformer is at fault. With each step the receiver should be subjected to various conditions in order to make the intermittent action occur so that a reading can be obtained on the meter.

Should the circuit check perfect from the second detector to the speaker, the signal generator is moved to the input of the IF amplifier to see if the cut-out occurs with this stage in the circuit. Remember that fading at this point may be associated with the AVC circuit. If your test proves that fading (intermittent action) occurs in this circuit, then all parts of both the IF and AVC stages should be checked carefully.

The next step is to couple the test oscillator to the first detector input. The signal generator frequency should then be set to some point in the broadcast band. The receiver is tuned to the signal. If fading occurs, switch over the oscillator to the IF frequency of the receiver without disturbing any connections. Should the fading stop and not return, the defect is in the receiver oscillator. If fading continues, the first detector stage is at fault. The RF amplifier and preselector are, of course, checked by feeding the proper test frequency into their input.

In this discussion consideration of the various components of the RF, oscillator, IF, etc., as a whole has been made. The student must realize that when there are two stages in the IF or RF amplifier, each should be checked individually once the defect is traced to that particular section of the receiver. This will narrow down the field of operation and make the location of the actual defect a simpler matter. Remember that when the output meter or oscillator is moved from a steady signal connection to a point where intermittent action occurs, the defective stage has been included in the circuit.

The AVC, of course, governs the plate currents of the tubes which are under AVC control and any increase in plate current indicates that the signal to the AVC input has decreased. If the output signal from the signal generator is kept at a low energy level, the AVC system will not complicate the problem. Should you find your output meter to have insufficient sensitivity when connected to the second detector output, a milliammeter in the plate circuit of an AF tube may be used instead of the regular output meter.

When the stage-by-stage method does not isolate the defect in one particular stage, it is in a common voltage supply circuit, and milliammeters of appropriate size in the various voltage supply leads will register a change in current when the receiver fades.

Milliammeters are suggested instead of voltmeters, because they do not constitute an extra load and so change the operating voltage as the voltmeter might do. Often when a voltmeter is connected in a circuit for test purposes, the defect will not show up because the voltmeter will lower the voltage unless a high impedance vacuum tube voltmeter is used.

One point so often overlooked by servicemen is that certain peculiarities regularly occur in commercial receivers. In a group of receivers bearing the same make and model number and made during the same run at the factory, the same complaints will develop in each as they are all made from the same batch of raw materials, and were given the same tests.

These complaints will be due to the same part going bad in each case. Where known defects develop in a certain model you should, after looking for obvious defects, go straight to that part. For example, if the coupling condenser in a certain make and model of receiver has been known to open repeatedly and cause intermittent reception, do not test around or apply the stage-by-stage method. Instead, use a new condenser and try out the receiver first.

The distributor's service manager should be consulted on all stubborn cases. He has a wealth of information, as he works on the same receivers day in and day out. He can freely interchange parts (on account of a large stock) which unfortunately cannot be applied by the independent serviceman or small dealer.

Magazines often carry service notes on the *tricks of the trade* as they are sometimes called. These notes should be cut out and filed for reference. They will often save you hours of testing. Write down your own special observations too, because you cannot keep them in your head indefinitely.

Instruments Which Aid in Locating Intermittent Defects in a Receiver

Up to this point in the lesson, all recommendations for testing for intermittent conditions has been done from the view point of using common types of test equipment. This was done to acquaint the student with methods of analyzing and testing for intermittent conditions without the aid of elaborate test equipment. Although some of the foregoing tests may seem tedious, they are sound in principle and will allow an accurate test procedure for checking intermittent receivers. However, there are several newly designed test instruments which will aid considerably in locating intermittent defects as well as other receiver defects. A more thorough discussion of these instruments will be given in a later lesson. Their use in locating intermittent defects only will be considered in this lesson. The name *signal tracer* is usually given to this type of equipment. There are several inexpensive signal tracers on the market some of which are not too well adapted to intermittent testing. The more elaborate type which is best suited for intermittent receiver testing is the type which can make several measurements upon the receiver at the same time. As the intermittent defect may be in any stage of the receiver from the audio output up to and including the antenna circuit, if this equipment is going to aid to any extent it must be so designed to measure signal voltage in all the stages of the receiver. This is just what a good signal tracer can do. The voltage that will affect the signal in the RF, and IF stage, of course, is RF voltage and these voltages especially in the antenna circuit are very low. Thus, a highly sensitive AC voltmeter will have to be used. Not only must these RF voltmeters be sensitive but they should be so constructed that they will not affect the circuit to which they are connected. For instance, if the voltmeter adds considerable capacity to a circuit such as the oscillator the frequency of the oscillator will be changed. Thus an accurate reading cannot be taken with the meter.

The meter which is to measure the RF, oscillator and IF voltages requires a special design. Most of the commercial models consists of a tuned radio frequency circuit with a sensitive indicating device to indicate resonance. The indicating device may be a sensitive moving coil type meter or an electric eye tube. As the circuits are tuned to resonance for an indication, they must be retuned each time the frequency to be measured is changed.

However, this is no real drawback as far as testing for an intermittent defect is concerned for the test frequency is usually a fixed frequency. As these testers are of the TRF type and are made highly sensitive they can detect very weak signals, making it possible to measure the small RF voltages in the antenna and RF sections of the receiver.

There are usually two TRF type meters in a manufactured signal tracer, one being very sensitive and capable of measuring voltages of a few microvolts whereas the other is not quite as sensitive.

The sensitive meter is used to measure voltages in the RF and antenna circuit and the other is used to measure voltages in the IF amplifier and the local oscillator.

There is an audio frequency voltmeter for measuring audio voltages throughout the audio amplifier of the receiver and a vacuum tube DC meter is also provided in the better type instruments. Some of these manufactured signal tracers incorporate a wattmeter for measuring the power drawn by the receiver. More about these instruments will be given in a later lesson.

Now how can such an instrument be used to help locate an intermittently operating receiver? A method of using a signal tracer for finding receiver defects which causes intermittent operation will be discussed so that the student can become familiar with the operation and also see the usefulness of such an instrument. The type of signal tracer used in this discussion will be one of the standard types having two TRF type vacuum tube voltmeters, a vacuum tube audio voltmeter and a vacuum tube DC voltmeter.

As all of these meters are separate units having no common connection and each unit independent of the others, it is possible to measure voltages at four different positions in the receiver at the same time.

For the purpose of demonstrating how to use this signal tracing equipment a typical broadcast receiver will be used. The test procedure outlined and discussed will be typical and can be used for any other receiver. The schematic diagram, shown in Fig. 21 is that of a typical modern receiver.

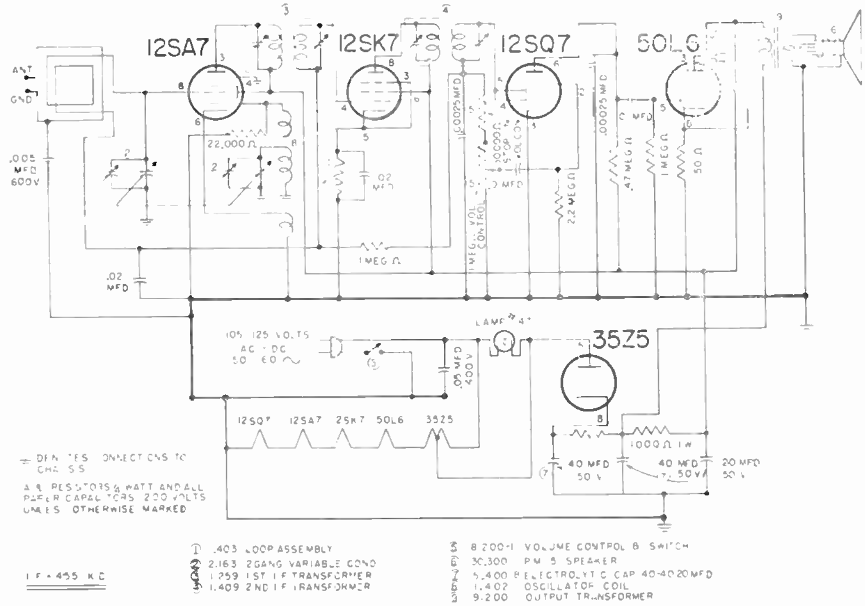


FIG. 21

A majority of the newer designed receivers are of this type. This receiver is an AC-DC Garod Model 5A2.

To make the discussion practical so that the student will become familiar with locating any type receiver failure that can cause intermittent reception certain conditions will be assumed which are typical of intermittent receiver failures and then by a very thorough procedure each symptom of receiver failure will be traced to one particular stage. In this way a thorough test procedure can be devised which will allow for the quickest and most effective way of locating intermittent receiver defects.

Figure 22 shows a block diagram of the receiver of Fig. 21. The separate units of the receiver are indicated in block form. As you can see from the diagram the receiver may be divided into six separate units which are essential to the operation of this receiver. If one of these units becomes defective. the receiver will either be completely or partially inoperative and if the defect is intermittent the operation of the receiver will be intermittent. Now by the use of signal tracing equipment the stage in which the defect exists can soon be located and with the aid of a localized test upon the circuit in question, the actual defect can be located. After the stage in which the defect is located is identified the time required to locate the actual defect is usually very short. Therefore. if a quick method of locating the faulty stage can be devised, the time it takes to service a receiver is shortened considerably.

In using the signal tracing equipment for locating an intermittent condition there is a definite procedure to follow which will allow for the quickest method of locating the faulty stage. This procedure may vary some from one receiver to the next, but the procedure which will isolate the defect to one or two stages with the first measurement is a time saver. Referring to Fig. 21 if the test equipment is connected to the receiver such that the operation of the most number of circuits can be measured the test will no doubt prove most advantageous.

To begin the test of the receiver shown in Fig. 21 connect the sensitive TRF voltmeter to the grid of the 12SA7 tube. This will indicate if the antenna circuit is operating. Connect the second less sensitive TRF voltmeter to the plate circuit of the 12SK7 tube tuned to the intermediate frequency of the receiver. This will allow a measurement of the operation of the 12SK7 IF amplifier and also the operation of the receiver oscillator as there will be no IF signal voltage if the oscillator doesn't work. The audio voltmeter is connected to the plate circuit of the triode section of the 12SQ7, thus allowing a check of the second detector and first audio tube. The speaker of the receiver itself will indicate any failure in the output stage. Thus, no voltage measurement is necessary at that point until a closer check is needed if all the other stages prove normal. The fourth meter which is the DC vacuum tube voltmeter type should be connected to the common B + lead at some convenient point.

Because the receiver under test is intermittent in operation, it may be necessary to stimulate this action by subjecting the receiver to various conditions such as jar, vibration, heat and any other condition which may cause the receiver to cut off so that measurement can be made while the receiver is inoperative. As this type of defect is critical in operation, any changes internally or externally may cause the receiver to click on or off. Moving the test leads from one point of the receiver to the next or turning on a switch in the shop may cause this action to occur and as the only time you can measure any abnormal voltage on the receiver is when the defect occurs, it is necessary that the receiver cut off to get a check on which stage is causing the defect. To avoid unnecessary changes due to the movement of the receiver caused by loose connections of the test equipment when testing for an intermittent condition, it will prove helpful to solder the test leads to the different positions in the receiver. Then the receiver can be moved about without interfering with connections to the test equipment, thus allowing you to mechanically jar or vibrate the receiver to hasten the intermittent defect to occur without disengaging the test equipment.

After the leads of the test equipment are securely fastened to the receiver, a test signal with the same intensity as that of a normal signal re-

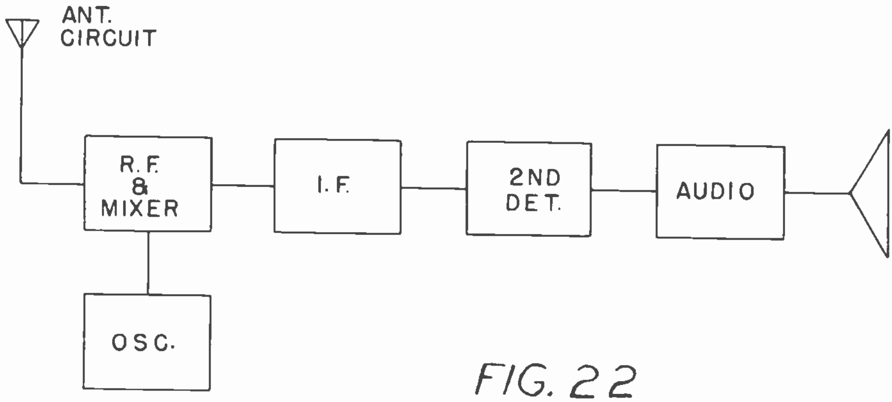


FIG. 22

ceived from a station should be applied to the antenna circuit of the receiver. The frequency of the signal depends somewhat upon the receiver under test but usually a frequency in the middle range of the broadcast band is used unless the intermittent operation is critical to frequency. Then a frequency should be used which will allow the intermittent action to occur. When the signal is applied to the receiver adjust each meter to a convenient range so that the voltage which the meter is to measure can easily be read on the meter scale.

After allowing time for the signal generator and the test equipment to warm up. then turn on the receiver and adjust the frequency of the receiver to the frequency for the stage involved. The first TRF meter which is connected to the grid of the 12SA7 should be tuned to the frequency of the signal generator and the other to the IF of the receiver. Now observe carefully the readings upon all meters. If the signal is coming through normal. the receiver is working as it should. It may be a good idea to record the readings on all meters while the receiver is operating normally. This will allow a check on the voltages when the receiver cuts out or fades.

As already stated. it is impossible to make any measurement that will lead you to the defective stage until the receiver cuts out. Therefore. you must wait for this to happen. Many times the cut off time can be reduced by jarring or in some other way causing the receiver to cut off before it ordinarily would. thus reducing the waiting time.

When the receiver cuts off observe all of the meters in the circuit for an increase or a decrease in value. The readings upon these meters are clues to the stage causing the intermittent failure.

First assume that all of the meters read normal when the receiver cuts off. This immediately indicates the trouble is not due to the RF, IF, second detector. or first audio tube. The search is now limited to the output audio stage and the speaker itself. If this is the case. place the audio signal voltmeter across the voice coil of the speaker (Fig. 21) and the DC voltmeter on the plate of the 50L6. Moving these leads may cause the receiver to cut back in and operate normally once again. Thus it will be necessary to wait until it cuts out once more before the voltage in this stage can be measured while the receiver is inoperative. Again if the test leads are soldered in place. the receiver can be given a mechanical jar or whatever is necessary to cause the receiver to cut off. Don't jar it so hard that you cause other defects to occur. If upon cutting off you find the plate voltage abnormal. then the trouble can be traced to the supply voltage or to the rectifier tube. If the defect is due to a short or an open in the line. the pilot light of this receiver will usually indicate the change. If the light gets brighter there is an overload. If it becomes dimmer an open circuit. When the plate voltage reads normal but there is no signal voltage across the voice coil of the speaker. the defect must be in the output transformer or a shorted voice coil. A quick continuity test with a good ohmmeter of this circuit should disclose the defect.

Now assume that the RF voltage upon the grid of the 12SA7 and the DC plate voltage are normal but the IF voltage and the AF voltages as indicated by the meter reduce to zero when the receiver cuts out. This indicates a defect in the mixer. oscillator or IF stages. To isolate the trouble move the TRF meter from the grid of the 12SA7 to the plate of the same tube and tune it to the IF frequency of the receiver and couple the other TRF meter to the oscillator of the receiver. The coupling to the oscillator should be very light to avoid frequency changes in the oscillator. The coupling can usually be done by just wrapping a few turns of the meter test lead around the oscillator grid lead. The coupling should, of course, be tight enough that a voltage is indicated upon the meter scale. If a voltage is indicated on the meter connected to the oscillator but none at the plate of the 12SA7 it indicates a defect within the tube itself or the tube socket. If no voltage is indicated by either meter the oscillator is no doubt at fault and a closer test of the oscillator stage including the 12SQ7 should be made. Both a visual and a continuity test should prove useful in this respect.

Assuming that there is voltage on all meters except the audio meter in the plate circuit of the first audio, this indicates a defect in the IF transformer, second detector, volume control circuit or the first audio stage itself.

To isolate the defect to a more definite circuit as in Fig. 21 move the test lead from the first audio stage and place it across the volume control and move the TRF meter from the plate circuit of the 12SK7 to the diode plates of the 12SQ7, tuned to the IF of the receiver. An indication on this meter but no voltage across the volume control indicates a faulty detector circuit. This could be caused by the tube or any one of the components within this circuit. An intermittent short of the .00025 mfd., RF by-pass condenser in this circuit or a faulty volume control could cause this defect.

This general procedure should be sufficient to exemplify the use of a signal tracer for intermittent conditions. The procedure is simple to follow and in most cases will reduce the time necessary to locate an intermittent defect within a receiver. However, it should be pointed out at this time that the intermittently operated receiver is in minority and unless the serviceman is set up to service a considerable number of receivers per day, it may not pay to purchase this type of equipment. As it has been pointed out, it is possible to locate an intermittent defect without signal tracing equipment.

This lesson doesn't mean to imply that the signal tracing equipment must be limited to intermittently operating receivers. As you will learn in a later lesson, this equipment can be used for numerous tests.

To sum up, remember that patience and alertness are the important factors in success on intermittent receivers. If you apply the ideas given here and take your time, you can solve any intermittent problem.

Never forget to make a final check by keeping the receiver in operation for three or four hours. You don't want a *comeback* on an intermittent job if you can possibly prevent it.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

No. 1 Are there any direct conclusive tests for all types of intermittent reception?

No. 2 Would you suspect a circuit defect due to corrosion to be in a confined or covered place or in an exposed place?

No. 3 Is it possible for by-pass or coupling condensers to show intermittent tendencies only at certain critical voltages?

No. 4 If intermittent reception is only evident at one point on the receiver dial, where would the trouble most likely be?

No. 5 If you suspected that a coupling condenser was faulty due to excessive and variable leakage current, could this be determined definitely by the average test?

No. 6 What is the basic defect caused by temperature changes in a receiver?

No. 7 Is an overload test of a radio part a cure of the defect?

No. 8 What usually signifies that a volume control is the cause of intermittent reception?

No. 9 Lacking a new volume control, what may be used in its place for a check on the original control?

No. 10 Is any part of the receiver entirely immune from the possibility of developing intermittent defects?

HOW TO CORRECT FOR HUM IN RECEIVERS AND AMPLIFIERS

LESSON NO. TV-18

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K3552M

HOW TO CORRECT FOR HUM IN RECEIVERS AND AMPLIFIERS

Lesson No. TV-18

As the sources of hum in radio receivers and amplifiers are many and varied, the first step in this work is to find a method of localizing the source of hum. The most natural step in this procedure is to classify the various types of hum and identify the type of hum in the receiver on which there is work to be done.

Much useless circuit analysis and testing can be avoided by making a few simple observations. While there is essentially only one broad classification of *hum*, it may occur under various conditions, and these conditions are extremely important. It is true that more than one condition of hum can exist at once but it is also possible to observe this fact in the operation of the receiver. Thus by carefully defining types of hum, additional time and testing can be avoided.

All of the hum of any importance comes either directly or indirectly from the AC line. It may get into the speaker from any filament circuit and be fed to any tube element, from the plate supply to any tube element or it may get directly into the speaker from the power supply. The following simple observations are important in localizing hum.

1. Constant hum: Volume level, tuning, or antenna and ground connection have no effect on it. It remains at a fixed intensity anywhere from an amount which is just noticeable to a very powerful hum. A signal tuned in with it may make the hum seem small by comparison.

2. Tunable hum proportional to signal: This type of hum will be loud only while a signal is being received, and as the signal is tuned out, the hum will vanish or reduce to an unobjectionable minimum. Frequently, it may still be of objectionable intensity even with no signal but is always noticeably louder with any signal that is tuned in. It is either exactly or apparently proportional to the signal strength at the speaker.

3. Tunable hum inverse to signal: This is a type of hum which acts in a manner just opposite to the above type. When a station is tuned in, the hum will be lower than when not tuned in. The signal and hum are therefore, inverse, or when one is higher in intensity, the other is low.

4. Hum varies with tuning band: Usually identified in the broadcast band, this type of hum will more often be loud at high frequencies around 1400 to 1600 KC, and low or negligible at the lower frequencies, around 550 to 600 KC. This classification includes any variation in the tuning band, as distinguished from any relation with a signal.

5. Tuning range hum with critical point in band: This may be described as a hum which abruptly stops at one particular place in the tuning range such, as for example, 1200 KC, or at say, 800 KC. It is usually accompanied by equally abrupt changes in receiving sensitivity, and the receiver is very sensitive to body capacity.

6. Intermittent hum: This hum either stops and starts spontaneously or changes its intensity or its *tone*

character spontaneously. It may or may not have characteristics of other hum types as mentioned.

7. Modulation hum: This type of hum is similar in action to tunable hum.

All hum will have one or more of the characteristics as mentioned, and therefore, can be identified as to type through simple observation. For example, by tuning in a station a constant hum can easily be distinguished from a tunable hum. There is, of course, no point in making any hum analysis until the receiver is capable of receiving a signal, because the comparative strength of the signal and hum is important in the final operation of the receiver.

A detailed analysis of each type of hum will now be considered, showing how it is localized and eliminated, or at least, made negligible.

Constant Hum

This is the most easily found and correct type of hum for a number of reasons. In the first place, since the volume level and the tuning or antenna or ground connections do not affect it, it is quite obvious that its origin is in the AF or power supply system. Any volume control, more particularly of the audio type, acts as a *bottle-neck* for signals. If hum were present in circuits preceding the volume control, the hum intensity would be affected by the volume level. If it were modulated on some RF carrier, it would be affected by tuning of the receiver. Analyzing each observation, the conclusion that such hum must originate in the AC or power supply section of the receiver is reached.

Although of very considerable help, this is still quite general information for actual service work. Suppose, for example, that your observations have indicated that hum must originate in the AF amplifier or power supply system such as the one shown in Fig. 1. There are still quite a number of hum sources even in this much of the circuit. This circuit is typical, and the same tests may be applied to other similar circuits.

The next logical thing to do in an effort to localize the hum source still more definitely, is to d e t e r m i n e whether the hum is due to the power supply or to the AF amplifier. First short the 6K6 plate to its screen with a screw driver or other tool with an insulated handle, or with a wire, being careful to guard against shock. This will absolutely prevent any signal or hum from getting from the AF amplifier to the speaker. Therefore, if the hum discontinues, it may be certain that its origin is in the AF amplifier. On the other hand, if the hum remains to an appreciable extent, it may be assumed for certain that its source is in the power supply. An AC voltage drop at ripple frequency may in this case be impressed across the field coil and it will supply the voice coil by transformer action within the speaker. The voice coil is a closed circuit and carries current according to the voltage induced in it. Although this action would be very unusual for speakers having a hum bucking coil such as L1 in Fig. 1, it would be possible if the input filter condenser C1 of the power supply were open or had excessive leakage. The effect would be very much reduced if the output filter condenser C2 were open.

It is not practical to attempt to measure the hum or ripple voltage of a power supply, but it is well to be able to make this hum audible by some means, so that its relative value may be ascertained. By far the simplest way of doing this is to use the circuit shown in Fig. 2. This is simply a pair of headphones with a condenser for blocking out DC. Of course, if you have an audio amplifier available, it may be used in place of the circuit in Fig. 2. A suitable amplifier for this purpose is shown in Fig. 3.

The AF amplifier section of any available radio receiver as well as any phonograph or AF power amplifier unit may be used as a hum tracer by making a very few wiring changes. Determine the point of greatest AF sensitivity in the amplifier and connect the .01 mfd. blocking condenser to this place in the circuit. In modern superheterodyne circuits, the .01 mfd. condenser would be connected to the variable arm terminal of the volume control or to the control grid terminal of the first AF amplifier tube, depending upon the design of the second detector tube circuit.

Many older models of receivers, particularly the TRF types, will require that the detector tube be used as the first stage of AF amplification in order to provide sufficient AF gain for sensitive hum tracing. When using receivers of this type, check the control grid bias voltage of the detector tube after the .01 mfd. condenser and test lead are connected, in order to be certain the tube is operating as an AF

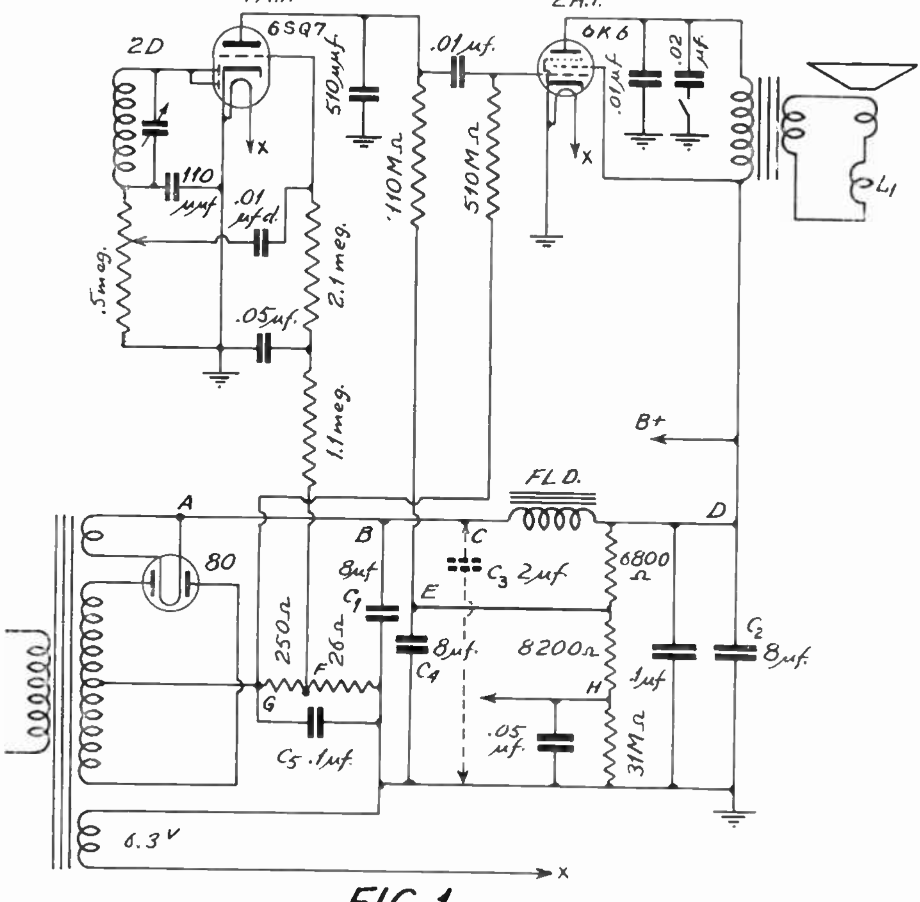


FIG. 1

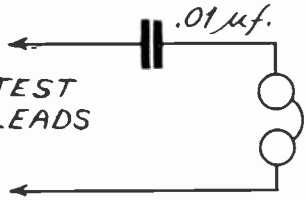


FIG. 2

amplifier. It may be necessary to change the circuit and bias voltage to prevent distortion of the hum signal. Sensitive AF amplifiers may require that the test lead be shielded, with the shield grounded, to prevent AF feedback and oscillation.

Connect one test lead of Fig. 2 at A of Fig. 1 and connect the other test lead to ground. Considerable hum here is normal and should be heard. At B, the positive terminal of the input filter condenser C1, the hum level will be the same and also at C— the field coil input.

In this way it is not always possible to determine if the input filter condenser is open or in good order. However, a comparative test at D and ground should now be made to determine the reduction in hum which has been produced by the filter. Some hum will invariably be heard at D, because no filter produces pure DC.

If the hum is much louder when testing at C than at D, it is an indication that a definite filter action is taking place. On the other hand, if there is little difference between these two connections with respect to hum, one or both of the filter condensers are open or otherwise defective.

The fastest way to check for relative hum is by placing a 2 mfd. paper type test condenser across the input condenser while the hum test is being made at the filter input or from B to ground in Fig. 1. If the addition of this condenser very definitely decreases the hum it is very probable that the regular filter condenser is defective. On the other hand, if there is just a noticeable hum decrease when the condenser is added, it is a sure indication that the condenser is operating properly. Exactly the same applies to the output circuit from D to ground in Fig. 1. Little reduction in hum means that the filter condenser C2 is performing its function. Another way to tell if condenser C1 is doing its job properly is to connect a voltmeter (0-300 to 0-1000 volts) from D to ground. If, on adding C3 (2 mfd.) across C1, the output voltage increases from 15 to 25% or more it is a definite indication that C1 is defective or open. If this output voltage does not noticeably increase, or if its increase is less than 5%, C1 may be assumed to be in good condition.

If condensers C_1 or C_2 are open or dried out, in case they are of the electrolytic type, the addition of capacity C_3 will reduce the hum heard either in the speaker of the unit being tested or by means of the headphones or test amplifier being used and also increase the voltage between D and ground.

However, if condensers C_1 or C_2 have internal corrosion and leakage, which quite often occurs in electrolytic type condensers used over a long period of time, the addition of C_3 will have little appreciable effect. Having localized the source of hum in the rectifier and filter, condensers C_1 and C_2 should be disconnected from the circuit and the increase of hum noted. Then reconnect condenser C_1 in the circuit and note the reduction in hum due to its filtering action. Make this same test with C_2 and note the change in degree of hum. The effectiveness of these filter condensers and hence their general condition may be easily determined in this way. Carefully observe the external appearance of any electrolytic condenser in the circuit under test. Any indication of leakage, corrosion, bulging or swelling of the condenser case or other abnormal condition is cause for suspicion. As a general rule, replace electrolytic condensers which show any signs of being defective, either by testing or by observation, both from a standpoint of customer satisfaction and the fact that a shorted electrolytic condenser may result in damage far more expensive to repair than the relatively low cost of the condenser replacement.

There is no convenient and practical way to measure the allowable AC ripple voltage of the power supply for purposes of hum analysis. In many circuit designs the ripple voltage is quite high and yet there is practically no hum reproduced. Hum-free operation is as much dependent on the circuit design as on the filtering efficiency of the power system. Hum analysis from the power supply standpoint is, therefore, limited to the recommendations as given. The only concern with the power supply is to see that the filter is normal—not that it produces no hum voltage because this cannot be expected.

Next test at E of Fig. 1 to ground with the headphone test circuit of Fig. 2. The hum here should be almost zero. If its level seems as much as at D, attention should be given to condenser C4. A defect in the form of an open of this condenser would cause serious hum. A considerable portion of the hum voltage at E would be impressed directly on the 6K6 control grid through the 110,000 ohm plate load resistor of the 6SQ7 type tube and the .01 mfd. coupling condenser. Point H in Fig. 1 is the screen grid supply and usually the oscillator plate supply as well in superheterodyne type receivers. However, for the most part, screen grids and other high voltage elements used other than for plate supply are taken from point D for the power supply, using a series type voltage divider. Thus, the shunt resistor (31,000 ohms) may or may not be used. This may or may not be regarded as a part of the power supply and will rarely, if ever, enter into the cause of hum in the audio system. On the other hand, points such as F and G in Fig. 1 are important from the hum viewpoint. The hum at point F to ground by the same test as before should be zero or barely audible. At G to ground, a trace of ripple voltage may be detected. An open of condenser (C5) would make this hum more noticeable. Any ripple voltage across G to ground other than a barely audible amount on this test must not be permitted. See that the parts and connections are in good shape so this can not occur. A numerical example will show the importance of the 6SQ7 grid filter. For any service work, it is well to get as good an idea of the characteristics of the AF amplifier as possible. In round numbers, the gain of this amplifier in Fig. 1 is about 840 from the 6SQ7 grid to the 6K6 plate —that is, .1 volt on the 6SQ7 grid will produce 84 volts at the 6K6 plate. This is almost exactly one-third of the maximum output of the 6K6 tube used as in Fig. 1.

Now, if there is a ripple voltage of 5 volts at point D, there will be a ripple voltage of about .025 volt or 25 millivolts at point F with respect to

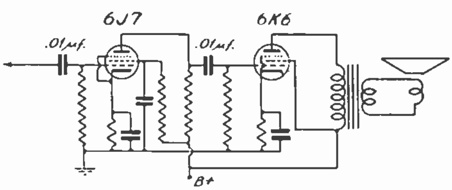


FIG. 3

ground. In other words, there will be about a 25 millivolt AC voltage drop across the 26 ohm resistor connecting F to ground. If there were no grid filter as shown here consisting of the 1.1 megohm resistor and .05 mfd. condenser, this 25 millivolts would be applied to the grid through the 2.1 megohm grid resistor. This would produce a hum signal voltage at the 6K6 plate of approximately .025 × 840 or 21 volts. An output audio power of about 45 milliwatts of hum would be produced. It would be noticed and would interfere with reception always, except when the tube was carrying its maximum power of 3 watts, due to an ordinary signal.

The importance of the grid filter is thus made evident. If the .05 mfd. grid filter condenser was open the hum voltage value as described would result. If the rectifier tube emission is unbalanced—that is, if one plate draws very much more current than the other, the input filter voltage will be less regular and the filter actions will be less complete.

To complete the analysis of constant hum, it is important to consider some of the details in power supply filter designs as it is the lack of a proper filter which usually causes a constant hum to exist.

Most receiver filter systems use a condenser type input filter. A typical power supply and filter is shown in Fig. 4. This circuit is a full-wave rectifier circuit. Thus a 120 cycle pulse is fed to the filter network consisting of C, L, and C1. Condenser C materially reduces the hum or ripple voltage. The amount it reduces the hum depends upon the voltage across it, the load impedance after it, and the current drawn by the receiver. The load impedance RL is equal to the voltage across the condenser divided by the current drawn by the circuit:

$$\left(R_L = \frac{E}{I} \right)$$

The mathematical relationship between the ripple voltage and the available DC voltage is expressed in the following equation:

$$\frac{E_R}{E_{DC}} = \frac{\sqrt{2}}{\omega RC}$$

Where E_R is the ripple voltage and E_{DC} is the available DC voltage across the condenser. ω is equal to $2\pi f$, where f is the frequency of the pulse voltage. RL is the load resistance and is calculated from the preceding equation $RL = \frac{E}{I}$ and C is the capacity of the condenser. As $\frac{ER}{EDC}$ is the percentage of ripple in the voltage across C, plot-

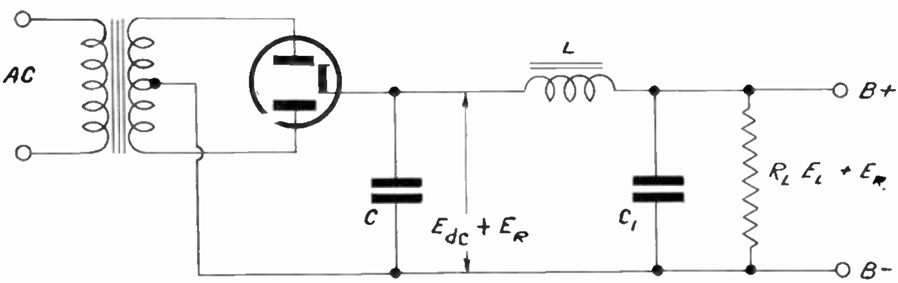


FIG. 4

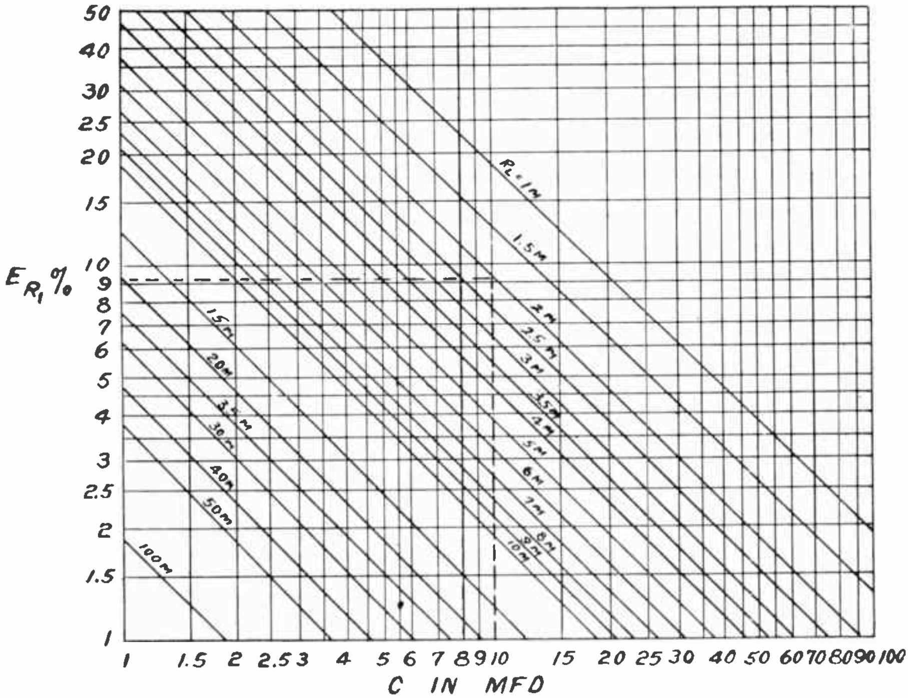


FIG. 5

ting the preceding equation in terms of the percent ripple against the capacity of the condenser and assuming a certain load resistance RL, a family of curves can be made which will prove useful in determining the ripple voltage across C at any given frequency.

As these curves are a function of the frequency applied to the condensers, this set of curves as indicated on the graph of Fig. 5 is plotted for 60 cycles—60 cycles being the most common power line frequency. However, these curves can be used for other frequencies by multiplying the horizontal capacitance scale by the proper constant—for 25 cycles multiply by 2.4; for 40 cycles multiply by 1.5 and for 50 cycles multiply by 1.2. To give an example of how this can be done, assume the frequency is 50 cycles instead of 60 cycles, then each capacitance value on the horizontal scale should be multiplied by 1.2. The 1 mfd. value would be 1.2 instead of 1 and the 1.5 value would be 1.2 × 1.5 or 1.8, etc. When a half wave rectifier is used, the capacitance is multiplied by 2.

The filter consists not only of C but L and C1 as well. The ripple voltage across C can be found in terms of the DC voltage from the graph of Fig. 5. This gives the percent ripple applied to the inductance L of the remainder of the filter. The graph of Fig. 6 is plotted in terms of the percent output ripple voltage and the product of the inductance of the choke in henries times the capacity of the condenser C1 in mfds.

The curves of Fig. 6 like those of Fig. 5 are dependent upon the fre-

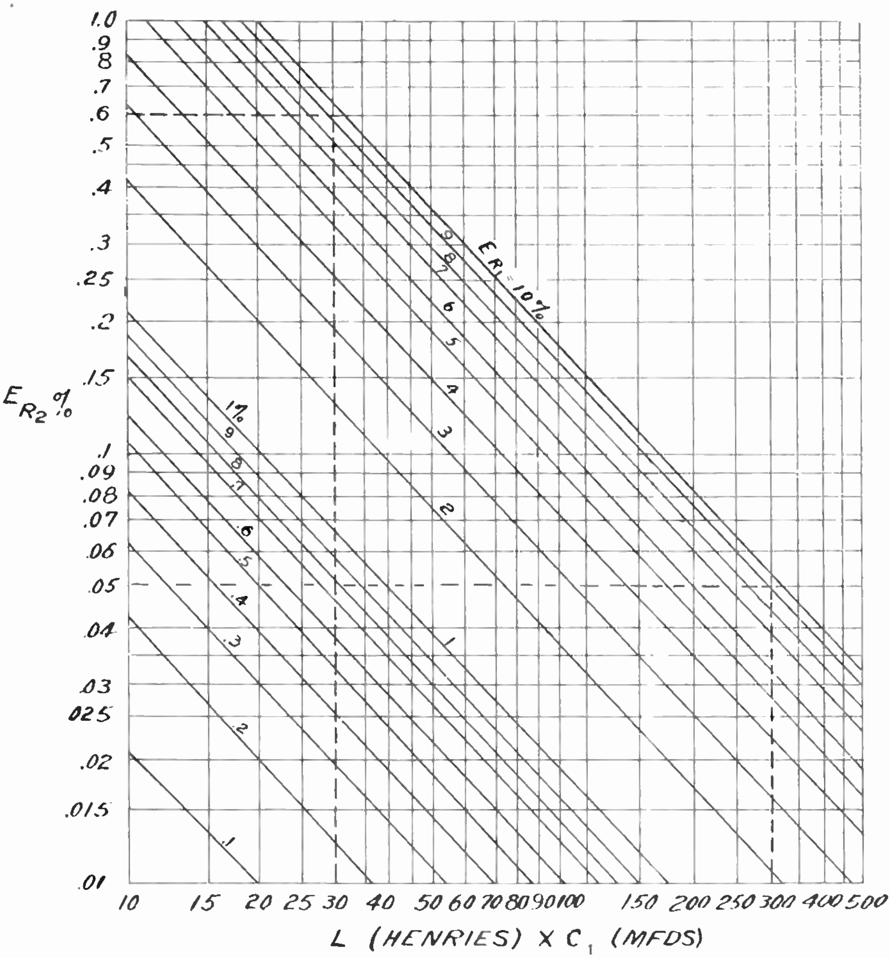


FIG. 6

quency but in a different way. The curves shown on the graph are plotted for a 60 cycle power line from the equation:

$$\frac{E_R}{E_{R1}} = \frac{1}{\omega^2 LC - 1}.$$

This equation is of special character and for every frequency a new set of curves will have to be plotted. Thus, there is no multiplying factor for these curves as there is for the preceding curves, but by the proper use of the equation of the curves, they may be plotted for any frequency other than 60 cycles if it becomes necessary to do so.

With the two curves of Figs. 5 and 6 it is possible to determine the value of the ripple voltage to expect from a given filter. How this is done is simple. The load resistance RL is calculated from the circuit by applying Ohm's law. After the load resistance or impedance across the condenser is found, then from the graph of (Fig. 5) the percent ripple voltage across C1 can be found. Then by applying the percent of ripple as found across C1 from the graph of Fig. 5 the value of the output ripple voltage can be found from the graph of Fig. 6.

A typical problem here will illustrate the usefulness of these graphs. Assume that a power supply and filter system similar to the one shown in Fig. 4 is found to have 200 volts DC across C and that there is a load across the output of the filter which causes 100 milliamperes of current to flow. Now if C is 10 mfd. what is the percent ripple across C? As there is a voltage of 200 volts across C and the current drain is 100 milliamperes, RL must equal $\frac{200}{.100}$ or 2000 ohms. By following the 10 mfd. capacity line of the graph. (Fig. 5) up until it intersects the 2000 ohm line (dotted line on graph) then by use of a straight edge held parallel to the horizontal lines from this point to the vertical scale at the left of the graph. the percent ripple can be read directly from the graph. In this case it will be 9.2%. That is the ripple voltage across C is 9.2% of the DC voltage across C. The ripple voltage across C is 200 × .092 or 18.4 volts which is, of course, far too great for use in a receiver. Thus more filter is necessary.

Now assuming that the choke coil in Fig. 4 is 30 henries and that C1 is also 10 mfd., what will the final output ripple voltage value be? By the use of the graph of Fig. 6 and the results of the preceding problem, this voltage value can be found. The product of L in henries times C1 in mfds. is 300. Follow this vertical line until it reaches E_R 9.2%, (as determined from the preceding problem). Then follow the horizontal line parallel to the other horizontal lines on the graph—from this point, the value of .05% is found on the left vertical scale. This is the percent ripple voltage in the output of the filter. Next observe that .05% of 200 is .1 of a volt which is low enough for most receivers.

Now if the condenser C1 reduces in value from 10 mfd. to 1 mfd. what will the output ripple voltage value be? Returning to the graph of Fig. 6 as L × C for this condition will be equal to 30, following the vertical line marked 30 until it reaches the 9.2% line then following a line parallel to the horizontal line from this point to the left hand scale, the percentage ripple will increase from .05% to .6%, or the ripple voltage has increased from .1 volt to 1.2 volts or an increase of 1.1 volts. This high ripple voltage would, of course, cause an appreciable hum to exist in a receiver. Thus by the use of these graphs it is seen how easy it is to calculate how much a filter condenser can vary in capacity without causing a high value ripple voltage.

These graphs are useful in the case of replacements where an exact replacement part is not available. If a substitute must be made, you can soon determine how much ripple voltage you can expect by replacing the filter condenser with different values.

It is not always necessary to use a combination condenser-choke filter in a power supply. In some instances where cost or space are the determining factors of a power supply, it may prove beneficial to use a resistor in place of the choke. The mathematical expression for the effectiveness of such a filter is given as:

$$\frac{E_{R2}}{E_{R1}} = \frac{1}{\omega CR} \times 100$$

E_{R1} is the input ripple voltage and E_{R2} is the output ripple voltage, C being the capacity of the condenser and R the value of the filter resistor. Fig-

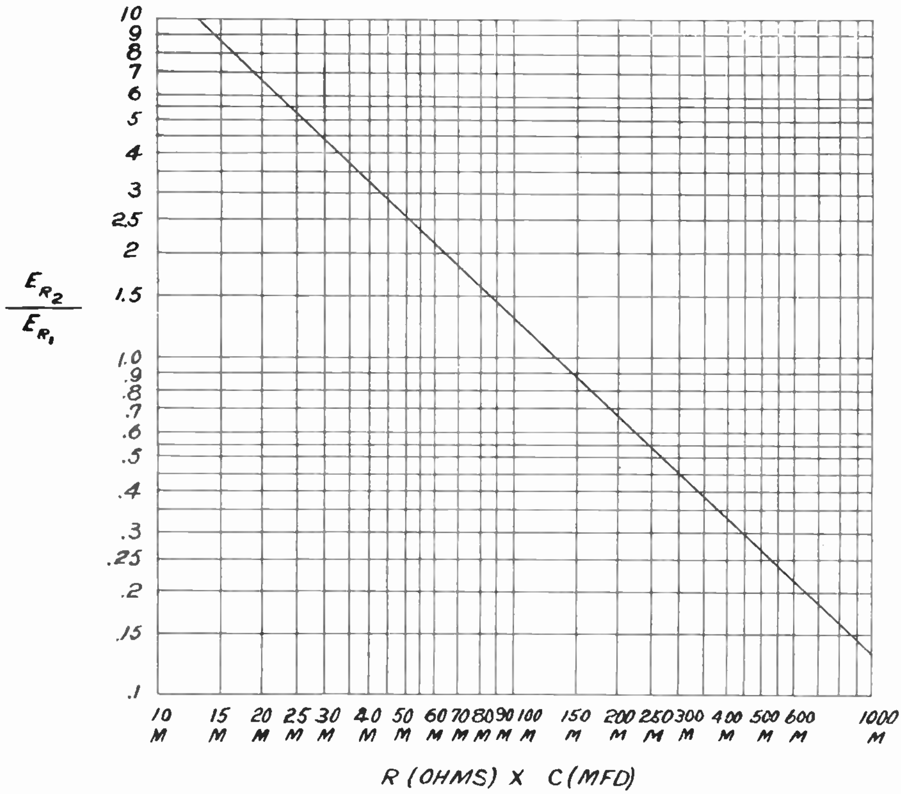


FIG. 7

ure 7 shows a graph of this equation plotted in terms of the percentage ripple voltage against CR of the filter. Here again the frequency applied to the filter enters in as ω is equal to $2\pi f$. The curve shown in Fig. 7 is plotted for a 60 cycle full wave rectified voltage. This curve like the curves in Fig. 5 can be changed to account for any frequency by multiplying the RC values by the same multiplying factors as used for Fig. 5. That is, each RC value, if the curve is used for 50 cycles instead of 60 cycles, should be multiplied by 1.2.

Sources of Hum in the AF System

Starting with the output transformer, it is necessary to take note of two possible sources of hum which can get into it. One way is through direct induction into the core of the transformer from some external magnetic field.

Although this type of hum induction is rare with a receiver as it was originally designed, replacements may have been made, however, and the same precaution as used by the manufactured may not have been followed. To avoid such difficulties, the iron core choke, the audio, and power transformer should be so arranged that the magnetic coupling between them is a minimum. Figure 8 illustrates the correct and incorrect method of arranging these components for minimizing hum. The first two positions with the units arranged one above the other illustrate the incorrect arrangement whereas the last two positions illustrate the correct method of placing these components and also how they may be shielded to prevent magnetic coupling if it is found necessary to do so. As a voltage greater than .1 volt can cause hum, if introduced in a high gain stage, the radiated hum due to magnetic coupling can easily cause hum to exist. Thus when making replacements of transformers and chokes, a careful analysis of the best location for the least magnetic coupling should be chosen. Association of the power transformer with the speaker and speaker field is not likely to cause hum as the speaker magnetic field should result from an almost pure DC which as you know will not induce a hum voltage, and a power transformer of correct design is adequately shielded so that its radiated magnetic field leakage is held to a minimum and therefore, will not induce a voltage into either the output transformer or speaker field winding, especially so in the case of the field winding as it is in the least sensitive and responsive position in the AF amplifier circuit.

The other way that the output transformer is subject to hum is, of course, through its windings. It may be the source of hum in this case, only if in a push-pull circuit half of the winding is open, or, if as in Fig. 1, the 6K6 tube emission has stopped and there is a feeding of energy through the plate by-pass condenser or tone control condenser from the B+ to ground. Only if such condenser were very large, or had considerable leakage, would this be a source of hum. As this would also materially affect the signal, it would probably be located before the hum analysis would be reached. Better designed transformers have an electrostatic shield between primary and secondary to reduce capacitive coupling between the primary and secondary.

Tracing the signal circuit backwards from the speaker, in Fig. 1, the 6K6 type tube comes next. It must be emphasized here that any structural qualities of the tube which tend to produce hum have no importance to the serviceman or technician, because he is unable to remedy this directly. There are, however, a number of hum balancing circuits which are used to take care of tube inequalities and hum

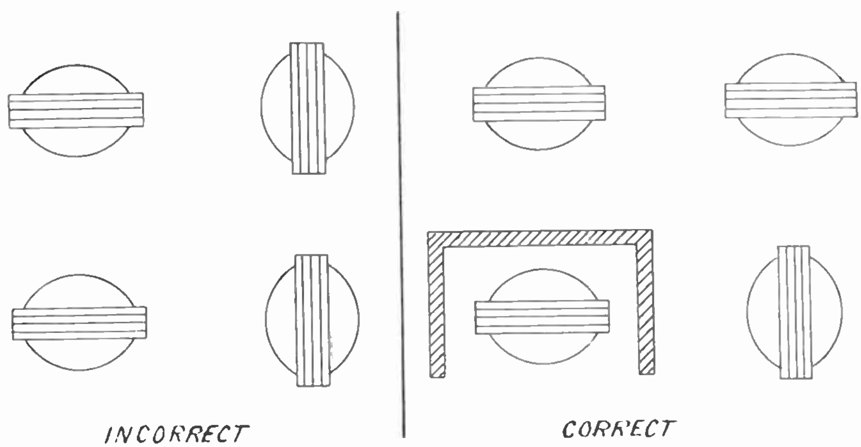


FIG. 8

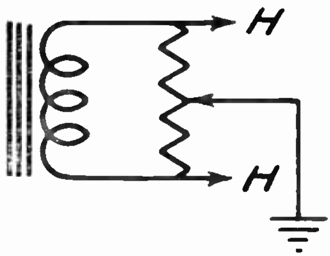


FIG. 9

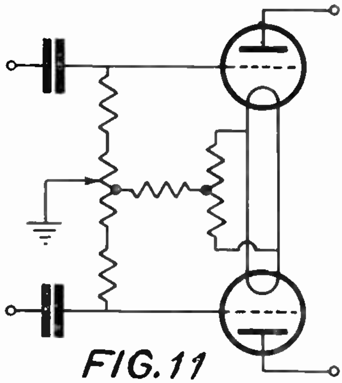


FIG. 11

arising within the tube. For example, the heavy AC filament current is attended by a strong AC magnetic field. It may thus induce voltage into a grid or screen grid lead in the base of the tube or in the wiring to the tube socket. Much of the harm due to this source is eliminated by parallel wiring or twisted wiring, but within the tube structure this is not possible.

Circuits such as those in Figs. 9, 10, 11, 12, and 13, are used to balance out hum arising from the sources just mentioned. By the introduction of a voltage equal and opposite to that of the hum voltage it is possible to eliminate it no matter if its source precedes or follows the hum balancing circuit.

In the circuit of Fig. 9 the output tube filament or filaments may be made to have a slightly greater voltage on one side than the other. This may compensate for a slight ripple in the plate or grid supply voltages of opposite phase. In Fig. 10, the output of two tubes may be equalized with respect to hum by permitting one screen grid to carry more hum than

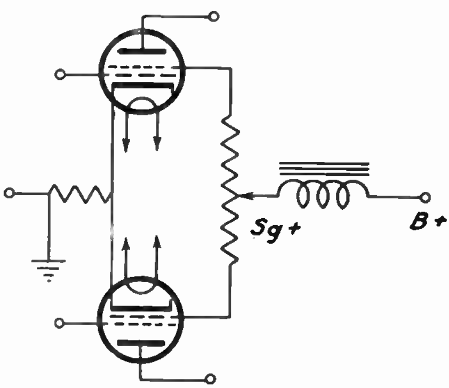


FIG. 10

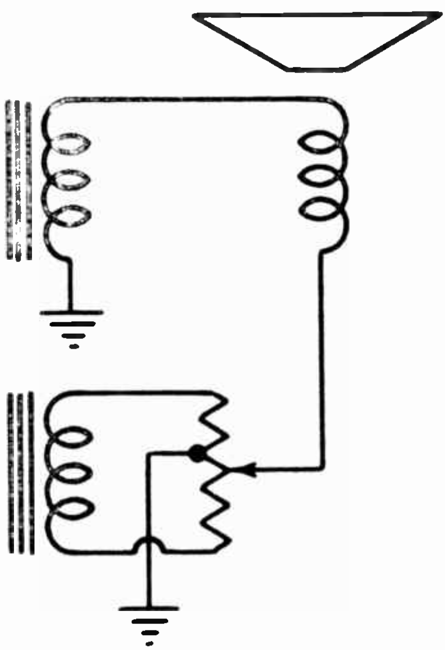


FIG. 12

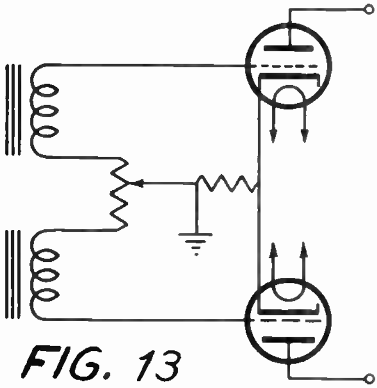


FIG. 13

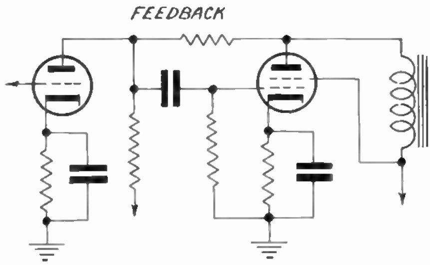


FIG. 15

the other. Circuit Fig. 11 is another adaptation of the idea making one grid carry more hum than the other. In Fig. 12. a hum voltage is forced into the voice coil from a filament winding which is adjusted to be out of phase with the possible hum carried by the signal. The two thus cancel one another. The circuit of Fig. 13 is the transformer counterpart of Fig. 11.

Where there is ample audio power, often negative feed back can be used to reduce hum. Two circuits which can be used for this purpose are shown in Figs. 14 and 15. Using negative or inverse feed back will also improve the audio response of the receiver. As already pointed out a hum voltage can often be fed out of phase to a circuit causing the hum to be cancelled out. Figure 16 shows how hum introduced into the screen grid through condenser C1 can cancel out hum in the plate circuit. This is possible due to the phase relationship between the screen grid voltage and that of the plate as they are 180° out of phase. The hum introduced into the screen grid circuit will tend to cancel out any hum in the plate circuit.

Most circuits due to their construction have a cancelling effect upon hum. In some instances it has been found that upon increasing the filter values in part of a circuit. it has caused the hum to increase. Therefore. in many cases it is important that the replacement of a faulty part should be the exact value as originally used in the circuit.

Often the speaker used with a receiver has a hum bucking coil which aids in reducing hum. If this coil is shorted. open. or the leads of the coil are reversed hum will be the result. Thus, where the speaker has been replaced or tampered with. the polarity of this hum bucking coil should be checked.

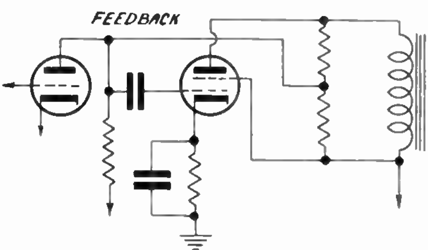


FIG. 14

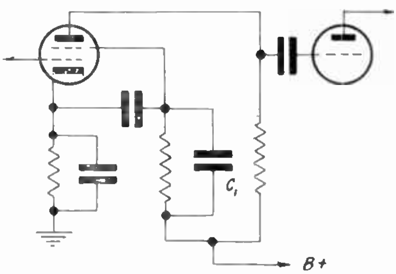


FIG. 16

As most of the modern receivers use a power switch which is connected to the rotating arm of either a tone or volume control, this switch can often cause hum to be introduced into the audio amplifier. This is made possible due to grease and dirt collecting, forming a path for the hum voltage allowing it to reach the volume control element and as this element is directly connected to the audio amplifier, it will be amplified and fed to the receiver speaker producing considerable hum. To check this switch, remove it from the control and notice any change in the hum level. If it is found to be the cause of the hum, clean the grease and dirt from it and the control. If this doesn't cure the hum, it may be necessary to either secure another switch or move the on-off switch to some other convenient point separate from the control.

Another similar cause of hum is dirt or grease between the tube elements at the tube socket. This is especially true of wafer type tube sockets. Cleaning the tube sockets of dirt and grease will often clear up hum in the receiver.

An accumulation of dirt or dust any place in the radio receiver may result in current leakage paths which will cause hum and also a noisy condition. As the average owner of a receiver is apprehensive concerning cleaning his receiver, due to the possibility of resultant damage, it is more usual than not to find the chassis has acquired a considerable deposit of dust and grime. Make it a standard policy and habit to thoroughly clean the radio receiver—preferably with an air hose, using a moderate pressure to prevent damage to delicate parts, such as trimmer and padder condensers.

A somewhat similar condition whereby leakages occur may be due to poor insulation on wires, wire bundles and insulating tubing where the insulation has aged and deteriorated. Wiring near power transformers and resistors which carry high currents is particularly susceptible to having its insulation damaged due to the high degree of heat in these areas. Also, leakages of waxes, tars, and sealing compounds tend to rot insulation due to the corrosive effects of some of these compositions, especially if they have been subjected to heat. Any abnormal leakage path offers possibilities of an increase in hum as well as other objectionable effects such as noise, loss in sensitivity, etc.

A partial short or leakage between the high voltage windings of the power transformer may be a source of hum. This short may not be great enough to cause a burned out transformer but it can cause an unbalance of voltage to the plates of the rectifier tube, which will cause hum, as mentioned before. There may be leakage from the high voltage winding to ground, with a resultant hum. Leakages between the primary winding and other windings or between the high voltage winding and the filament windings may cause hum. Usually the effects of transformer leakages are cumulative and transformer failure soon results.

If the power transformer is not designed with electrostatic shields between windings, especially between the primary and high voltage secondary, grounding of the transformer core may reduce the hum by reducing electrostatic coupling. Loose transformer and choke coil laminations are a source of hum, as well as mechanical vibration which may cause annoying sounds. It may be necessary to carefully wedge a thin piece of wood or insulation between the laminations and the inside core of the winding or to paint the laminations with a non-hardening lacquer or varnish to prevent lamination vibration.

A change in capacity of condensers or a change of reactance values in a tuned type filter can cause considerable hum. Usually a circuit of this type requires a careful balance between capacitive and inductive reactance. If the filter circuit is unbalanced, try varying the capacity or adjust the air gap of the iron core reactance coil until hum is reduced to a minimum. A shorted filter choke coil or one with appreciable leakage is an almost certain source of hum.

Even with a heavy duty iron core filter reactance coil of the brute force type an abnormally heavy current through it will reduce its reactance, due to saturation of the core, so that its filtering effectiveness is reduced and hum results. Check any possibility of excessive high voltage current, due to shorted or leaky condensers, incorrect tube bias voltages, etc.

Any defective tube which has any type of internal short or leakage, is gassy or microphonic is a definite source of hum. This is especially true in the case of defective detector, power amplifier and rectifier tubes. Induction from a rectifier tube, either defective or normal, sometimes occurs when the radio receiver or amplifier is very compact. Shielding of the rectifier tube will usually correct this condition and reduce hum. Mercury vapor, helium and other gassy types of rectifier tubes, such as the 0Z4, 82 and 83 almost invariably produce considerable interference noise and hum, which requires effective shielding and filters in both the low and high voltage circuits. Check all shielding grounds and filters in circuits of this type. Defective 0Z4 type tubes in automobile radio receivers cause considerable hum.

Careful attention should be paid to corroded or poorly soldered connections when tracing for hum, as well as to grounded connections made with rivets, which may loosen. This is especially true with respect to grounds on transformer shields, condenser cases, RF and IF transformer shields and tube shields which are grounded by means of spring clips. Oxides and corrosion form between the spring clips and the tube shields. If one side of the pilot lamp wiring should become grounded, hum quite often results.

Many types of small, inexpensive models of radio receivers were designed with a minimum of filtering capacity. Quite often a small lessening of capacity in this type of receiver, due to normal aging of the condensers, will result in abnormal and annoying hum. The usual remedy in this case is to replace all filter condensers with new ones which have larger capacities than the original units.

Defective speakers are a source of hum under certain conditions. As there is normally a small amount of vibration of the speaker voice coil and diaphragm due to the normal amount of 60 and 120 cycle hum present in the output circuit of the AF amplifier, a small amount of hum is present which is not ordinarily objectionable. However, if there is a condition of cone *break-up* (one portion of the cone becoming flat or distorted), loose cone or cone rim, voice coil leads touching cone, loose voice coil windings, dirt or metal chips between the voice coil and pole piece or frame or other similar defects, the normal small movements of the cone and voice coil due to a small amount of hum will cause a loud rattle, buzz or hum. The remedy, of course, is to repair or replace the defective speaker. Closely associated with this type of hum producing condition are loose speaker grills and grill cloths, loose cabinet parts and cabinet resonance which may accentuate the normal hum so that it is increased to an objectionable amount. The position of the radio receiver in the room is also important. Possibly the accoustics of the room are such that standing waves are created which amplify the small amount of normal hum from the speaker. Try various positions of the radio receiver, paying particular attention to bare floors, resonating alcoves, flat walls, etc.

Improper neutralization of TRF receivers is often a source of hum especially if any amplifier stage is oscillating or on the verge of doing so. A remote cut-off or super-control type of tube in place of a regular type or vice versa may cause hum.

Radio phonograph combinations and assemblies have their own particular sources of hum. These may be a defective phonograph motor or *radio-phonograph* switch; a worn, loose or defective volume or tone control; loose motor field laminations, etc. The motor may be radiating an AC magnetic field which reaches the pickup or tone arm. It may be necessary to ground the tone arm and the frame of the motor or to place an electromagnetic shield between the motor and the turn table or between the motor and the pickup head or arm. All leads from the pickup should be adequately and completely shielded, with the shield securely grounded at both of its ends.

Often hum in an audio stage can be reduced by reducing the filament voltage to one of the tubes in the audio section. This is done by placing a low value resistor in the filament lead of this tube, making sure that the resistor is placed in just the one tube filament circuit.

In addition to those sources mentioned, there are other causes of hum in the first audio stage or stages. It is important to observe that in a stage having a gain of, for example 40, the presence of hum in the grid circuit is just 40 times as important as in the plate circuit. Thus at the beginning of any audio system where the signal is relatively low, the amount of hum is of greater importance—very little can be tolerated at this point. Now refer to Fig. 17 which is typical of the usual audio amplifier. An RMS signal voltage of approximately .22 volt on the 6Q7 grid is sufficient to drive the 6F6 tube to maximum output. If there is a hum voltage of more than .03 volt, it will be not only noticeable but objectionable even at maximum output of the amplifier. At a more normal listening volume level of about 1/10th maximum output power, a hum voltage on the 6Q7 grid of .01 volt would be objectionable. For this reason, the grid lead and its coupling circuit is thoroughly shielded. This much voltage could be induced in the grid circuit from a magnetic field having but .0001 microwatt strength. These figures are merely to show the extreme sensitivity of the grid circuit in this, as in any other circuit, of comparable gain. If this grid circuit shield is not grounded, usually more hum as well as other *electrical noise* will be picked up than if no shield were used. In most cases there is no actual metal cover on the grid wire but the grid wire is brought through the metal tube shield to its top cap. Where this is not mechanically possible, a shield grid wire is used.

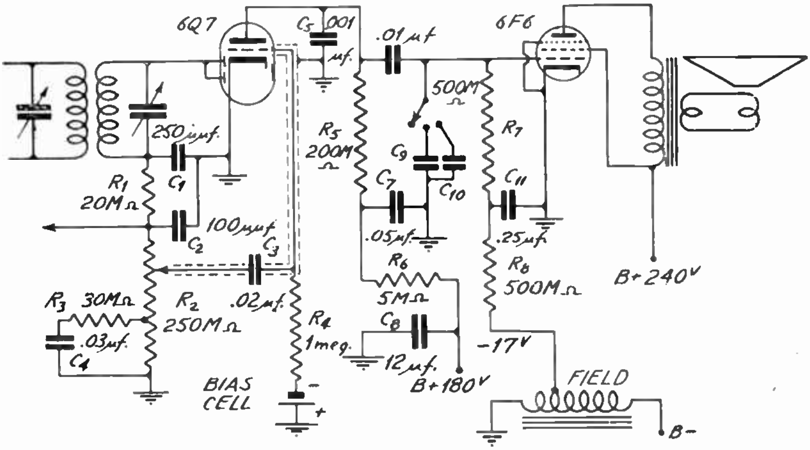


FIG. 17

This brings the discussion to the possibility of hum in a diode detector AF amplifier, such as in Fig. 17. Hum modulation which comes into the IF transformer with the signal will be excluded from the discussion at this point. Other means will be discussed for dealing with sources of hum preceding the second detector.

While resistor R1 and condenser C1 and C2 in Fig. 17 will not produce hum if shorted or open they will, of course, vitally affect the continuity of the signal. The presence of the bass compensation circuit R3-C4 will, of course, accentuate any hum already present because of their frequency discriminating action. This, however, cannot be called a hum source but rather a result of the characteristics of the circuit. If the hum is not present in the signal it will not be present in the volume control.

If the volume control resistance R2 becomes open at any point or increases considerably in value due to excessive wear (more than 50%), hum is almost always the result. If open, there will be considerable distortion of the signal and hum when the movable arm is above the open point, while there will be little or no signal or hum when the movable arm is below the open point or points. If C3 is open, there will be considerable hum due to the increased sensitivity of the grid circuit. In this case, the grid will more easily follow induced voltages from the other tube elements. This, of course, will follow even if the grid circuit shield is intact. An open or large increase in the value of R4 will produce a considerable hum. The grid impedance cannot be increased more than 15 or 25% for this circuit without causing serious hum. If the grid is open, the tube will display considerable body capacity effects and will pick up increasing hum as you bring your hand near it. Although this body capacity effect is not so noticeable when metal tubes are used, the open grid will produce hum nevertheless. Usually an actual oscillation is set up in a tube with an open grid if it has a large plate load. It is called *relaxation oscillation* and frequently follows the 60 or 120 cycle frequency by which it is affected from the power supply.

An open or increase in the value of R5 in Fig. 17 will usually cause severe hum but not nearly as loud as that due to an open grid. Condenser C7 acts as a hum filter, and if it is open the hum will rise noticeably. An open of the .01 mfd. coupling condenser is quite likely to cause hum although not so pronounced as that caused by an open of the 6Q7 grid because much more voltage is required to drive the 6F6 grid than the 6Q7 grid for the same output.

An open of any of the filter condensers, such as C8, will cause hum even though the plate filter remains as shown. This filter cannot compensate for a large voltage ripple at B+. The tone control condenser C9 and C10 here would rarely cause hum even if open. In some few cases they would cause hum if open at their ground ends. On the other hand, the condenser C11 is very important for hum elimination and must be in good order. If it is open, serious hum will result because the bias voltage is taken directly from the field coil in the negative plate supply lead. An open of either R7 or R8 would cause hum, R7 being by far the worst offender.

It should be quite obvious that any intermittent condition in the parts described would cause a corresponding interruption in the hum or signal in this as well as any similar circuit. Any part of a circuit similar to any part of this one would be subject to the same conditions.

Causes of Hum in the High Frequency Circuits

Unfortunately, the RF or IF circuit, in a receiver cannot be analyzed one part at a time, as has been done with the AF amplifier for purpose of studying the cause and cure of hum. In nearly every such circuit, the components are more closely related, and action in one part is more vitally affected by other actions than in the AF system. The RF amplifier must, therefore, be discussed as a unit.

A very widely used RF-IF circuit is shown in Fig. 18. It will serve as a basis for a discussion of hum correction in RF and IF circuits. In order for hum to reach the 6Q7 second detector diode circuit by way of the IF amplifier *it must be modulated onto the intermediate or signal frequency.* This would indicate that if you were to short the antenna to ground or short the plate or grid coils of any of the circuit shown there would be no hum. It also means that any hum in this section of the receiver would be *tunable*—that is, it would be received only with a signal and would vary in volume with the signal.

Such hum when received is rarely ever a direct product of the plate or screen supply ripple voltage but usually a by-product of some other undesirable action within the circuit.

For example, if C1 in Fig. 18 has considerable leakage, the AVC voltage impressed on the 6A8 signal control grid will be reduced and the signal strength will be accordingly increased to the 6K7 grid. With the lowered bias of the 6K7 tube which will also result, the signal being large will cause some amount of demodulation. Under these conditions, any plate or cathode ripple voltage present will be modulated on the signal to some degree. This can also happen in the 6A8 tube, due to the oscillator plate ripple, the cathode ripple, or the plate ripple voltage. In such a case, there would be no exact method for the absolute determination of hum from this source available to the practical serviceman. Any good channel type tester would disclose as much hum on the plates, cathodes, etc., as before, and these could not be ascribed as the direct cause. An open condenser such as C1 would cause hum in an entirely different way although the hum would not be likely to be so great.

Because the hum component cannot traverse the signal circuit by itself an open grid in an RF or IF section will not ordinarily cause hum. In cases where this would unbalance some other circuit, hum may be produced but it is not at all common. In a high gain pentode tube the plate voltage might vary as much as 5 or 10 volts without causing any noticeable increase in hum. The reason for this is that the amplifying power or ability of the tube is substantially the same for any of the plate voltages and the hum would not, therefore, be modulated onto the carrier. The presence of a plate supply ripple is, therefore, no cause of hum in RF circuits. There may be also considerable ripple in the oscillator plate supply without causing hum, because only a small portion of the oscillator energy is used, and in the mixing process, the oscillator and hum components are practically, if not entirely, lost.

Considering the case of condenser C2 of Fig. 18, while it will not directly affect the first detector as far as hum is concerned, it can cause some hum indirectly if either open or shorted. This may be nothing more than making the existing hum more dominant through loss of signal. Here again is an indirect source of hum which cannot be directly analyzed. It is fortunate that each of the things mentioned will cause some other fault in reception, and therefore, may be serviced according to the other fault. Nothing will serve so well to eliminate hum in keeping with the design of the receiver than making sure that it is operating properly otherwise.

Every source of hum in the high frequency sections of the receiver, without exception, will be accompanied by some other fault in reception. This other fault may not be detected as easily as the hum or may not be detected at all in some designs, but is there nevertheless.

Any lack of emission or very low emission of the cathode of the 6A8 tube in Fig. 18 will greatly increase the AC plate resistance of the tube and it will be more sensitive to hum. That is, it will more easily modulate the signal with hum than otherwise. However, before this condition can advance very far, the oscillator will cease oscillation and the signal will be stopped. Similarly if R1 is open, there will be no signal. If it is shorted, the signals will be poor and there may be

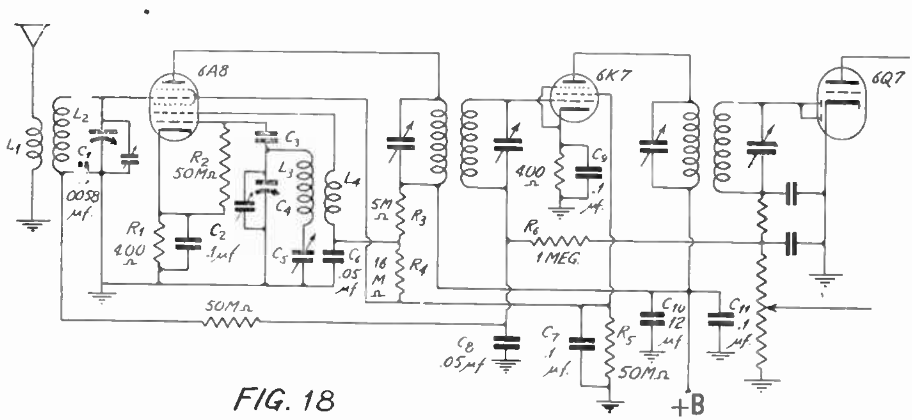


FIG. 18

hum. Such a condition will not always cause hum. Any defects. such as opens or shorts in R2. C3. C4. L3. L4. or C5. will simply stop oscillation and hence stop any signal. The receiver will be dead and any hum present will have its source in the AF system or power supply.

Condenser C-6, however, is important from the hum viewpoint. Some 90% or more of the voltage ripple existing at the screen grid divider between the 5000 and 16,000 ohm resistors is impressed across condenser C6, so you can see that *its presence in the circuit is not intended to filter the ripple voltage out of the circuit.* This same ripple voltage across C6 is applied directly to the oscillator anode and causes corresponding changes in the plate current of the 6A8 and corresponding changes in the oscillator output. This. however, does not constitute a source of hum mixed with the signal because the plate voltage ripple produced by it is of opposite phase, tending to maintain a constant current. It neutralizes the plate ripple from the B + power supply to a great extent.

However. if C6 is open. some regeneration between the oscillator plate is likely to develop causing hum. In addition, this is likely to change the oscillator frequency, causing lack of sensitivity of the circuit. On the other hand, if C6 has leakage or is shorted, it will not contribute to hum but will have other effects on the operation of the circuit.

Condenser C7 is by far the most important unit from the hum viewpoint in the high frequency part of the receiver. For this condenser, as in many others as pointed out, no substantial filtering action of the ripple voltage is intended.

Opening of C7 will cause R3 and R4 to act as a load to both screen grids. The 6K7 screen grid having by far the largest signal on it due to its action as an anode, will feed back this energy to the 6A8 screen grid and regeneration or oscillation will result. In some receiver designs there will only be regeneration, while in others, there will be continuous oscillation at the IF frequency. while in still others, there will be regeneration at some points on the dial and oscillation at others. There will result a loud hum if in the regenerative condition and station heterodynes (squeals) with little hum in the oscillating condition. The hum will be affected by tuning as it will increase toward the high frequencies as a rule. Where it is not affected by tuning it may be easily identified as being in the high frequency part of the receiver, due to the instability of the circuit. If affected by body capacity, it will increase on bringing the hand near the tubes and will in general be accompanied by serious distortion.

Condenser C8 in Fig. 18 is also quite important as it will cause hum either by having leakage, being open or shorted. Any of these troubles will affect the AVC produced and will very likely cause *motorboating* as well as hum or failure of AVC action.

If resistor R5 rises excessively in value (50% or more) there will be hum, while if it is open, the hum will increase. However, more change will be noted in the tuning characteristics than in the hum. If resistor R6 becomes open, the grids of both the 6A8 and 6K7 will be left open and *motorboating* and hum are likely to result.

An open of C10 and C11 will also cause hum. These appear to be in parallel, which indeed they are, but C11 is usually connected very near the plate supply connections of the IF transformers, while C10 may be at a considerable distance from these connections. Thus, there is a possibility of IF feedback or pickup in the connecting lead which is prevented by C11. The two condensers thus have independent functions and hum will result if C10 is open and may result if C11 is open. Shorting or leakage of either of these will simply lower the sensitivity of the receiver.

Practically any tube which has poor emission will cause hum. This is true even for rectifiers and is, of course, worse when the emission to the plates is unequal. It is also more serious for a push-pull stage than for a single stage when the emission of the tubes is not equal.

Filament to cathode leakage is likewise a source of hum and this is made especially troublesome in AC-DC receivers where the AC voltages across these elements are considerably higher in the average tube than in other AC receivers. In addition to the many things mentioned so far, the AC-DC receiver has other factors which are important from the hum viewpoint. Since half-wave rectifiers are essential for this universal application, much larger filter condensers must be used. Moreover, the close association of the filaments and cathodes with relatively high AC voltage on the filaments usually causes more than normal hum. Of course, more hum is expected from these receivers than from the larger AC receiver or the battery receiver.

Outside Sources of Hum

There are many sources of hum which cannot be identified with any factor of design in the receiver or with any defective part in the receiver. Such cases of hum are due to defects of installation of the receiver or conditions beyond the control of the manufacturer.

For example, in many cases, receivers are used without connecting a ground wire lead. Because there is usually enough capacity to ground through the line cord or otherwise, this will often work out all right. However, there are many cases when the receiver will hum abnormally under these conditions. This may be attributed to the instability of the circuit, causing a sort of regeneration because of the chassis not being electrically held at ground potential or at a constant potential. The solution, of course, is to provide a good ground connection.

There are cases where the input circuits are unstable and tend toward regeneration. Such receivers will often break into oscillation when the antenna is removed or when it is too short. This type of circuit will pickup hum from nearby electrical cords, from house wiring or its own line cord, and is subject to body capacity —that is, its hum will increase when your hand is brought near its lead-in. This type of receiver should use a long antenna or, preferably, one of the transmission line type.

Sometimes the capacity coupling to one side of the line cord will be greater than to the other and, of course, even if it is equal, one side of the line is grounded while the other is not. In many receivers, therefore, the hum will be greater when the polarity of the line is one way than the other. It is a good idea to try the receiver with the line cord first one way and then reverse it, in the receptacle of the power outlet. When the addition of a ground connection to a receiver actually increases the hum, this is usually very effective in minimizing it. It also may be an indication that the ground is not a good one. This is not a certainty because of the way a ground may affect the input circuit of a receiver.

Other sources of externally created hum are nearby high-tension power lines which may be in a normal condition or may have transformer leakage or insulation break-down, which will increase the amount of radiated noise and hum. The power companies operating high tension power lines are usually very cooperative in eliminating or reducing noise and hum from this source as any leakage or malfunction of the power line represents a power loss which they are anxious to avoid. Under some conditions it may be expedient to shorten the length of the outside antenna to improve the signal-to-noise ratio. This will depend on the type of receiver and local conditions and, therefore, will require some experimenting to determine the optimum antenna length.

Unusual types of radiated hum and noise should be investigated. An incandescent lamp whose filament wire has burned out and separated only a few thousandths of an inch will still emit almost its normal amount of light, as the current will arc across the gap between the broken ends of the filament and be sufficient to heat the filament. The arc formed under these conditions will radiate an intense field of radio noise and hum which may extend for a considerable distance. Usually, if the switch connected to the defective lamp is opened the lamp ceases to function and therefore it can be easily located.

Quite often a lamp or clock placed on top of the radio cabinet or close to it will induce a hum into the receiver. A second receiver in the immediate vicinity and which has the same intermediate frequency can cause one type of modulated hum.

The difference in sound between a 60 cycle and a 120 cycle hum can be determined with a little experience and close listening to the radio receiver speaker. Although many types of hum are composed of a mixture of these two frequencies, if either frequency predominates, a general indication is given as to its cause.

Unpredictable Character of Hum

You have, no doubt, noticed the extensive use of probabilities in the foregoing. The statements that this or that condition *may* or *likely* or *probably* will produce hum were used. Except in the specific case of filter circuits and certain definite audio defects, this has been essential for accuracy.

The conditions under which hum is produced are not subject to direct analysis as has been described. One tube, which is two years old, may produce considerable hum, while another which is new or three years old, may not produce hum either directly or indirectly in the same socket or in any other circuit. The reason for this lies in the condition of the other tubes, the alignment of the receiver, its installation, its other faults or short comings, its location and even how much it is used. The foregoing discussions, therefore, pointed to the most likely causes of hum from actual experience and in most cases have described the electrical reason for it so that in an equivalent unit in any receiver it can be analyzed from the same ideas.

The screen grid by-pass condenser C7 in the circuit in Fig. 18 is symbolic of any receiver circuit using pentode or even screen grid tubes. Information given with reference to C7 of Fig. 18 will apply to all superheterodynes, TRF or regenerative receivers, using pentode or screen grid tubes, automotive, AC-DC, and all but battery receivers, public address amplifiers, call systems, etc. This method of wiring for the screen grid circuits is common to at least 5000 different circuits. In an all-wave receiver, whatever conditions will produce regeneration will also usually produce hum. Some of these sources are:

- Open or shorted grid trimmers.
- Defective band switch contacts.
- Failure of shield, due to defective ground.
- Leakage or defect in padding condenser.
- Defective ground for tuning gang.
- Open or high resistance grid return.
- Open grid return by-pass condenser.
- Excessive plate or screen grid voltage.
- Open cathode by-pass condenser.

Testing for the presence of hum in individual circuits is not effective in servicing for hum. A good procedure is to shunt various items in the receiver with a 4 to 8 mfd. paper condenser while the receiver is in operation. Listen for any change in quality or intensity of the hum and for other effects such as a change in signal strength. Start with the filter condensers, and proceed to the plate and screen by-pass condensers, the cathode by-pass condensers, both sides of the filament circuit, and AVC filter condensers, and in fact, all condensers which are not of the coupling or tuning type, or are not an actual part of a tuned circuit. It will do no good to by-pass any part of the signal circuit.

When you come to a definite reduction in hum by this process it is most likely that you will find that the condenser you have by-passed is open or otherwise defective (except shorted). If it is shorted, shunting it with another condenser will not change the operation of the receiver in any way.

It is best to determine the general location of the hum by the simple observation suggested. Then a detailed trace of circuit conditions for the AF and another for the RF should soon lead you to the source of the hum.

Modulation Hum

The term *modulation hum* is given to RF signals which are being heterodyned with the 60 cycle line voltage causing a noticeable hum along with the signal from the wanted station.

This type of hum is usually associated with a strong local signal. Due to this fact it could also be classed as tunable hum. This modulation hum is due to the mixing of the AC power line voltage with the RF voltage from the signal. It is, of course, necessary that the two voltages be impressed upon a non-linear impedance before they can form a beat note which will cause, in this case, hum in the receiver. The non-linear impedances which can cause this mixing are the power rectifier tube, non-linear resistance connections within the receiver, non-linear resistive connections within the house wiring or to the grids of the RF or IF tubes. If the signal and the power line voltage are impressed upon anyone of these non-linear impedances, a heterodyning effect will be produced which will cause the signal to appear to be modulated by a 60 cycle tone.

Now if the 60 cycle AC is prevented from reaching the non-linear impedance at the same time as that of the signal or if the signal is prevented from mixing with the AC at one of these points, this heterodyne action cannot take place. Thus, one of these voltages must be filtered out before it reaches the non-linear impedance.

Most modern receivers employ an RF filter across the power line to eliminate RF voltages from reaching the

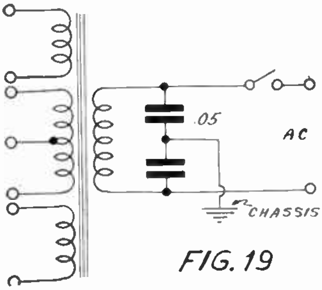


FIG. 19

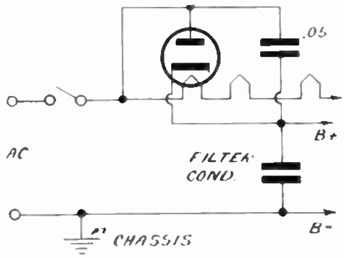


FIG. 21

receiver through the power line, causing a hum which is called, in this case, modulation hum.

It is for this reason that RF filters and traps are placed in the power supply leads to prevent RF from getting to the rectifier tube. This is usually in the form of a pair of condensers connected from each side of the power line to ground as shown in Fig. 19 or in AC-DC receivers and transformerless AC receivers, one condenser is connected directly across the power line as shown in Fig. 20 or an alternate method with these type receivers is to shunt a condenser between the plate and cathode of the rectifier tube as shown in Fig. 21. This method is not as satisfactory as that in Fig. 20 although it is used in some receivers. Two condensers as in Fig. 19 can also be used with transformerless receivers as shown in Fig. 22.

The condenser values commonly used with these filters are indicated in the diagrams. The heterodyning action between the signal and the power line voltage may take place at some non-linear resistance connection in the house wiring. Therefore, this modulation hum may occur before it reaches the receiver. Thus, it cannot be remedied at the receiver itself. This type of hum must be filtered at a point above the non-linear connection. With the use of .05 mfd. condensers connected to the house wiring at several points, starting with the fuse box, hum of this sort can usually be cured.

As this type of hum is usually due to the RF and 60 cycle power line voltage being mixed together at some point either within the receiver or ahead of it, this receiver complaint is often overlooked by the serviceman if the receiver is serviced in his shop. Most radio repair shops take special pains to eliminate RF from the power line thus any hum entering through the power line will be filtered out. If a receiver in which the hum was due to the mixing of the RF and the power line voltage at the receiver or a lead of the receiver, was brought to the shop for repair, the serviceman would not

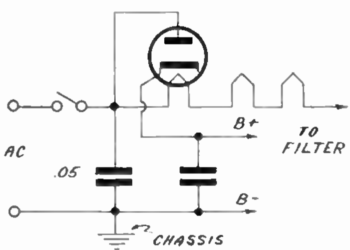


FIG. 20

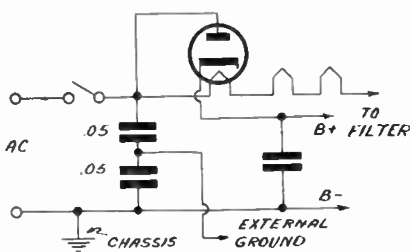


FIG. 22

be able to locate the defect. Some receivers are more susceptible to modulation hum than others. A simple way to test if a receiver is susceptible to this type of hum is to connect a couple of small RF chokes in the power line leads to the power socket as shown in Fig. 23 without condensers. If the power line is well shielded and filtered at some point ahead of the power outlet, it will be necessary to connect an outside antenna to the hot side of the line through a .002 mfd. condenser as shown by the dotted line in Fig. 23. This circuit will in most cases identify receivers which are susceptible to modulation hum.

Do not use the antenna for any other purpose while using it for this test, as you may get a hum condition from some other source, making your test on the receiver you are working on of no value.

It always pays to make sure that the cause of the hum is entirely due to the receiver and not to faulty house wiring or to some local interference at the receiver location. Thus, it is always advisable when you are not certain you have found the difficulty that you reinstall the receiver at its original location to make certain that the hum is eliminated by your service work.

Where there is a non-linear resistance connection in the house, not only modulation hum in a receiver operated from this line is likely to occur, but also cross modulation between two strong signals may occur. Cross modulation although it isn't defined as hum will cause considerable distortion, making receiver reception on two stations whose frequencies are near interfere with each other. This can be cured in the same manner as modulation hum by grounding the

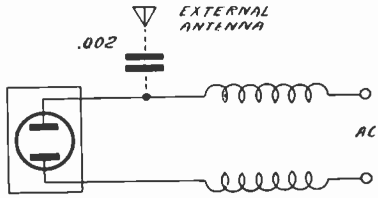


FIG. 23

power line with .05 condensers in several places.

In case a receiver uses the power line for an antenna and you ground the power line, a separate antenna will have to be provided for the receiver.

Hum in AC-DC Receivers

A large percentage of receivers are either of the AC-DC variety or the AC transformerless variety. These transformerless AC operated receivers are more likely to develop hum trouble than the type receiver where a transformer is used due to the high voltages on the filaments of these tubes.

Most of these transformerless AC receivers use the 12 volt and high voltage heater type tubes and as these tubes are connected in series with the power line, there is an appreciable AC voltage between the heaters and the cathode. Thus, if there is any type of mechanical fault in the tube, the AC from the heater may be introduced into the cathode circuit. In this way it is amplified through the receiver and appears as an AC hum in the speaker of the receiver.

The series filament string in AC-DC receivers should be so arranged that the second detector tube filament is connected nearest to the side of the AC line to which the negative plate supply is connected. This usually is the place in the series filament circuit nearest ground potential. The rectifier tube is connected in the series circuit at the place of greatest potential difference. By this arrangement, the sensitive second detector circuit is not subject to as great a hum influence as the other less sensitive circuits.

Aging of the tubes in these receivers often causes a hum to develop due to coupling of the AC from the heater to the cathode caused by a weakening in the heater element from continued use.

Sometimes the resistance of the heater element of one of these tubes after being used for some time changes resistance value, causing an unbalance of the filament voltages on all of the other tubes in the circuit, causing them to change characteristics. This change may cause an unbalance of the circuit causing hum to be developed.

A good number of these AC-DC and AC transformerless receivers use half wave rectification. Because of this, a better filter system is necessary. Condensers with capacities as high as 40 to 50 mfd. are often used in these receivers. The majority of hum trouble in these receivers is due to the loss of capacity of these filter condensers. Thus, it will prove profitable to keep a stock of high capacity condensers of the electrolytic variety in your shop. The condensers used in these receivers are usually of the dual type having two or more condensers in one container. One important point to remember when replacing dual condensers in a receiver is the polarity of the common lead if one is used. The majority of condensers use a common negative. For this reason it is easy to be misled when a condenser using a common positive with two or more negative leads is encountered. There are a number of receivers which use dual condensers having a common positive with several negative leads. Always make sure which type of condenser is needed before proceeding to install the new unit. You will find as you continue to service receivers that the majority of hum complaints in most receivers are due to the filter condensers. You will soon develop a technique for making quick filter replacements. However, don't jump to conclusions as there are, as has been pointed out in this lesson, many other causes of hum remote from the filter condensers.

Due to the high AC voltage on the filaments there is a greater tendency for AC pickup from capacitive coupling between wiring in the AC-DC receiver. Carelessness in the handling of the receiver and tampering with the placement of the receiver wiring can often cause hum to develop in such a receiver. Because of the physical size of most of these AC-DC receivers, the placement of the wiring is more critical than other larger receivers. When servicing receivers of this type care should be taken that the wiring and also the parts within the receiver are not moved to any great extent from their original positions. When it is necessary to move them, make sure they are replaced in their original position when you have completed the repair on the receiver.

If someone has tampered with a receiver and mixed up the wiring, remember that the filament wiring should be as close to the chassis as possible and at the same time as far away from grid leads as possible. A visual inspection of the wiring of a manufactured receiver will soon reveal if the receiver wiring has been altered.

One side of the power line is usually connected directly to the chassis of these receivers and when the power cord is inserted in the power outlet in the wrong direction, it places the receiver chassis 110 volts above ground. When connected in this manner, hum may be introduced into the receiver. Many times hum can be stopped by merely reversing the power cord in the power outlet. As in previous lessons, the student is cautioned about grounding a receiver of this type direct to ground.

When you are installing or servicing a receiver, if you are not certain of the type, always use a condenser in series with the receiver ground lead when grounding it.

Index to Aid in Hum Location

First determine the general classification of the hum from an actual observation. Then check the items under that classification in the order given. Their arrangement is approximately that of greatest relative recurrence, and hence should lead to the hum source very quickly.

Constant Hum
Unaffected by Volume or Tuning Controls—
Confined to Audio and Power Systems

1. Power supply:
   - (a) Check filter condensers for opens and leakages.
   - (b) Check for open voltage divider resistor.
   - (c) Check rectifier tube for emission and balance of emission to both plates.
   - (d) Test power transformer for open or shorted high voltage winding.
   - (e) For mercury vapor rectifiers, check effectiveness of ground for shield and for shorting of RF plate choke coils.
   - (f) Check transformer for loose laminations or poor mechanical mounting.
   - (g) Check for shorted filter choke or speaker field.
2. AF System:
   - (a) Check tubes for balanced emission.
   - (b) Check grid circuits for opens.
   - (c) Test for bias voltage and open grid filter condenser.
   - (d) Check for defective resistor in a bridge bias circuit.
   - (e) Test coupling condensers for high resistance leakage.
   - (f) Check setting of hum control.
   - (g) Check for open cathode or plate filter by-pass condensers.
   - (h) Check for the proper grounding or by-passing of filament circuit.
   - (i) Check for effectiveness of input shielding where used.
   - (j) Check wiring for possible grid coupling to any filament or power lead carrying the line frequency current.
   - (k) Check values of parts and continuity of interstage couplers for degeneration, tone control, volume expanders, phase inverters, etc.
   - (l) Check for magnetic coupling of transformers by orienting transformers or by separating by a heavy iron plate or ring.

Hum Proportional to Signal Volume
Confined to the High Frequency Section of the Receiver

1. Second Detector Circuit:
   - (a) Check emission of detector tube (diode, triode, tetrode or pentode).
   - (b) Check for possible increase (more than 30%) of all filter, cathode or volume control resistors.
   - (c) Check for leakage or open of any RF filter condensers in the second detector circuit.

(d) Check for correct voltages and loads in plate, screen and cathode circuits and for diode loads.

2. IF Amplifiers:
   (a) Check for good alignment.
   (b) Check for ungrounded coil shield, tube shield and for a possible feed-back causing a regenerative condition.
   (c) Check the cathode or bias resistor or for AVC, the grid return circuit.
   (d) See that the proper tubes are used, that is, supercontrol types and sharp-cut-off types in their proper sockets.
   (e) Be sure of the proper plate and screen grid by-pass condensers and voltage.

3. First Detector or Mixer Circuit:
   (a) Check cathode emission.
   (b) Check the value of the grid leak resistor of the oscillator.
   (c) Check the oscillator anode and mixer screen grid voltages and their by-passing.
   (d) Check the return circuit of the signal control grid with the AVC or other filter it may have.
   (e) Check the cathode by-passing and the cathode resistor.

4. RF Amplifier or Other Input Circuits:
   (a) Check for open grid, improper bias, or improper plate or screen grid voltages.
   (b) Check for feed-back causing regeneration.

Tunable Hum

(Comes in Only with Station Signal)

1. Audio System:
   (a) Check bias values and plate voltages to be sure that this is not caused by overload.

2. High Frequency System:
   (a) Check bias and plate and screen grid voltages to avoid detection in amplifier stages.
   (b) Check alignment and interstage coupling for possible traces of regeneration.
   (c) Check shielding of tuning units and open or excessive resistance grid returns.
   (d) Look for open or high resistance plate circuits.
   (e) Look for excessive screen grid voltage.

Tunable Hum

(Reduces When Station is Tuned In)

1. High Frequency System:
   (a) With receivers having AVC check same condition as outlined in the foregoing.
   (b) With non-AVC receivers, check excessive grid return resistance and sources of regeneration.

Modulation Hum

1. Power Supply:
   (a) Check power line filter; replace condensers if found faulty.

2. External Circuit:

(a) Check ground to electric outlets and receiver ground. If no ground is used make one.

(b) Increase the antenna length or select a better position for it.

(c) Check the position of the receiver; by changing its location, you may correct the condition. In one case this condition was caused by a steel beam inside the wall where the receiver was located.

(d) For AC-DC receivers, ground the chassis through a .1 mfd. condenser; reversing the plug of this type receiver often helps.

Always keep in mind that the elimination of hum is a matter of refinement of circuit conditions. See that all circuit parts and conditions of operation are proper and the hum will almost invariably be eliminated in the process.

* * * * * *

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 In which specific part of a receiver would you check for tunable hum?

No. 2 Does the presence of a ripple voltage at the power supply filter output always indicate a source of hum?

No. 3 Would the same ripple voltage have more importance at the first AF grid or at the AF output amplifier plate?

No. 4 If the hum disappears when you open the first AF plate circuit, where would you check for its source?

No. 5 What may be done about hum arising from lack of balance in a push-pull stage?

No. 6 What defect in addition to hum will an open screen grid by-pass condenser cause?

No. 7 Is it possible for a lack of a ground connection or a short antenna to be responsible for hum?

No. 8 In what way does shielding of parts protect against hum?

No. 9 What is most likely to be the hum frequency for a half wave and a full wave rectifier system assuming they both operate from a 60 cycle power line?

No. 10 What are the conditions under which poor tube emission will cause hum?

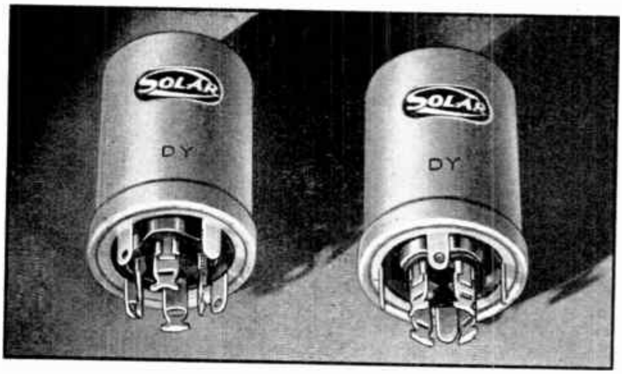
HOW TO ELIMINATE RECEIVER INTERFERENCE

LESSON NO. TV-19

Sprayberry Academy of Radio

CHICAGO, ILLINOIS

K3552M



Condensers are one of the most prolific sources of noise or interference in radio receivers and amplifiers. All types and makes are subject to this type of defect so it is no reflection on a particular manufacturer when this occurs in a condenser which he makes. The above view illustrates a high grade of electrolytic condenser as made by *Solar*.

How to Eliminate Receiver Interference

Lesson TV-19

Frequency modulation transmission has reduced the effect of receiver interference, but due to the characteristics of frequency modulation, it is not practical on the broadcast band as it is set up today. With the numerous AM broadcasting stations in operation today, there are relatively few locations where the signal strength from the nearest radio station is not considerably higher than the natural noise of the location for ordinary operation.

However, there are certain conditions which are not normal which may cause interference far greater in strength than the signal strength of even a local station. This interference may be due to a defect within the receiver, or it may be due to some outside interference. In this lesson, both types of interference will be considered in detail. Bear in mind, however, that all unwanted sound emanating from the receiver may not be due to interference. The receiver may be out of adjustment or the station tuned-in may be transmitting a pickup from overseas, etc.

Many attempts have been made to design a receiver which will entirely eliminate static and other forms of interference but none of these have been entirely successful except frequency modulation (FM) and even this is not 100% effective.

Internal Receiver Interference

Anything that interferes with the proper reception of radio signals and with the proper reproduction of such signals as speech or music, is properly called *interference*. Thus a frying noise or hiss which spoils reception is properly called a form of interference, even though it may have its origin in the receiver proper, and even though its cause might be a defective part.

In this section of this lesson, causes of interference will be considered that originate in the receiver proper. They may make themselves evident as a loud hum, a buzz, a crackle, a whistle or a growl.

In many instances with the receiver operating normally, it is impossible to tell from the audible effect of the interference whether its source is in the receiver or whether it is coming in through the antenna system. This however, can be determined simply by shorting the antenna and ground terminals of the receiver. If the interference is still heard, the origin of the interference is definitely in the receiver itself.

It is possible, of course, for the interference to be received through the power line in the case of AC operated receivers, but the serviceman usually knows the locations where this is likely to happen and if the receiver he is called on to service is in a neighborhood that is generally free from power line noises, he need not worry about this. On the other hand, the temporary installation of a line filter can be made and the power line checked on the spot. A test receiver that you know is normal may prove useful for these tests.

A schematic diagram of a typical power line filter is shown in Fig. 1. Manufactured line filters are inexpensive, however, and simple to install. It is recommended that one or more line filters be kept on hand, both for checking purposes and for permanent installation where a noisy power line is known to exist.

Interfering noises may still further be classified as those due to natural defects in parts or circuits and those only accompanying a received signal, but arising entirely from within the receiver. For example, a hum or a hiss or motorboating may accompany each tuned signal while the receiver may be quite silent between stations. The careful noting of such effects will help considerably in finding the exact source of trouble.

Now, assuming that it has been de-

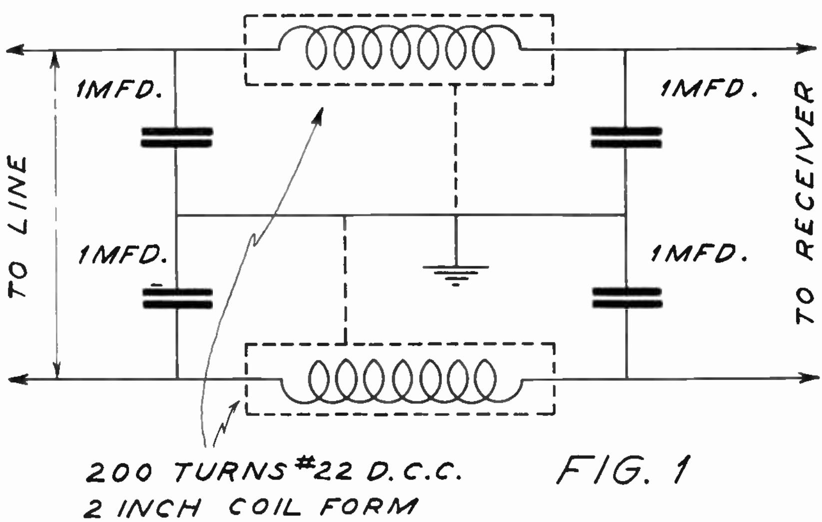


FIG. 1

termined that interference is within the receiver, the next thing to decide is whether the interference is electrical or mechanical. If it is electrical, the interfering voltage combines with the signal voltage somewhere in the circuit where it may be amplified by the various stages and both are fed to the speaker to appear as a disturbing noise with the signal reproduction. If it is mechanical, some part in the receiver or in the room is vibrating and setting in motion the surrounding air, causing sound waves which reach the ear directly—not by way of the speaker. It can sometimes be determined merely by listening to the noise whether or not it is a sound wave coming from the speaker.

Of course, any vibrating part or body has a natural frequency of vibration (resonance) and if a loose part of core lamination is caused to vibrate by the speaker, the vibration will be more prominent at certain speaker frequencies. In fact, it might vibrate at only one frequency—that is, at the frequency at which the loose part is resonant. Where a condition of this sort is encountered, the serviceman need look no further—he will know immediately that the source of the interference is mechanical.

Among such mechanical defects will be found vibration of the shielding structure of the receiver, loose condenser gang rotor assembly, loose mounting brackets, loose tube structure and elements within the tubes, and loose screws and nuts. Any cloth, paper or metal coming in contact with the speaker cone will cause serious interference and should be corrected. The cabinet in which the receiver is placed may have loosened and may have thin veneer or plywood panels which will vibrate freely. Where loose pieces of wood or warping from supports exists, furniture glue should be used, but where the wood naturally vibrates, it should be covered with celotex or suitable sound proofing material.

Totally outside of the receiver and cabinet, such items as trays, ornamental trinkets and dishes and countless other things produce sound through resonance. These sources must individually be studied, traced and corrected.

There is a remote possibility that the output transformer (usually mounted on the speaker frame) is at fault. If you wish to definitely eliminate this unit as a possible noise source, temporarily short the output transformer secondary, thus completely silencing the speaker. Any sound heard in this case is due to vibration of transformer laminations and may be prevented by tightening the lamination screws, or reclamping the transformer or winding it with steel wire, or by wedging the laminations tight with one or more small nails driven between the laminations, or replacing the transformer.

It is only natural to clear up the most obvious defects first, so that they will not enter into further tests if these are necessary. For example, if adjustment of volume is accompanied by noise of any kind, such as scratching, clicks, sudden volume changes at definite points of adjustment, the volume control must be repaired or replaced. It usually does not pay to repair volume controls for many reasons. With some types of controls it is impossible, and with others it is impractical.

If noises such as scratching, motorboating or clicking accompany tuning adjustments with the station selector dial, look for defective contacts of the rotor section to the chassis. Usu-

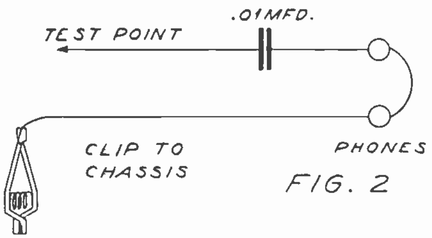


FIG. 2

ally these are brush or pressure contacts and may need both cleaning and tightening. Cleaning of any electrical parts may be done with white gasoline, benzine or alcohol.

An accumulation of dust between the condenser plates may cause noise while tuning, to say nothing of decreased efficiency of the circuits. This may be removed with a smokers pipe cleaner. If the metal plating is peeling off of the plates and thus intermittently shorting them, this defect may be overcome by applying 300 to 500 volts, AC from most any power transformer across the condenser. While this voltage is being applied, the rotor plates should be rotated. The metallic pieces will be burned out permanently.

In tracing down the source of internal interference in a certain stage, a continuity tester is particularly valuable. Either a visual continuity tester, or preferably, for this work, a good ohmmeter can be used. The chief purpose of the continuity test is, of course, to locate an improper or varying resistance, leaking condenser, or otherwise defective part.

With an aural continuity tester as shown in Fig. 2, listen for crackles or other noises as the tester is connected in various circuits. Any variation in resistance will result in a sound in the headphones. Thus, a poor connection in the wiring or a defective resistor, or a coil with a varying resistance, will be located.

Tests may be made in any order and the following are suggested: Attach the clip to the chassis, and touch the test point to all tube cathodes. Every noise other than a slight hum and the signal in the case of detectors and audio amplifiers will indicate a defect in that stage or in a preceeding stage. Do not suspect the cathode resistor or condenser immediately, as the defect may be in the plate, screen grid or suppressor grid circuits.

Test all of the coil B+ connections to determine if any noise exists. Crackling and irregular hissing will usually indicate a defective plate bypass condenser or plate to screen resistor. No appreciable signal should be heard on the B+ line. Next test the common Sg+ lead. Noise here may indicate an open or leaky screen bypass condenser or series or shunt screen grid resistor. A defective or leaky output filter condenser will affect both plate and screen grid circuits and may be identified by testing for noise at the B+ output lead.

Poor or improper contacts at any point tested will be revealed by sharp clicks. A resistor may increase or decrease in value 20% or more, but if its value remains constant, no noise will be created in the circuit. However, since it has changed in value it is subject to changing values under operating conditions and should be replaced.

Testing at the actual control grids or plates will not be effective as this will greatly reduce the signal output to the speaker and will serve no purpose in establishing the cause of the noise.

If a visual continuity tester is employed, an unsteady reading on the meter will indicate varying resistance. An improper contact in the wiring will show up as a high resistance.

Even a low resistance contact will show up if a sensitive continuity tester is used.

It will be a great help to have the proper resistance values of all parts at hand, either in the form of manufacturer's service manuals, or in the form of notes made from previous experience with receivers of the same make and model. Then an ohmmeter test will enable you to check the various parts and the wiring connections in a really professional manner.

In any event, be sure that all the tubes are in good condition. It is a safe rule to follow that all tubes should be tested on every service job, as defective or worn out tubes are the cause of a large percentage of service calls, due to noise as well as to lack of sensitivity.

Then, if an aural and visual inspection has failed to locate the source of the interference, make your job as easy as possible by locating the stage in which the interference is orginating. This is done by the elimination method with which you should be very familiar by this time.

With the receiver in operation, all tubes in place, and the antenna lead disconnected, short circuit the grid of the output tube as in Fig. 3. If the last stage contains two tubes in push-pull, short the grids of both tubes. If the interference is still heard, you have definitely localized its source in the output stage. On the other hand, if the interference is not heard, move to the previous stage and short the grid of its tube—removing the short from the output tube or tubes. Continue until you reach the stage where shorting the tube's grid does not cause the disappearance of the interference. This will be the stage in which the defect exists.

It is extremely necessary for the serviceman to keep his eyes open and his mind active as he goes over a circuit, regardless of the type of testing equipment he is using. For example, should he notice a bit of green discoloration at any point in the wiring or at any connection, he would not need his ohmmeter to tell him to stop and investigate. And on general principles he would clean the connection thoroughly and r e s o l d e r it. The chances are that this bad connection was causing some or all of the noise. If not, it would have caused trouble at sometime in the future—so stop and make sure.

When repairing doubtful connections, break the connection entirely, scrape both ends, or the end of the wire and the terminal to which it connects, thoroughly, then resolder.

Sometimes an improper connection will open and close, depending on the surrounding temperature. In a case of this kind, the receiver might operate satisfactorily until it is thoroughly warm. Then the signal might become weak for a while, then come in strong, and so on, intermittently. Or the receiver might actually become silent and then start up again, just as if the power were turned off and on again.

A connection of this kind is *thermostatic*, which means only that it is affected by temperature. A thermosta-

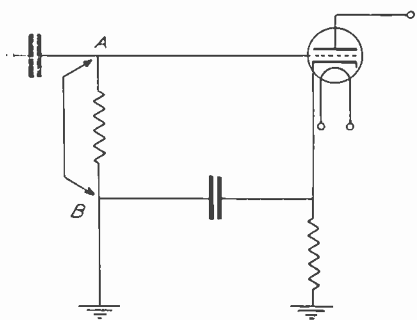


FIG. 3

tic joint can usually be located most easily by going over the wiring and testing each connection by giving each wire a sharp pull. The connection causing the trouble, being in a weakened condition, will break apart when pressure is put on it. It should then be cleaned and resoldered.

In checking the wiring for thermostatic joints, you may break one or more connections that were merely weak and not thermostatic. You should not feel that it is a waste of time to open and resolder these connections, for there is every possibility that these would cause trouble, sooner or later, if they were not resoldered.

Noises Originating in Defective Parts

As previously stated, in checking receiver parts for defects, it is always wise to start with the tubes. With a good tube tester you will, in all probability, be able to locate the source of noise, if it is caused by a defective tube. Without a tube tester—and if you are not equipped to substitute new tubes, or tubes known to be in good condition, for all the tubes in the receiver, look for gassy and microphonic tubes. You will be able to spot a gassy tube by the purple haze about its elements. This applies to all tubes except the pentode type. These tubes normally have a blue glow around the elements. If a gassy tube is found, replace it and the chances are the source of the noise will have been removed.

Unless a tube has been in use for a long time, the cause of its gassy condition will be improper voltage—either plate voltage too high or grid voltage too low. Be sure these voltages are proper before replacing a gassy tube, or the new tube may become gassy in a short time.

To locate a microphonic tube, tap the envelope of each tube, one at a time, with the receiver in operation. If clicks are heard, or if the operation of the receiver is affected in any other way when a particular tube is tapped sharply with the finger, you can usually assume that the tube is microphonic—that is, its elements are loose and are caused to shift their positions or vibrate. In actual operation, the loose elements may be caused to vibrate by the action of the sound waves from the speaker or any other receiver vibrations that might be present.

Another possibility that must not be overlooked is that of poor contact at the tube and speaker plug sockets. As you know, there are spring contacts in the sockets which are made of spring steel or phosphor bronz. Sometimes these contacts lose their tension or become bent so they do not press firmly against the tube prongs. In a case of this sort it is usually advisable to replace the socket, although temporary repairs can be made by carefully bending the spring contact back to its original position.

Before discarding an apparently defective tube, examine the tube pins. The lead from one of the elements may have worked loose from its pin. In this case, a visual inspection will show that the solder has dropped from the inside of the pin. Just a drop of solder on the tip of the tube pin will sometimes repair the defect and a tube is saved.

Grid resistors of the carbon or graphite type become noisy when overloaded. The same is true of the resistors used in the voltage divider, in plate circuits and in filter systems.

Excessive voltage in a circuit is usually caused by the breaking down of a condenser. Therefore, when you come across a defective fixed resistance in any circuit, before replacing it,

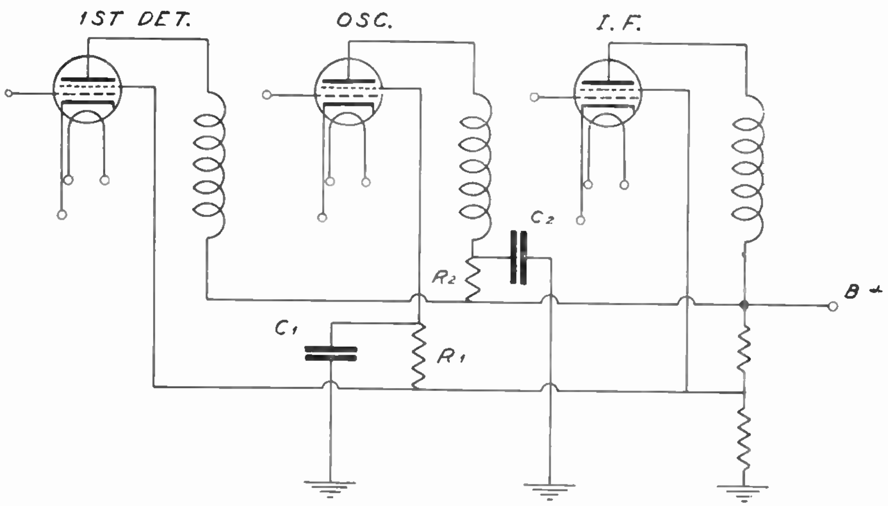


FIG. 4

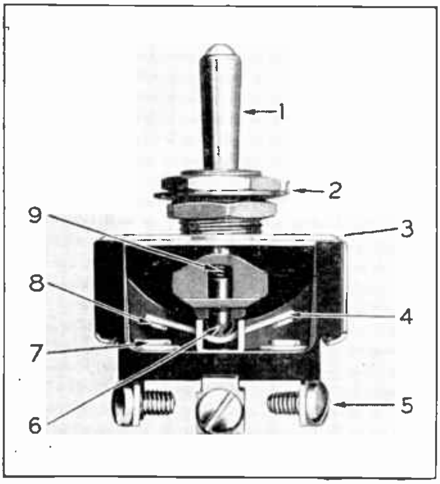
check the condensers by passing the circuit so there will be no danger of overloading the replacement resistor. Noises resulting from defective resistors are usually of the *hissing* variety.

Figure 4 shows a good example of what can happen to a resistor when a condenser becomes fully or partially shorted. This circuit shows the plate circuits of the first detector, oscillator, and IF stages of an ordinary superheterodyne. Resistors R1 and R2 reduce the common plate and screen grid voltages of the receiver to fit the requirements of the oscillator stage. C1 and C2 are the by-pass condensers for the two resistors. If either condenser shorts, excessive current is caused to flow through R1 or R2. If the short is of the low resistance type, the resistors (R1 and R2) are likely to overheat and burn out in a very short time. On the other hand, if C1 or C2 (or any other similarly connected condenser) develops excessive leakage, the associated resistors (R1 and R2) will be overloaded and this wil' result in noise. Thus even though you ascertain that R1 and R2 may be overheated (causing noise) it does not necessarily mean that you will correct the defect by replacing the resistor. A resistor only overheats because excessive current flows through it. Therefore, find the cause of the overheating, and you will have located the root of the trouble.

In working on older types of receivers, you may come across a resistor that is being overloaded—yet the circuit conditions seem alright otherwise.

The chances are in a case of this kind, that the resistor is a replacement resistor of improper power rating. You should not make the same mistake—replace with a resistor of the proper rating. Remember that power is equal to voltage multiplied by current—and to calculate the proper power rating all you have to do is to multiply the known voltage drop across the resistor, by the measured current flowing in the circuit.

Noises similar to those resulting from defective resistors are sometimes caused by defective insulation on the circuit wiring. If there is a partial short between high voltage leads on



This switch is typical of many receiver parts in which noise and receiver interference can be created. In due course of time, any movable radio part will wear and thus may break down or change in characteristics. This action may or may not cause noise or interference. When grease, dirt or dust forms between insulated terminals a current leakage path is provided which may cause noise. So on switches and other such parts, be sure the insulation between terminals is thoroughly clean.

the outside of the chassis, sparks will be visable as the flashover occurs that causes the interference. The cause of defective insulation is usually water condensation which causes the outer insulation to rot and crack, at the same time causing the inner rubber insulation to dry out and deteriorate.

This trouble is seldom encountered when leads are run through *spaghetti* and the remedy in other cases is to replace the defective leads with leads run through *spaghetti* insulation.

In receivers employing a bakelite or other composition terminal strips, the condensation of water and the gathering of dirt or oils from the various packing materials of condensers, etc., may cause a partial short with resulting noise. The remedy is obvious—clean the terminal strip carefully. Certain oils will break down the insulating properties of bakelite and other compositions and for this reason will cause shorts to contacts connected to them.

Should the adjacent turns of a coil be partially shorted, due to defective insulation, as sometimes happens where the climate is particularly moist, the entire coil should be removed and soaked in hot parrafin. Be sure the coil is thoroughly dry before treating it. Dry it out if necessary, in a warm oven.

Should all of these points be checked and the source of the interference still is not found, test the audio transformers. In testing the windings use a high voltage and a high resistance voltmeter as partial shorts due to defective insulation might not show up if a low voltage is used. Even then the transformer might apparently be in good condition and still be the source of interference. If a stage-by-stage elimination test shows that the noise is originating in an audio stage and all the parts and leads are found to be in good shape, it is frequently worth while to try a new audio transformer.

A good method of testing the primary of any AF transformer or in fact, an RF and IF unit as well, is shown in Fig. 5. Use a high reading milliammeter 100 or 250 milliamperes, allowing the connection to remain closed for about 10 seconds. A large current will flow through the primary as the total B supply current is shunted through the winding. If the meter reaches a steady deflection and remains stationary, the winding is in good order. Under these conditions, the winding will carry 10 to 20 times as much current as it would ordinarily carry. All plate and screen circuits may be given this overload test.

Grid load windings may be tested

in the same way as in Fig. 5. Be sure to remove the tube from the socket when making this test. For resistance plate and grid loads, the shorting test as previously described is superior.

A pilot light that is loose in its socket, may also cause noise. Of course, in this case, the pilot light will flicker and it will be apparent at first sight.

In many cases, the pilot light of a receiver will flicker although tight in its socket. This may be due to shorting of one side of the pilot light circuit to ground from its socket support. Or it may be due to a short between the transformer center-tap of the filament winding and either side due to a ground of either side of the filament to the chassis. To check the transformer for an internal short, the filament connections should be detached at the transformer and its voltage should be measured from ground to either side. A defect will thus be made evident.

To sum up this chapter on internal receiver interference, due to defective parts—a defect in almost any part will result in noise, if it does not prevent the receiver from operating. And if a visual inspection does not lead you to the source of the interference, a stage-by-stage test will localize the source in a particular stage. Concentrating on that stage, test all the parts, leads and connections in that stage. This, of course, applies only when the interference is of the intermittent type—crackles and frying noises, not whistles, which will be considered a little further on in this lesson.

Oscillatory Interference

Interference due to regeneration and undesirable oscillation can readily be recognized by its audible effects—whistling, hissing or squealing.

Undesirable oscillation within the receiver may have one of any number of causes, such as plate to grid feed-back inside or outside of the tube, stage to stage feed-back due to plate, screen, suppressor, cathode or control grid coupling or to lack of proper circuit adjustment. Open grid circuits or open tuning condenser circuits will usually cause oscillation. If a receiver is poorly adjusted, each signal tuned-in may have an undesirable *swish* connected with its tuning. Ordinarily this is traceable to faulty neutralization or alignment producing undue regeneration. Particularly true in the

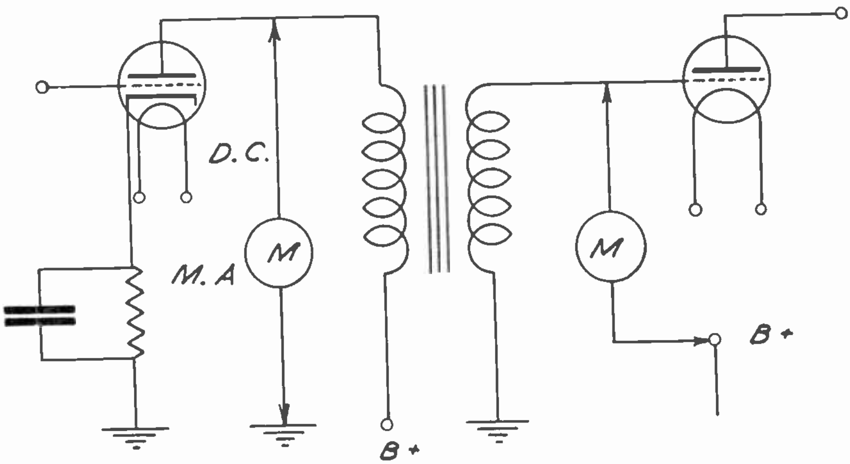


FIG. 5

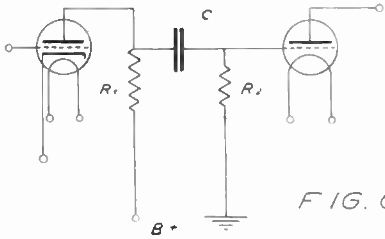


FIG. 6

superheterodyne—this type of defect is due to regeneration or unstable adjustment of the IF amplifiers.

Corrections for these defects consist of proper alignment according to standard procedure, and for all types of feed-back, circuits may be decoupled by means of shields, filters where they are connected to a common B+ supply, by-passing more completely where necessary and the proper application of plate, screen and control grid voltages. Excessive plate voltage or screen voltage will commonly cause this trouble. Open plate or screen by-pass condensers or an open screen to ground bleeder resistor will cause this trouble.

In cases where appreciable current must be carried from one circuit to another, the circuits may be decoupled by means of a choke coil in series with a by-pass condenser in shunt with the circuit to ground at either end of the choke.

Where the circuit is not called upon to carry any current except that incidental to the charging of its own filter condensers, high resistance resistors may be used for effective circuit decoupling and isolation. The AVC circuit is a good example of this. If one or more AVC resistors are shorted, feed-back may result. If any of the AVC by-pass condensers are open, the same may result and if leaky or shorted, the circuit will be erratic and noisy.

If oscillation is in the audio stage, it will usually have a constant tone and thus may be readily identified. At a low frequency, such oscillation will resemble a motorboat sound. There are various types of motorboating and each has its special correction. For example, the grid of an output tube due to too high a resistance load will alternately block with electrons and discharge affecting the plate current of the tube. This may be remedied by using a lower grid resistor value. The original resistance value may have increased, unduly causing the trouble, in which case, replacement of the same value of resistance with a higher power rating may be sufficient to correct the defect.

A coupling condenser such as C in Fig. 6 with the slightest leakage, will cause motorboating as leakage is rarely constant and even so, the action of a fraction of a volt on the output grid from the plate of the preceding tube with the slightest trace of gas in either tube will cause motorboating due to the internal resistance characteristics of the tubes. Very often simply replacing the coupling condenser will prevent motorboating.

Resistor R1, Fig. 7, must be constant in value and it is sometimes necessary to add a plate filter such as in Fig. 7. It consists of Ro and Co. The value of Ro should be ½ to 1/10 the value of R1 and Co should be .5 to 8 mfd.

Unfortunately it is not always possible to isolate the defect to one par-

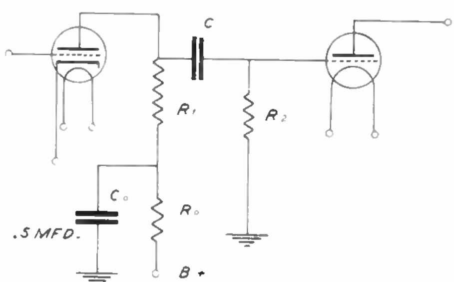


FIG. 7

ticular part of a system of this kind as the motorboating noise may be found at almost every point in the circuit and it will stop with the opening of almost any part of the circuit.

Start by trying new or good tubes. Then place a condenser either .01 mfd. or .05 mfd. of good quality in series with C of Fig. 7 just as a test. If the noise stops, replace C with a new condenser of high quality and having the same capacity value as C. If this does not prove effective, shunt R2 in Fig. 7 with various high value resistors until you find a value which stops the trouble. If you are forced to use so low a value that the gain is appreciably reduced, the plate filter is recommended. This procedure is bound to stop the AF oscillation.

In servicing receivers of the neutrodyne type—those in which triode RF amplifiers are used and definite neutralizing circuits provided, the serviceman usually makes sure the receiver is properly neutralized before attempting to localize the source of interference in a particular stage or part. Neutralization is an arrangement as in Fig. 8, whereby a voltage, exactly similar to the voltage fed-back from the plate to the grid of a triode, but opposite in phase, is fed to the grid. In this way the feed-back voltage is balanced out and the oscillation is suppressed. In one type of neutrodyne circuit the neutralizing voltage is taken from a tap on the secondary of the RF transformer of the stage it neutralizes. See Fig. 8. It is fed to the grid through an adjustable condenser —the neutralizing condenser (C1 of Fig. 8).

In neutralizing a receiver of this type, a modulated oscillator should be used—and for near perfect neutralization, two complete adjustments should be made—one at about 1200 KC. and the other at about 650 KC.

Assume that it is found necessary to neutralize an RF stage. First the tube is removed and an adapter (the type with open filament circuit) is inserted in the socket which will prevent filament current from flowing through the tube. The tube must be in place because the tube constants must be considered in making the adjustment. If an adapter is not available, one of the filament pins should be insulated so it will not make contact to the socket. This can be done by wrapping a small piece of cloth around one filament prong, or by

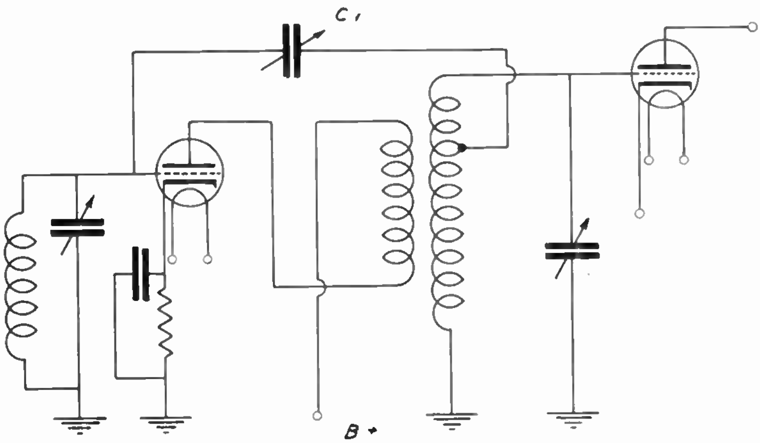


FIG. 8

slipping a short length of drinking straw over it.

For receivers using series filaments, the cathode may be insulated and in every case where a cathode tube is used, this should be the procedure. If the tubes do not have cathodes, a cut-off bias may be externally applied to the grid of the tube being neutralized —care being taken not to detach any other part of the circuit.

Then with the modulated oscillator and receiver in operation, adjust the neutralizing condenser—using a special neutralizing tool—for minimum speaker output or minimum output meter reading. When each stage has been adjusted in this way, at about 1300 KC, repeat with the modulated oscillator set at about 650 KC. If there is a great difference between the setting of a neutralizing condenser at 1300 and 650 KC, adjust half way between the two extremes, favoring the adjustment at 1300 KC because the circuit is much more critical at this frequency and thus more likely to go into oscillation.

With the receiver properly neutralized, if whistles and squeals are still heard, locate the stage in which the interference is originating and look for defects as mentioned in the foregoing.

An imperfect ground at some point in the circuit may result in oscillation, or unstable operation with consequent squeals and whistles. Make sure that all parts that are supposed to be grounded, are actually grounded, and that the receiver itself is properly grounded.

Some receivers are more sensitive to the use of a ground connection than others. For shop or work bench testing be sure you have a good ground on the receiver for this type of work.

Many receivers especially of the earlier types require fairly large antennas for proper operation. Hence they are designed and adjusted for use with large antennas. The use of short antennas or no antenna will quite often produce instability in the first RF stage, causing oscillation.

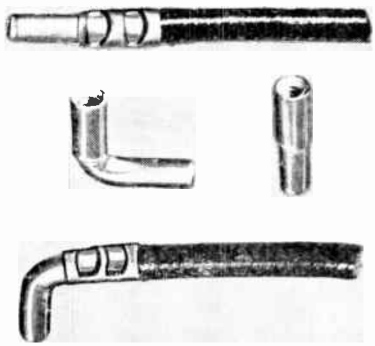
To avoid useless searching for a defect, use a large antenna or, if one is not available, load the antenna-ground circuit with resistances from 2000 to 50,000 ohms to prevent oscillation while making adjustment. Remember that this is a normal characteristic of the receiver which can only be corrected by detuning the RF circuits considerably. This difficulty has been greatly reduced in the newer type receiver as most of them use a built-in or loop type of antenna.

Actual feed-back of energy is possible from the speaker leads to the detector circuit. In this case, the speaker leads should be removed as far as possible from the detector circuit. The same is true of all the audio plate leads.

An open in one of the plate circuits will also result in audio oscillation. This open may be in the primary of an AF transformer or in the power supply. The AF transformer suspected of being defective should be tested and if found in good condition the power supply connecting lead should be traced and checked.

After ascertaining that the source of interference is definitely in the receiver, it is usually a comparatively simple matter to determine whether the defect is mechanical or electrical by listening closely to the speaker. A mechanical defect resulting in noise will *not* cause the speaker to respond —interference of this kind does not reach the ear by way of the speaker.

If you have decided that the source



Whenever an electrical joint is formed, it is subject to the development of noise. So whenever you have a noisy condition, always be sure to inspect visible joints such as those illustrated above. Make sure of good soldered connections and see that all mechanical joints are tight so that there is no chance for arcing.

of noise is electrical, the next question you will have to ask yourself is whether the interfering noise is the result of oscillation or the result of a defective resistance or intermittent contact. This can usually be determined by the audible effect of the interference. If it is the whistle or squeal type, the chances are that oscillation is taking place somewhere in the RF section. If it is of the *pop-pop* type, it is motorboating or AF oscillation. If the interference is of the frying or hissing type, you will look for bad contacts, defective resistors, condensers or for defective tuning alignment.

In any case, the stage-by-stage elimination method will lead you to the particular stage in which the interference is originating—and a visual inspection of the wiring and connections in this stage, plus an electrical test of all the parts in this stage and the associated circuits will enable you to locate the defective part or connection.

External Receiver Interference

Any electromagnetic wave or impulse that reaches the antenna system of a radio receiver will induce a voltage in it, which in turn will be fed to the input of the receiver. It is then amplified to some extent in the RF stages, rectified in the detector, again amplified in the AF stages, and converted into sound impulses in the speaker.

All this is comparatively simple, and clear radio reception at all times would be a simple matter if the wanted signals were the only electromagnetic impulses that could reach the antenna. Unfortunately the air is full of electromagnetic waves—natural and artificial, or man-made waves. The very rays of the sun are electromagnetic impulses—but of a frequency so high that they do not affect our receivers directly. Lightning flashes result in the dissemination of electromagnetic waves which *do* affect our radio reception. Furthermore, a lightning storm need not be in the immediate vicinity of a receiver for its effect to be noticed.

You will recognize this natural interference as *static* which is one of the greatest draw-backs to satisfactory long distance radio reception. In modern radio terminology the use of the word static is giving way to the expression *back-ground noise*, which is more descriptive of the effect of static on reception. For static is always present in the atmosphere, in a greater or lesser degree, depending on the season of the year, the time of day, and weather conditions. For example, there is more static in summer than in winter—more in the day time than in the night time, etc. To put this into modern radio language, the background noise level is higher in the summer than in the winter—in the day than in the night, etc.

Satisfactory radio reception requires that the signal level be much higher than the noise level—at least 12 to 20 times as high. On cold, clear, winter nights, radio reception is usually very good, and far off stations can be brought in at understandable sound levels. On a sultry summer night, the noise level might be so high that only local stations can be tuned in satisfactorily. In the first case, the *signal to noise ratio* is high, in the second, the signal to noise ratio is low.

As back-ground noise is purely a natural phenomenon, there is nothing the serviceman or the radio engineer can do about it. There have been many attempts to reduce the noise level—but no way has yet been found of reducing the back-ground noise without reducing the signal strength. And the more sensitive a receiver is, the better its distance-getting qualities—the more back-ground noise it will pick up.

This back-ground noise will vary from .25 to .5 microvolt minimum in a winter night to 50 or 60 microvolts minimum on a summer day. Its maximum for the summer time is almost without limit, depending on the distance and intensity of an electrical storm from the receiver location.

Incidentally, the noise level is practically constant over comparatively long stretches of time. This is noticed when tuned to a station that has a tendency to fade. If the volume is increased to compensate for fading, the back-ground noise usually becomes very prominent for then the noise to signal ratio is high.

Where automatic volume control is provided, the same effect is noticed, but without adjustment of the manual volume control.

For an accurate picture of this situation refer to Fig. 9. Here an average constant noise level of 20 microvolts

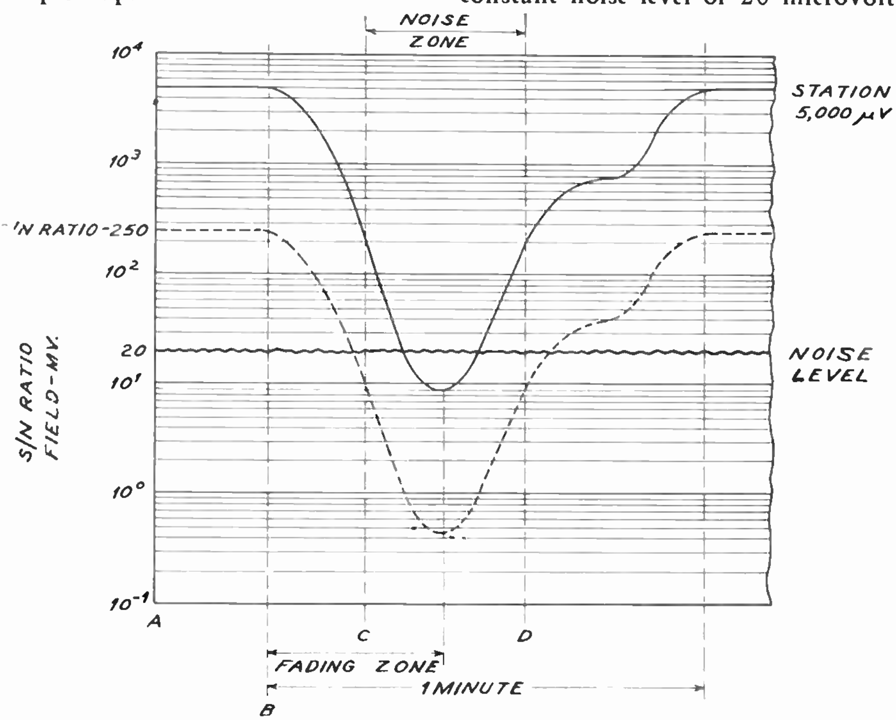


FIG. 9

marked by the wavy line identified as *noise level* has been assumed. Note that to confine this wide range of values on a single graph. the vertical divisions are logarithmic.

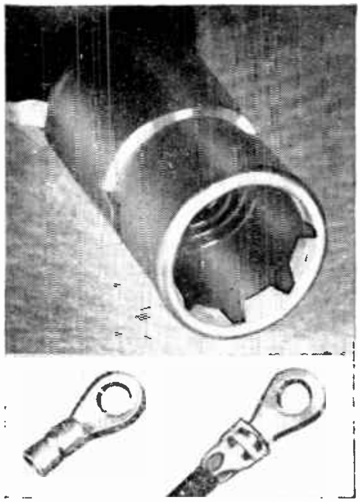
A signal intensity maximum or normal of 5.000 microvolts. as would be expected from a powerful station about 100 miles distant. has been assumed. Invaribaly from one cause or another the signal strength at the receiver will reduce. and an average case where the signal has reduced down to 9 microvolts and again increased to 5.000 microvolts all in one minute's time is shown. You will recognize this as a common experience in distant reception.

Now at the start (point A on the graph) the signal is just 250 times as strong in voltage as the noise level. Note that 5000/20 =- 250. Under these conditions. it would be utterly impossible to hear the noise as it would represent only 0.4% of the entire signal (1/250th).

At point C. where the signal has faded to 200 microvolts. with the noise. of course. still at 20 microvolts. the ratio of the two (200/20 or 10) is reduced. the noise now making up 10% of the entire signal. One curve shows the actual signal strength while the other shows the signal to noise ratio.

Further points in the complete fading zone of the incoming signal with corresponding signal to noise ratios are listed in the following table. Many values from the start at A are listed in this table.

When the noise constitutes 10 or 12% or more of the signal, it becomes audible and as it increases to 100 or 200%, it makes reception unsatisfactory as the noise is as loud or louder than the signal.



This view illustrates a compression type joint. Solder lugs are also shown all of which are possible sources of noise. Such joints must make firm contact, be clean, with no dirt, dust or corrosion present.

In this zone of unsatisfactory reception where the signal strength is below 200 microvolts. the noise will appear to increase to a maximum if AVC is used. It is obvious that the same effect will result if a manual control is used as in compensating for this fading the volume is increased which keeps the signal level. but increases the noise.

Knowing that there is no possible solution to this noise level problem, many manufacturers have made receivers having a minimum sensitivity of 100 microvolts. As long as the average noise level stays below 10 microvolts. and the signal above 100 microvolts, reception will be satisfactory. but if the signal drops below 100 microvolts, it will be inaudible, and the receiver will be silent until the signal strength again rises above 100 microvolts (this refers to an AVC controlled receiver).

Point	Signal (μv)	Noise (μv)	Ratio (Sig. to noise)	Of Noise to Signal
A	5,000	20	250	0.4
B	5,000	20	250	.4
	400	20	20	5.
C	200	20	10	10.
	100	20	5	20
	20	20	1	100.
	10	20	1/2	200
	9	20	0.45	222

This action is regarded by many as being just as satisfactory as continual reception with noise blanketing out the signal.

The fundamental cause of natural electromagnetic impulses is the breaking down or leveling out of an electrical unbalance in the atmosphere. This can be visualized if you consider the well known action of a condenser. If charged with too high a voltage, the dielectric will break down, there will be a momentary flash as the condenser discharges through the dielectric, and both plates will be in electrical balance—both at the same potential. Now if certain elements in the atmosphere become charged at opposite potentials by natural effects, or if a cloud becomes charged with the earth as the other condenser plate, at a certain point of charge, the dielectric will break down and there will be an electrical discharge. This discharge is visable in the case of lightning. Smaller discharges which result in most of the usual back-ground noise, are not visable.

The energy is sent out from the disturbance as a single magnetic impact similar to one-half cycle of a very high frequency wave. It induces this half cycle voltage in the antenna and the tuned circuits are energized just as a tuning fork or bell is energized by a mechanical impact such as being hit with a hammer. The oscillation of the tuned circuits corresponding to the vibration of the tuning fork or bell forms a carrier frequency of short duration at *any frequency to which it may be tuned.* The same hammer may energize any number of bells or tuning forks of different frequency and thus it is that such a magnetic impulse will penetrate the tuned circuits of a receiver on any frequency. Sounds will be reproduced corresponding to the wave forms produced by the *tuned circuits.* They will be received with or without a signal already being received by the receiver.

Although this problem has been dealt with by many investigators, nothing practical has emerged from the laboratory for its elimination in present day apparatus and present day situations (except for FM which largely overcomes most electrical noises).

It is the serviceman's problem to be able to recognize the difference between this type of external interference and be able to distinguish it from man-made interference which can all be eliminated by the proper steps. This natural interference is rarely objectionable in the winter time so far as its interference with entertainment is concerned as it is only serious for the distance (dx) fan, the amateur operator in dx work and the short-wave dx fan. Its main objection is in the summer season on occasions when an electrical storm in the vicinity is in progress. The serviceman can do nothing about this condition with the receiver, or transmitter as there is no solution to it under AM transmitting conditions.

Man-Made Interference

Artificial or man-made interference results from exactly the same sort of magnetic impact or impulse action. Such a magnetic impact will be formed anywhere that an *electrical current is rapidly stopped or started.* The entire problem of man-made interference consists in finding where any electrical circuit is rapidly broken or connected. There are a vast number of such cases to be found in every house and in every town and city.

The various sources of man-made interference fall into rather definite classifications. This study will be greatly simplified and clarified by so dividing the subject. For example, there are two main classes of man-made interference sources: (1) Those which result from the normal operation of electrical apparatus, and (2) those which are due to defective circuits or appliances. For example, interference resulting from an electric motor, and ignition system for an oil burner or a sign flasher would come under the first classification, and interference due to a defective electric lamp, a loose connection in the power line or a defective electric plug comes under the second classification.

The serviceman must be prepared to suppress unwanted interference due to apparatus which normally creates it and to prevent it from other sources which cause it *only because of a defect.*

The electric motor will be considered first. While it is almost impossible to describe all of the possible applications of electric motors in the home, some of the more common uses are listed below. This complete list is given so that the serviceman may call attention to all of these possibilities to the owner of the receiver who may not suspect the source of trouble.

Vacuum cleaners.
Sewing machines.
Washing machines.
Ironers.
Hair dryers.
Massage vibrators.
Electric razors.
Oil burners.
Drill presses.
Electric refrigerators.
Automatic stokers.
Fans and power ventilators.
Water pumps.
Water circulating pumps.
Dish washers.
Electric eggbeaters and other powered kitchen ware.

Motor generator battery chargers.
Air-conditioning blowers.

Contrary to popular belief, motors are not the major sources of radio interference. The larger the motor the more true this becomes because in the interest of efficiency of the motor the voltages within it are made to rise and fall as gradually as possible. This is done through the use of interpoles, correct brush settings and in many other ways.

Trouble arises when the motor is out of adjustment, overloaded, or actually defective, due to an internal short. A dirty commutator or badly worn brushes will sometimes cause trouble.

First, it will be assumed that the motor is in good condition and is causing slight but noticeable interference in the receiver. The interruption of current drawn into the motor armature causes magnetic impacts in the power line to which the receiver is connected. These impact waves radiate from the line whenever it is exposed and the radiations travel to the signal input or antenna connection of the receiver. This may take place inside the chassis of the receiver where the power line connects to the power transformer or it may take place between the elevated power feeders to the house and the antenna or both.

Because of the possibility of induction of this impact to any part of the antenna and lead-in as well as to the first or second RF stage within the receiver from any part of the power line, it is obvious that the best cure of the interference is to *stop it at its source*.

The first step is to start the motor with the receiver on and note the interference. Although lacking the low frequency vibration, the reproduced noise will sound very much like the motor itself. Now with the motor running and the radio receiver turned on, use a test circuit as in Fig. 10, touch the lead which is attached to the shield to ground and the other to each brush terminal individually. Regardless of the type of motor or the number of brushes, this circuit should be used. For a 110 volt line a 400 volt condenser must be used and for a 220 volt line, an 800 to 1000 volt condenser must be used.

Where attached to the one or more brushes which are grounded, there will be no change, but on one or more other brushes the motor interference in the radio receiver will be definitely reduced or eliminated. In some cases each of two brushes may cause a similar disturbance in which case one condenser should be attached to each brush, as for the test, while successive brushes are tested for interference. The test leads should not be more than a few inches to a foot long and should be well insulated over the shielding of the leads to prevent shock. This same value of capacity (.1 mfd.) should be used for all motors large and small, AC or DC.

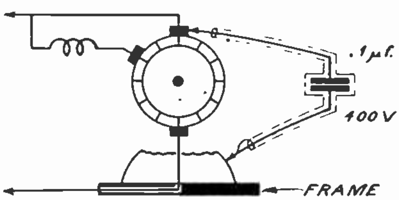


FIG. 10

While there are almost as many different kinds of motors as there are radio receivers, this remedy will apply to all of them. If a motor has no brushes or commutator, it cannot cause interference in this way. In other types of motors having brushes for starting only, these may be treated in the same way.

When the test circuit definitely stops interference a condenser having the same rating as that used for testing should be permanently connected from each of the brushes where interference was found from ground to the frame of the motor. In certain rare cases, it may be necessary to ground the frame of the motor to a cold water pipe if this is not already done. Never use *electrolytic condensers in this work*. The leads should be insulated, as short as possible and make the best possible permanent connections to the brushes and ground.

This is impractical in some cases, because of the limited space available or for appearance sake. A vacuum cleaner or hair dryer motor, or an electric razor motor are good examples of this. Here the same thing can be done with a small plug type filter. Two common types of these small filters are shown in Fig. 11. At A one is connected to a shielded line with 3 contacts, two for the line and one for a ground. It is attached as near as pos-

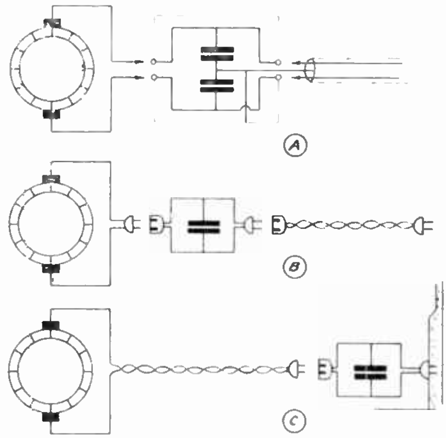


FIG. 11

sible to the line leading to the motor brushes and has a condenser from each brush to ground so that it will suppress interference from either brush. A simpler form is shown at B, which is widely used where one side of the line is grounded as for the usual case. This will work perfectly in most all cases, if it is placed closely enough to the motor causing the interference. At C is shown another method of using a filter of the type shown either at A or B. It is attached at the wall socket end of any motor appliance having a 5 or 6 foot cord. In some cases, this will fail due to the radiation from the line between the motor and filter, but it should be *tried* first in every case, as it is by far the simplest installation. Just plug in the filter and then plug the appliance into the filter socket.

A more complete filter as in Fig. 12 is used in motor and other installations where the plain condenser type will not completely stop interference. It consists of two RF choke coils and two condensers wired as shown. The choke coils are not at all critical in inductance value, but obviously the line current to the motor must flow through them. The wire of which they are wound must therefore be as large as the wire of the line itself. In many cases 25 turns of No. 14 to 18 wire wound on a 2 inch diameter coil form will be satisfactory, while in other cases 75 to 100 turns must be used. These *choke coils* suppress the rapid charging currents of the filter condensers when a very great amount of interfering noise would be created. As the amount of interference cannot be easily measured, the type of filter needed may easily be determined by test. For example, if interference still exists after the tests as described for Fig. 10, the choke coil filter may be necessary. Filters of this type are available on the market. They are designed and specified for various types of standard appliances from actual field conditions.

Where the simpler methods as described, fail to give the proper results, it is better for the serviceman to purchase these filter units ready made than to try to duplicate laboratory and field research which is already developed.

As for motor defects, this matter lies entirely with you as to whether you want to go into it or not. You can easily recognize motor troubles by excessive vibration, sparking at the commutator, noisy operation, overheating or blown fuses. Overloads are

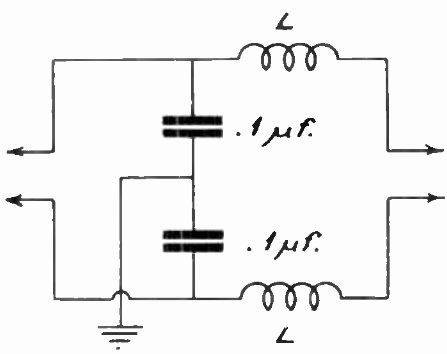


FIG. 12

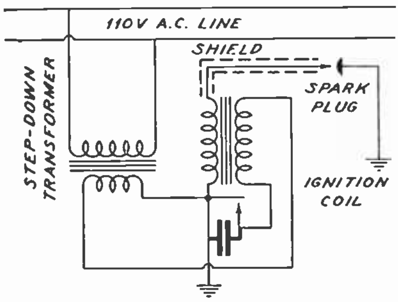


FIG. 13

detected by noting that the motor draws more than its rated current from the power line.

Circuit Interrupters

Circuit interrupters are more varied in type and style than motors and all of them cause serious radio interference while in normal operation. The best approach to this problem is to classify intentional circuit interrupters into groups of *single isolated interruption and continuous interruption*. The first type includes the electric appliance switch and the automatic thermostat relay control, while the second type is best demonstrated by the violet ray machine, the door bell buzzer, or the continuous spark type oil burner ignition system.

It must be recognized from the start of this study that the first type of isolated interruption is usually disregarded. For example, almost every time a light or heater is switched off, there is a sharp click reproduced by a radio receiver in operation. This happens much less frequently when the appliance is turned on. This is not ordinarily regarded as objectionable unless in a large hotel or apartment house where each listener can hear every switch that is turned off in the building. Curiously enough this type of interference requires much more thorough filtering than for a motor as it causes a maximum electrical impact to be radiated. Usually the cost of individually filtering each unit is not justified and rarely if ever is attempted. In a broadcast studio where microphone pick up of this disturbance would be possible, this might be done, but rarely if at all elsewhere. A .1 mfd. condenser shunted across the switch contacts will sometimes prove effective.

Ignition Systems

For some types of oil burners for heating systems or hot water systems having no continuous pilot burners, continuous ignition systems are used. Their wiring is shown basically in Figs. 13 and 14. In one case, the interrupter armature is grounded and in the other case it is not. In all cases, noise from the interrupter may be stopped by placing a .5 to 1 mfd. *paper* condenser (220 volt minimum) across the vibrator contacts. The leads connecting the condenser to the contacts should be as short as possible. This will reduce the impact in the primary circuit as the contacts open and thus prevent radiation.

The secondary or spark plug circuit is often responsible for radiation. There are three ways to suppress ra-

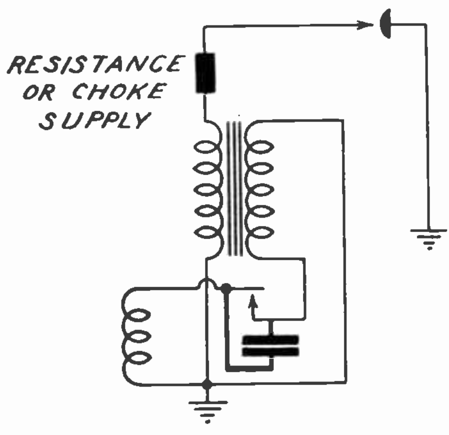


FIG. 14

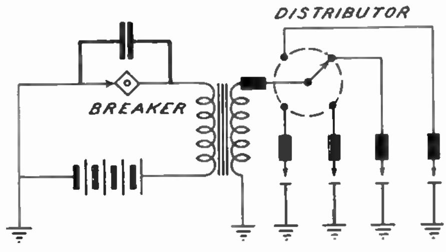


FIG. 15

diation in this circuit: (1) Shield the high tension leads to the spark plug or plugs. (2) Place a resistance suppressor in each spark plug lead (and distributor lead in the case of an engine). The suppressor resistance values range from 10,000 to 25,000 ohms and ordinarily does not affect ignition. (3) Place RF choke coils in the spark plug lines and distributor line.

A typical ignition suppressor system for a motor is shown in Fig. 15. This subject is covered thoroughly in your study of automotive installations.

A very simple type of sign flasher not showing the mechanical or electrical means for time delay is given in Fig. 16. Here again, condensers are simply placed across the relay contacts to suppress the noise. These flashers of the circuit breaker type may have only one contact or a great many. It is possible in the case of a great many contacts to put a line filter in the main line supply and thus prevent the interference from traveling in the power line. Another method is to use a multiple section filter, connecting a condenser or a coil and condenser in each contact circuit.

A rotary contactor is often used in which case each stationary contact may be by-passed, while the rotor hub may be grounded or by-passed. If neither contact is grounded, a filter as in Fig. 17 is recommended. This, of course, applies to any case of this kind, and not only to the rotary unit.

There is a wide variety of uses for multiple contactor devices in the home and shop and store, where there is usually occasion to use a radio receiver. In the home continuously operating contactors are not very numerous or common. An ignition system as described, a door bell, a dial telephone, and possibly a mechanical battery charger would complete the list. In small shops and business property one might add one or all of the following:

Adding machines.
Billing machines.
Addressing machines.
Cash registers.
Computators.
Business sorting machines.
Magneto telephones.
Annunciator buzzers.

Many of these, of course, have motors in addition to contactors which must be treated for both possibilities of noise production. Since the casings of practically all of these devices are of metal, they are effectively shielded from radiation. For

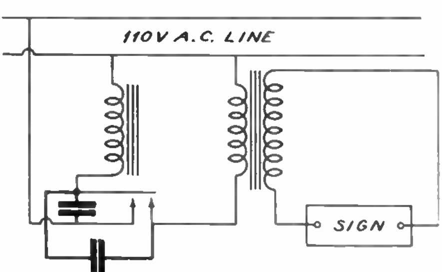


FIG. 16

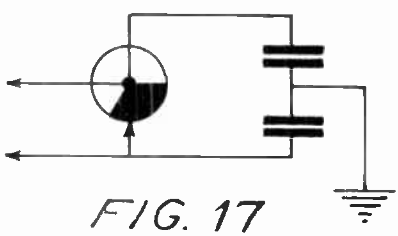


FIG. 17

this reason, usually a line filter will take care of the problem. The type and location of the antenna for the receiver has considerable to do with this noise pick-up and this will be treated further on in this lesson.

There are many types of devices which will produce a regular or rhythmic clicking or sputtering interference although single contact circuit breakers are used. These are traffic light signals, vault time clocks, elevators and their controls, telephone switchboards, telegraph relays and others. They yield to the same treatment, but if the trouble is definitely localized in any of these devices, permission must be obtained from the companies operating the equipment to effect cures of the trouble. Ordinarily this apparatus is kept up rather well and will rarely cause serious trouble.

High Tension Apparatus

By far the most difficult types of noise sources to control are various types of high tension apparatus. This may include:

X-ray apparatus.
Medical induction coils.
Infra-red ray generator.
Violet ray apparatus.
Diathermy machines.
Arc sun lamps.

Most of this list consists of high voltage apparatus. A line filter will as usual, prevent noise from escaping into the supply line, but nothing can be done to the secondary circuits to prevent radiation as this would usually destroy the utility of the apparatus. Shielding cannot be completed as the apparatus must be partially exposed during use and resistance suppression or choke coil suppression of the apparatus would in most cases, render it useless.

Fortunately, the direct radiation does not usually get very far from the source. This indicates that a transmission line type antenna may usually be used with success in this connection.

The usual antenna is simply a wire used as a pick-up device for magnetic radiation. Its pick-up properties are practically the same for any part of its length from the tip of its remote end to the receiver antenna lead or binding post and further into the receiver if it is not shielded. Where RF coils are unshielded, they furnish part of the pick-up themselves, just as the antenna. While the antenna and lead-in are usually thought of as two separate sections of an antenna system, they are as one to the magnetic wave. Signal voltages will be induced in any metal or conductor in the path of a magnetic wave.

The noise-free antenna is simply a means of separating the pick-up section of the antenna from the receiver. Here, as usual, the entire antenna and transmission line pick up signals, but those picked up by the transmission line are grounded and do not affect the receiver input. Thus the actual antenna may be placed outside of an interfering zone while the signals may be brought through the interfering zone to the receiver.

For example, in Fig. 18 is shown the top view of a house in which there is a laboratory or clinic or in which any one of the last mentioned devices are used. The interference travels to the power line by induction and from there is induced into the telephone line, the plumbing and lighting fixtures, any buzzer or annunciator systems, etc. The house is completely surrounded by an interference field 10 to 15 feet or more from its walls, and thus far in every direction from telephone and overhead power lines there is an interference field.

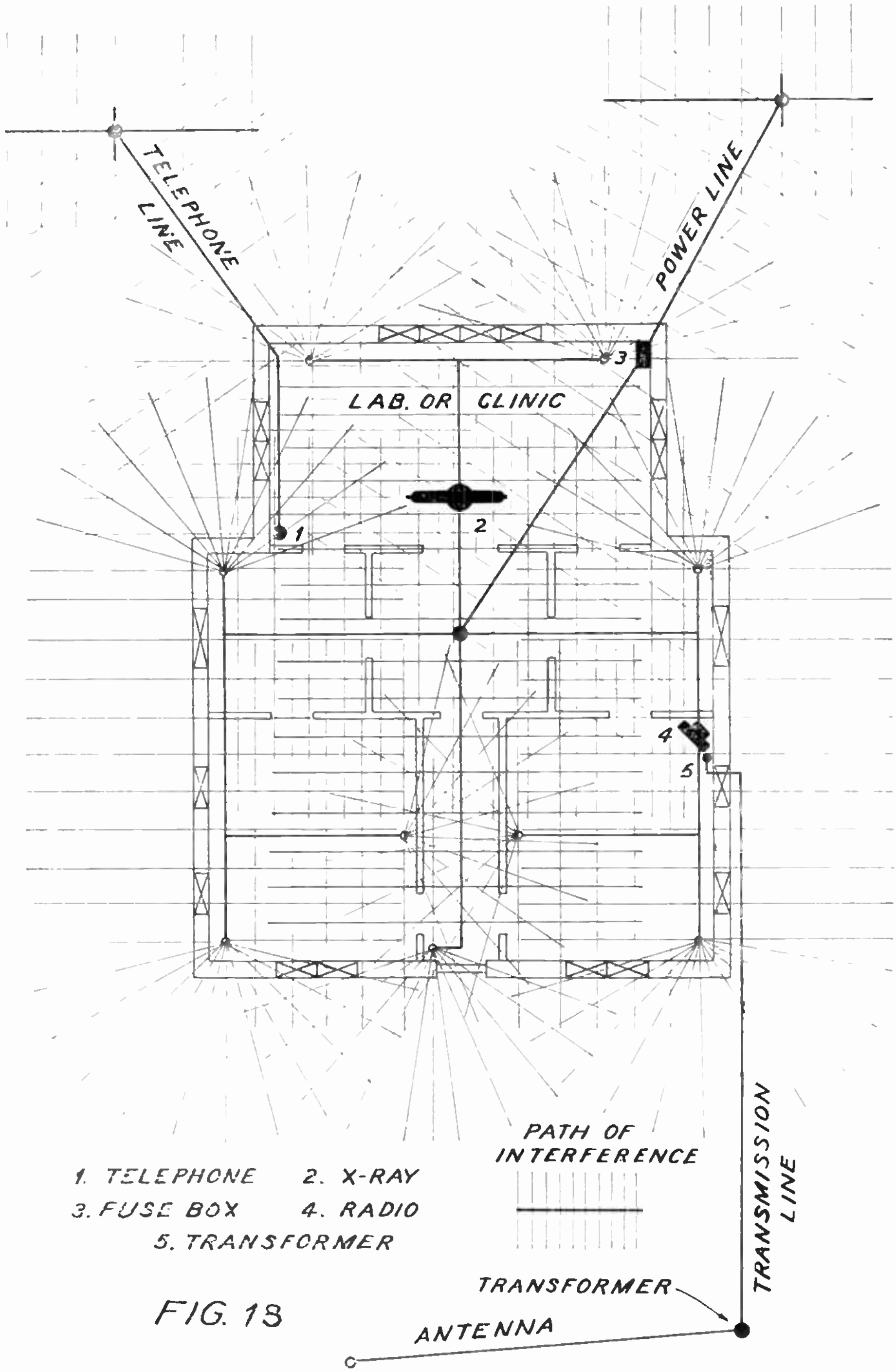

TELEPHONE LINE
POWER LINE
LAB. OR CLINIC
1
2
3
4
5
PATH OF INTERFERENCE
1. TELEPHONE 2. X-RAY
3. FUSE BOX 4. RADIO
5. TRANSFORMER
TRANSMISSION LINE
TRANSFORMER
ANTENNA

FIG. 18

Now, if the receiver is properly shielded and a line filter is used at the X-ray or other interfering device, or at the receiver (preferably at the former), a transmission line as shown may be used. The actual antenna is out of the interference field and the transmission line brings the signal through perhaps 40 or 50 feet of the interference field without conveying any noise to the receiver.

The only other possible alternative is to completely shield the room in which the high tension apparatus is used. This is quite expensive and is, therefore, rarely done or recommended.

Interference of this kind may be conducted over any insulated metallic system, such as a power line, a telephone, a fire alarm system, a metal fence on wood poles for several blocks in many severe cases. Its intensity is, of course, reduced with distance, but to a lesser degree the same sort of interference pattern will be set up in neighboring houses because of their common connection by power and telephone lines. Gas and water mains will not conduct interference from one house to another, because they are grounded.

Bear in mind, that a line filter will not stop this trouble as interfering signals will be induced in the lines within the room in which the device is operated.

When a source of interference is identified as being due to some sort of high tension equipment as described and the owner is unwilling to shield the room in which it is operated, every receiver owner within a block or two must use noise free antennas to avoid this trouble.

Of course, any type of interference will traverse a power or telephone line and the distance it will travel depends largely on its original power. For this reason, wherever possible the interference should be suppressed at the source.

Defective Apparatus

A type of interference which may be eliminated simply by repairing the apparatus causing it will now be considered. The apparatus referred to normally cannot cause any interference, but does so because of a defect.

In the wiring of a house, there may be a partly burned fuse, a loose fuse, a poor switch contact or a current leak through insulation which has broken down. Any of these will cause intermittent spurts of current and hence interference. An electric light bulb or lamp may burn out and an arc may take place between two broken filament ends. This will cause a severe interference. A switch may make poor contact causing a constant arc. A metal sheathed cable may have been under water causing insulation breakdown and arcing may take place between the wires. Any defective appliance will produce the same effect as though the house wiring were not in good shape. All of these defects may be localized by detaching one circuit or appliance after another until the interference ceases.

A very unusual source of trouble will be found in all heater elements, such as electric irons, toasters, heaters, stoves, etc. Because of high operating temperatures the nicrome or iron alloy wire heating element cannot be soldered to the copper wire line cord. Attachment is often made by riveting. Continual expansion and contraction of the rivet will loosen the connection, and moisture will usually corrode the heater wire. A poor connection which will cause sputtering and arcing will result. Remove and clean both contacts, and replace with a bolt, using

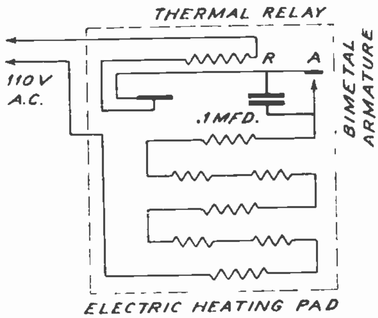


FIG. 19

several lock washers and one or more brass washers if possible. This will allow for expansion while heating.

Thermo-electric relays or thermo-relays are used in connection with oil burners, heating pads, poultry incubators, fireless cookers, waffle irons, acquariums. etc. Ordinarily they will open and close their circuits in accordance with their operation to maintain constant temperature causing only a click of interference every 15 minutes to 1 hour. Normally this would not be regarded as troublesome interferance any more than switching off a light. However, the contact points on these thermal relays often become oxidized and pitted causing continuous arcing or intermittent arcing. A typical thermal relay is shown in Fig. 19, such as is used for a heating pad.

While it is possible to put a condenser across the contacts R-A it is much better, both for a complete cure of the defect and for the safe operation of the appliance, to file or sand-paper the contacts just as you would do for a vibrator or auto distributor. The clicks reproduced by a receiver when the contacts are opened may be eliminated by shunting the contacts with a 0.1 mfd. condenser.

Bonding

In attics, walls and basements of houses there are various electric cables, pipes, etc., which often have a chance to touch each other on occasions, when people walk on the floor, or when trucks pass by the house causing vibration. Frequently these pipes and cables are not connected at every point where they cross or run parallel. Even if they all have a common ground, if they touch on occasions their ends will invariably be at slightly different potentials and current will instantly flow from one to the other. This will cause interference by impact waves and may be quite loud in a sensitive receiver. Numerous cases have occurred where a BX cable has been run over a cold water or gas pipe in such a way that the slightest vibration will change the contact resistance between them. The contact may normally be good and is intermittently broken or it may be open and be intermittently closed. Noise will be the result of either case.

Do not overlook any possibility in this case, as such occasional connections between any two of the following may cause serious interference:

Stove pipes.
Gas pipes.
Metal clothes lines.
Electrical drop cords (metal).
Gutter and spouting surfaces.
Water pipes.
Electrical cable.
Wire or screening in storage.
Metal roofing.
Stoves and furnaces.

Repairs may be effected by either permanently connecting any two such surfaces with a ground clamp or by permanently keeping them separated by tape, wood supports or insulating supports.

These items are difficult to locate, but the best way to find them is by inspecting all possible places where it appears that two metal surfaces touch, and jar or tap one of them, noting the result. If the trouble is suspected between the walls, a BX cable can frequently be pulled tight at one end, eliminating the trouble.

A very unusual source of interference is discovered at times. It has long been known that wherever two dissimilar metals are joined or where a joint between two metals includes a corroded coat on one metal, the metal circuit has *rectifying qualities.* These qualities of favoring current flow in one direction are often called nonlinear properties.

It must be realized that this condition can occur at any pipe joint or coupling. The result of radio waves intercepting these pipes as in practically every house is the production of audio frequency current flow. In a few isolated occasions where this audio frequency voltage generated was accidently applied across two adjacent metal surfaces the AF was reproduced from a nearby powerful radio station.

At a considerable distance, two radio signals widely separated, say 600 and 1450 KC, may both be rectified forming an RF beat of 1450-600KC or 850 KC which can be tuned in by the receiver. This 850 KC signal will carry the modulation of both the 600 KC and the 1450 KC stations. The pipe or cable system which receives these signals also radiates the third.

If it is relatively near the receiver antenna the intensity need only be 10 to 15 microvolts to be picked up. Obviously, this would interfere seriously with any regular station assigned to 850 KC. Although not prevalent, this type of interference has been found and measurements have been made proving that this is the source of trouble. The cure is obviously to couple the two sections of pipe with a ground clamp. This trouble may be so obscure as to be impossible to identify, but you can quickly short various pipe sections and note the results. This prevents rectification and stops the interference.

Outside Line Interference

Leakage of power lines and poor connections are costly to an electric power company or to the telephone company, and hence their line equipment is generally kept in good order. Too often the owner of a radio receiver or the serviceman is tempted to throw the blame for interference on one of these companies. They are responsible for far less than 1% of the interference for which they are blamed.

If the tap on a service feeder transformer opens and arcs either constantly or intermittently, the interference will radiate in both the primary and secondary circuits from 3 to 4 miles on overhead wires. If a pole transformer insulation breaks down, the same will be true. This interference will usually cover a complete section of a city or a large rural section. For the underground conduit, the interference will be damped out in a mile or so of cable but nevertheless is undesireable.

An open tap at a house line connection where the overhead wires are joined to the house wiring, will cause interference which will travel back through the service transformer chiefly through parallel line coupling or capacity coupling and from the main power feeder it will travel to other service transformers and hence into other secondary lines perhaps for a half-mile or more. A filter cannot correct this condition as it is simply a matter of correcting the fault.

Many of the power companies use interference locating receivers with output meters for quantitative as well as relative measurements. This is simply a sensitive TRF receiver using a loop antenna which may be turned in the direction of the signal. The direction of the interference radiation may thus be determined and it may be traced to its source. The serviceman should never attempt to remedy power line noise of this type. If he finds a power transformer or other power equipment causing radio interference, he should notify the power company.

Street Car Interference

The interference due to a street car or electric locomotive with overhead trolley has no solution at its source. The contact of the trolley wheel at the wire feeder cannot be perfectly constant. At practically every welded connection or wire support coupling there is a change in conductivity as the trolley wheel rolls over it. Even on the free suspended part of the line during starting load there is usually a change in conductivity. The numerous arcs formed at the trolley while the car is in motion are an indication of serious current surges. These may amount to 50 or 60 amperes and the impact radiation is quite severe.

To a great extent, interference may be controlled in receivers located near trolley lines by transmission line type antennas. The antenna proper should be placed as far as possible from the trolley line and at right angles to it. Fortunately the induction field surrounding the trolley wire dies out quite rapidly with the distance from the trolley and magnetic coupling to the trolley line is minimum when the antenna is at right angles to the trolley line.

Although radiation takes place all along the line, this means is usually effective and is the only practical means known to control the interference. It will not be 100% effective in all cases, but is worth trying in all cases.

Although the controlling mechanism of elevators is somewhat different from that used on street cars or locomotives, the power line is often the same. Many elevators operate directly from the 440 to 600 volts DC used for the car line. The control of interference is not essentially difficult for such elevators, but should be attended to by the elevator company. It is simply a matter of by-passing each relay contact with a large condenser, and each motor brush. Since DC is used, large capacities may be used as there will be no reactance l e a k a g e in the circuit. The voltage ratings of the condensers must be exceedingly high to take care of the voltage surges. Transmitting condensers are recommended. There is not much advantage in using capacity values in excess of .5 to 1 mfd., but the voltage ratings should be from 3000 to 5000 volts DC. Although DC is used here, electrolytic condensers cannot be used because of the danger of induced voltages of reverse polarity.

In elevator installations using 2 or 3 phase AC supply at 440 volts the problem becomes somewhat more difficult. Low capacities must be used and their voltage ratings must be at least twice the peak voltage which would make them considerably over 1000 volts. With the larger capacities or the higher voltage uses it is recommended that a series resistance be used to limit the charging current. This current will be extremely large if some means is not used to control it. If a choke coil is used, a condition of resonance will be established, causing radiation. With a series resistance of low ohmic value but with a high power rating, the problem may be solved. This resistance should be a large wire wound unit rated at from 100 to 1000 watts and at 20 to 100 ohms. The lowest value which will be effective is recommended and it is wired in series with the condenser connection. It is well also to put a fuse in series with these high voltage condenser installations to protect the line in case of a serious condenser failure. It would not be uncommon to use 100 ampere cartridge fuses in this case. The condenser charging current may often exceed this value without blowing the fuse because of the short duration of the current flow. The use of fuses in series with condensers is a good practice in every installation to prevent damage to the line.

In this lesson electrical interference chiefly of a disturbance nature has been considered. There are, of course, many other kinds of interference, such as heterodyne interference, harmonic radiation, wave interference and others totally outside of the receiving apparatus. These subjects are covered in turn in other sections of your SAR Course. They are readily distinguished from noise voltages.

A valuable aid in locating external interference and also for determining if the interference is internal or external, is a small portable combination battery and power line receiver. Operating this test receiver from the same power source as the receiver in question and the noise is evident it is apparent that the interference is external. This interference as has already been mentioned can get to the receiver in two ways, the antenna and also through the power line, or it may enter through both. If upon shorting the receiver antenna to ground no noticeable difference in the noise is noted you may be reasonably certain that the noise is not entering through the antenna of the receiver but you can not tell from this test if it is entering through the power line or if it originated in the receiver itself. This is where the test receiver can speed up your testing. If by operating the test receiver from the same power outlet the same noise is heard then the noise is external and entering through the power line. Now in case the noise is entering through the antenna this test receiver can be of further aid. This small portable receiver is usually provided with a directional loop antenna and where the interference is picked up by the outside antenna from a trolley line, power line or any other source where you cannot correct the interference at the source the portable test receiver can aid you in locating the direction of the maximum interfering signal. (A loop antenna has directional properties as you will remember from your previous studies). This will give you the correct information as to which direction to place the receiving antenna for eliminating this interference. This is done by rotating the portable receiver while operated from the batteries until the interference is at a maximum. The direction of the interference is then in direct line with the axis of the receiver loop. The correct position for the antenna installation should be along this same axis—that is the antenna should point in the direction of the interference for minimum pickup.

This same receiver can be used to trace down causes of interference. If you find a whole neighborhood troubled with the same type of interference it may prove profitable to locate the cause and either cure it yourself or inform the owner or operator of the apparatus causing it so that steps can be taken to eliminate the cause. Do not attempt to eliminate interference caused by power lines and other types of public utilities. Instead notify the proper authorities and they will take steps to eliminate the cause.

Interference both external and internal comprise a good portion of the serviceman's work on receivers. Thus it is very important that he understands the cause and the cures of all types of interference. This lesson was prepared with this idea in mind and the majority of the causes of interference and how to cope with them are discussed.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 What two things may be done to definitely determine if interference is caused from within a receiver?

No. 2 What is the quickest and best way to localize the source of interference to a particular stage?

No. 3 When a defective resistor is located, what should be done to insure that the replacement unit does not develop the same defect?

No. 4 Name several conditions which would cause noise when the tuning control is rotated.

No. 5 How can motorboating be distinguished from oscillation?

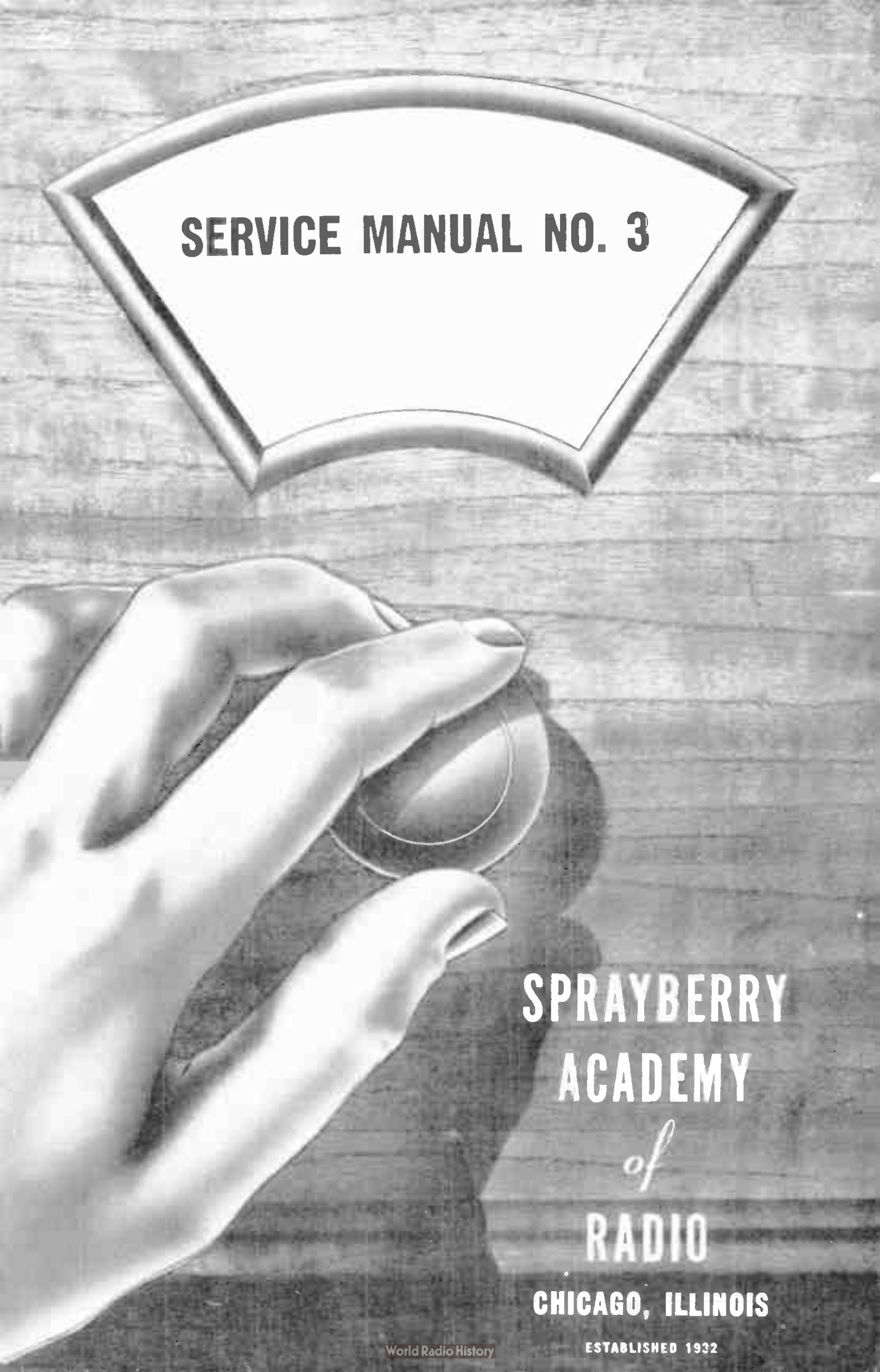
No. 6 What are the two general classes of external radio interference?

No. 7 Does interference have a definite frequency which might be tuned out of resonant circuits?

No. 8 If you traced interference to a motor and found it to be defective in operation, would you apply an elaborate filter or recommend that the motor defect be fixed first?

No. 9 Is interference best corrected at the receiver or at the device causing it?

No. 10 Why should a filter condenser be placed as close as possible to the electrical interrupter contacts which it is filtering?


SERVICE MANUAL NO. 3
SPRAYBERRY ACADEMY of RADIO
CHICAGO, ILLINOIS
ESTABLISHED 1932

K11472M

SERVICE MANUAL NO. 3

This is the third in a series of Service Manuals of wiring diagrams and service information on radio receivers in general use.

The following brief descriptions of these receivers may be used as references for the purpose of comparison and analysis of similar receiver circuit types.

MANTOLA (Goodrich). Page 2. Portable AC, DC and battery operated receivers.

MAJESTIC. Page 3. Broadcast and short-wave AC operated radio phonograph combinations.

MAJESTIC. Page 4. Eight tube radio phonograph combinations. Note voltage regulator circuit.

MECK. Page 5. Conventional six tube, AC-DC, broadcast band receiver. Note resistance type filter.

MOTOROLA. Page 6. Typical AC-DC receivers. Note open-ended oscillator coupling coil No. 5.

MOTOROLA. Page 7. Nine tube, AM, FM and radio phonograph receivers covering tuning ranges of 535 to 1620 KC; 5.6 to 12.2 MC and 88 to 108 MC. Note special type FM tuning units.

MOTOROLA. Page 8. Eight tube automobile receiver with push-button tuning. Use OZ4 or 6X5 rectifier.

NATIONAL UNION. Page 9. Typical six tube AC-DC receiver.

OLDSMOBILE. Page 10. Manual and mechanical tuned six tube automobile receiver.

PACKARD-PHILCO. Page 11. Eight tube automobile receiver with push-button tuning.

PACKARD BELL. Page 12. Ten models of radio-phonograph combination receivers.

PHILCO. Page 13. Thirteen tube, broadcast and short wave receiver with wireless remote control.

PHILCO. Page 14. Eight tube, broadcast and short wave radio-phonograph combinations.

PHILCO. Page 15. Eight tube, broadcast and short wave receiver. 115 or 230 volt operation.

PHILCO. Page 16. Seven tube broadcast and short-wave receiver.

PHILCO. Page 17. Fifteen tube, five band receiver with Automatic Frequency Control.

PHILCO. Page 18. Nine models of typical five tube receivers.

PHILCO. Page 19. Four models of typical six tube receivers.

PHILCO. Page 20. Portable AC, DC and battery operated receiver.

PHILCO. Page 21. Universal type, six tube automobile receiver.

PHILCO. Page 22. Broadcast, short wave and FM receiver with push button tuning.

PHILCO. Page 23. Table model, radio phonograph combination. Many changes have been made in this receiver, in the filter circuit, IF transformers, etc.

PHILCO. Page 24. Table model, broadcast range, radio-phonograph combination.

PHILCO. Page 25. Broadcast and short wave console model radio phonograph combination. Note bass compensation circuit.

PHILCO. Page 26. Eight tube broadcast and short wave radio phonograph combination.

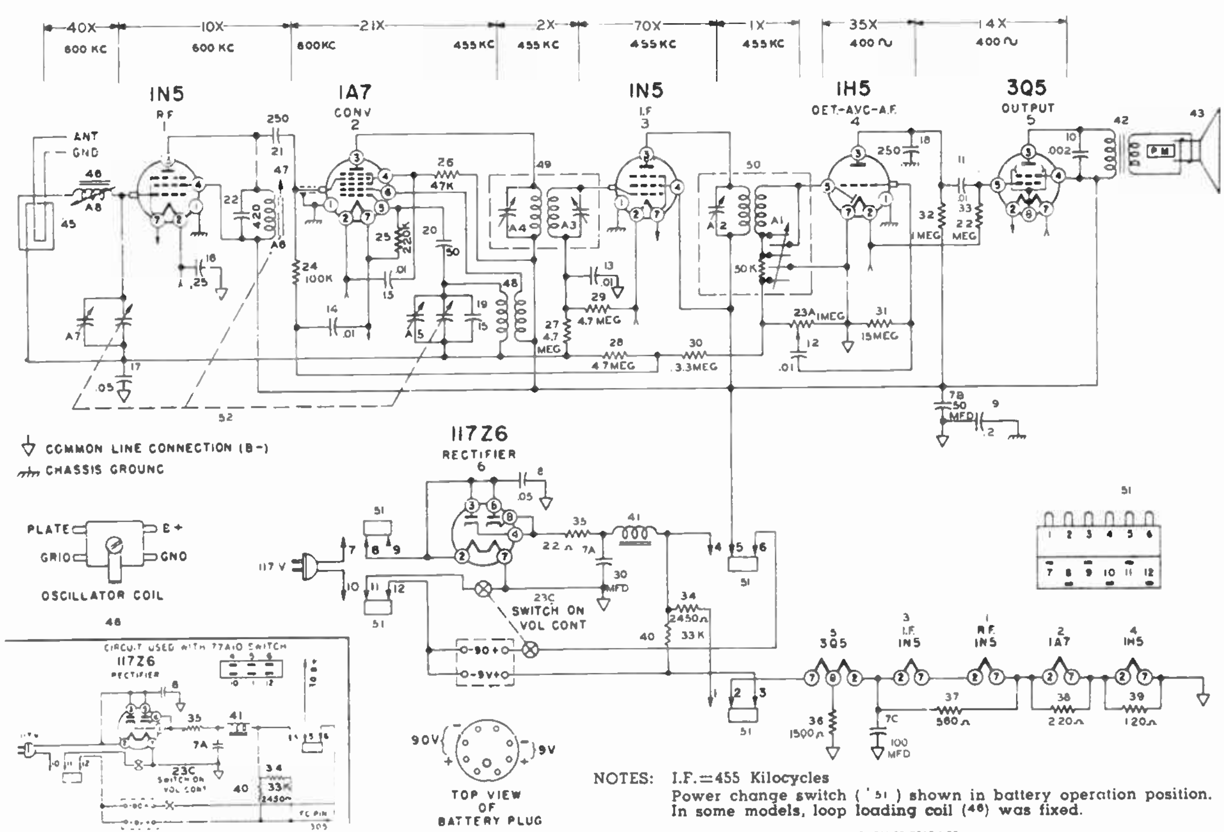
PHILCO. Page 27. Nine tube broadcast, short wave and FM radio phonograph combination.

PILOT. Page 28. Six tube, table model broadcast and short wave receiver. Note the power transformer circuit.

PONTIAC. Page 29. Seven tube receiver with push-button tuning.

MANTOLA
GOODRICH

MODELS R662 R662N



NOTES: I.F.=455 Kilocycles
Power change switch (51) shown in battery operation position.
In some models, loop loading coil (46) was fixed.

VOLTAGE READINGS

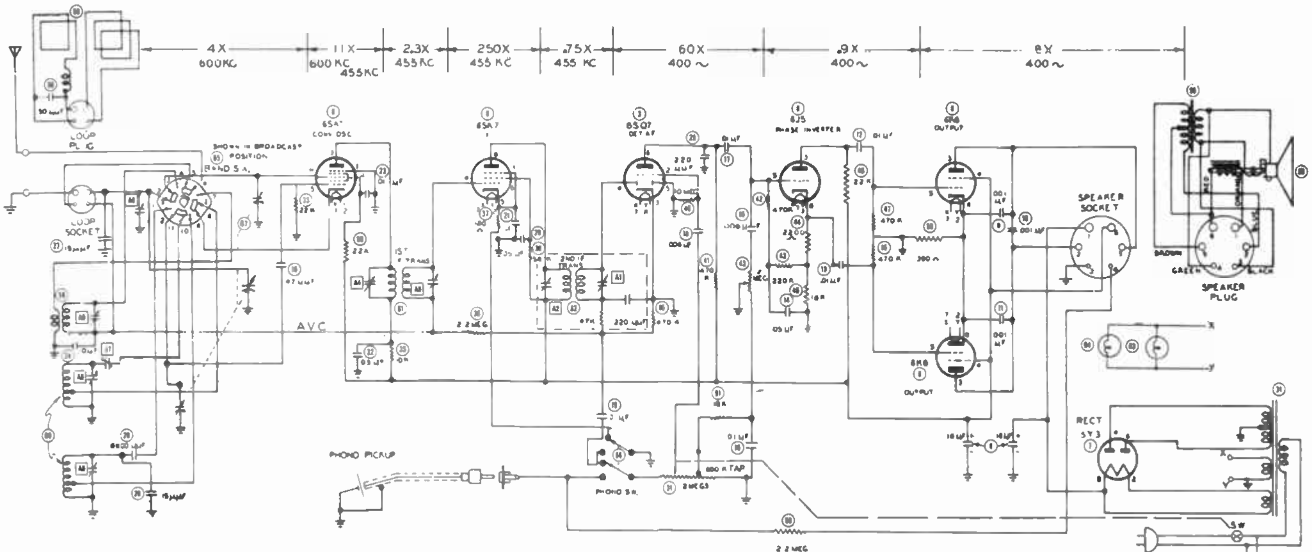
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Cap
1	IN5GT	OV.	4.4V.DC	110V.DC	110V.DC	OV	OV	2.8V.DC	OV.	OV.
2	IA7GT	OV.	2.8V.DC	110V.DC	80V.DC	OV.	110V.DC	1.4V.DC	OV.	OV.
3	IN5GT	OV.	5.8V.DC	110V.DC	110V.DC	OV.	2.9V.DC	4.4V.DC	OV.	OV.
4	IH5GT	OV.	1.4V.DC	65V.DC	OV.	OV.	OV.	OV.	OV.	OV.
5	3Q5	OV.	58V.DC	100V.DC	107V.DC	OV	OV.	8.2V.DC	70V.DC	
6	117Z6GT	OV.	117V.AC	117V.AC	127V.DC	117V.AC	OV.	OV.	127V.DC	

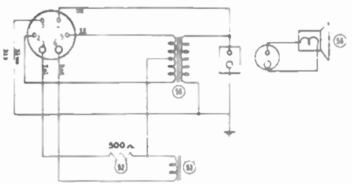
RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Cap
1	IN5GT	INF	45Ω	2200Ω	2200Ω	INF	3.2MEG	33Ω	INF	INF
2	IA7GT	INF	33Ω	2200Ω	48KΩ	220KΩ	2200Ω	18Ω	3.2MEG	3MEG
3	IN5GT	INF	55Ω	2200Ω	2200Ω	12 MEG	33Ω	45Ω	INF	3.2MEG
4	IH5GT	INF	18Ω	1MEG	2.2MEG	1.1 MEG	0Ω	0Ω	INF	12 MEG
5	3Q5	INF	55Ω	2600Ω	2000Ω	2.2MEG	INF	69Ω	62Ω	
6	117Z6T	INF	250Ω	250Ω	2400Ω	250Ω	INF	0Ω	2400Ω	

MAJESTIC

MODELS 7S433 7S450 7S470





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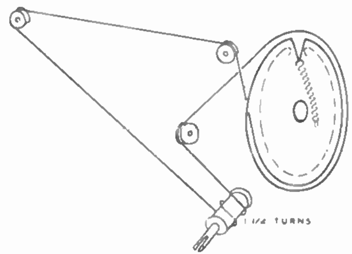


DIAL CORD DRIVE

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	6SA7	0V.	0V.	285V. DC	85V. DC	-3.5V. DC	0V.	6.3V. AC	12V. DC
2	6SK7	0V.	0V.	2.8V. DC	-2V. DC	2.8V. DC	112V. DC	6.3V. AC	280V. DC
3	6SQ7GT	0V.	-8V. DC	0V.	-.5V. DC	0V.	108V. DC	6.3V. AC	0V.
4	6J5	0V.	0V.	223V. DC	28V. DC	2.3V. DC	53V. DC	6.3V. AC	80V. DC
5	6K6GT	0V.	0V.	275V. DC	282V. DC	0V.	0V.	6.3V. AC	23V. DC
6	6K6GT	0V.	0V.	275V. DC	282V. DC	0V.	0V.	6.3V. AC	23V. DC
7	5Y3GT	0V.	340V. DC	0V.	335V. AC	0V.	335V. AC	0V.	340V. DC

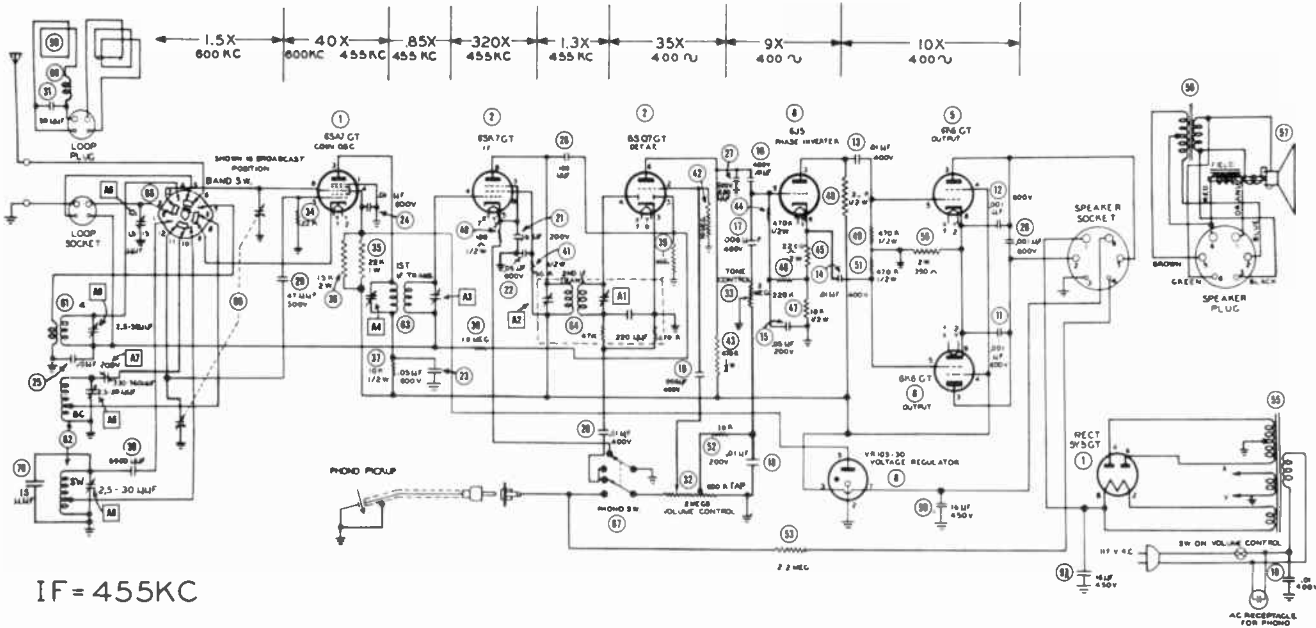
RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	6SA7	0Ω	0Ω	370KΩ	380KΩ	22KΩ	.5Ω	.1Ω	2.5MEG.
2	6SK7	0Ω	0Ω	180Ω	2.8MEG.	180Ω	415KΩ	.1Ω	380KΩ
3	6SQ7GT	0Ω	10MEG.	0Ω	480KΩ	0Ω	830KΩ	.1Ω	0Ω
4	6J5	0Ω	0Ω	380KΩ	250KΩ	700KΩ	18KΩ	.1Ω	20KΩ
5	6K6GT	0Ω	0Ω	380KΩ	380KΩ	480KΩ	380KΩ	.1Ω	370Ω
6	6K6GT	0Ω	0Ω	380KΩ	380KΩ	480KΩ	INF.	.1Ω	370Ω
7	5Y3GT	INF.	380KΩ	2 MEG.	90Ω	INF.	100Ω	INF.	380KΩ

RESISTANCE READINGS IN THE B+ CIRCUITS MAY VARY WIDELY ACCORDING TO THE CONDITION OF THE FILTER CAPACITORS

MAJESTIC

MODELS 8S452 8S473



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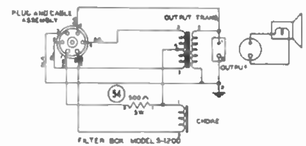
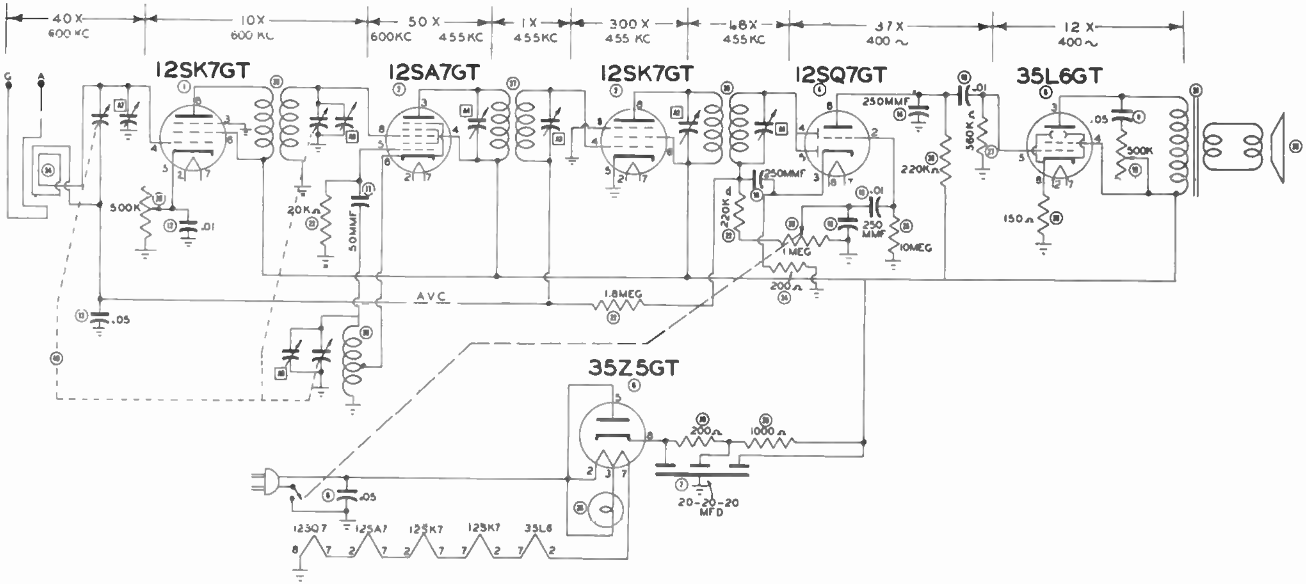


When permanent magnet speakers are used, Model S-1200 filter box is added to circuit.



RF GAIN CONTROL SET JUST BELOW OSCILLATION POINT

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7GT	0V	25VAC	[illegible]	135VDC	4V	92VDC	37VAC	94VDC
2	12SA7GT	0V	12VAC	92VDC	92VDC	-3VDC	0V	25VAC	0V
3	12SK7GT	0V	49VAC	0V	135VDC	0V	92VDC	37VAC	92VDC
4	12SQ7GT	0V	-4V DC	0V	18VDC	0V	62V DC	12VAC	0V
5	35L6GT	0V	87VAC	115VDC	92VDC	0V	0V	49VAC	92VDC
6	35Z5GT	0V	117VAC	114VAC	120VDC	117VAC	0V	87VAC	130VDC

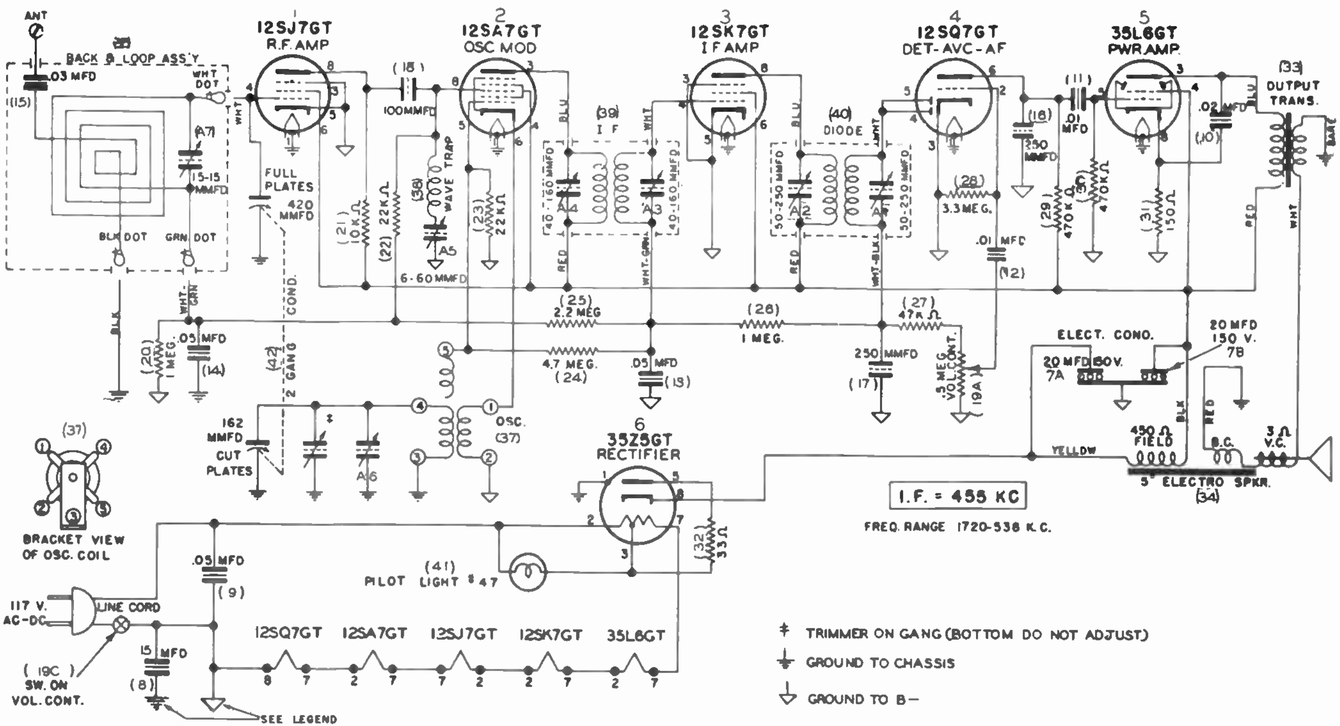
RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7GT	0Ω	25Ω	0Ω	3MEG	8KΩ	110KΩ	34Ω	110KΩ
2	12SA7GT	0Ω	11Ω	110KΩ	110KΩ	18.5KΩ	3Ω	23Ω	3Ω
3	12SK7GT	0Ω	44Ω	0Ω	3MEG	8Ω	110KΩ	34Ω	110KΩ
4	12SQ7GT	0Ω	10MEG	200Ω	1.2MEG	INF	330KΩ	11Ω	0Ω
5	35L6GT	INF	74Ω	110KΩ	110KΩ	500KΩ	INF	44Ω	123Ω
6	35Z5GT	INF	[illegible]	86Ω	110KΩ	[illegible]	INF	74Ω	110KΩ

MECK

MOTOROLA

MODELS 65X11A 65X12A 65X13A 65X14A 65X14B



VOLTAGE READINGS

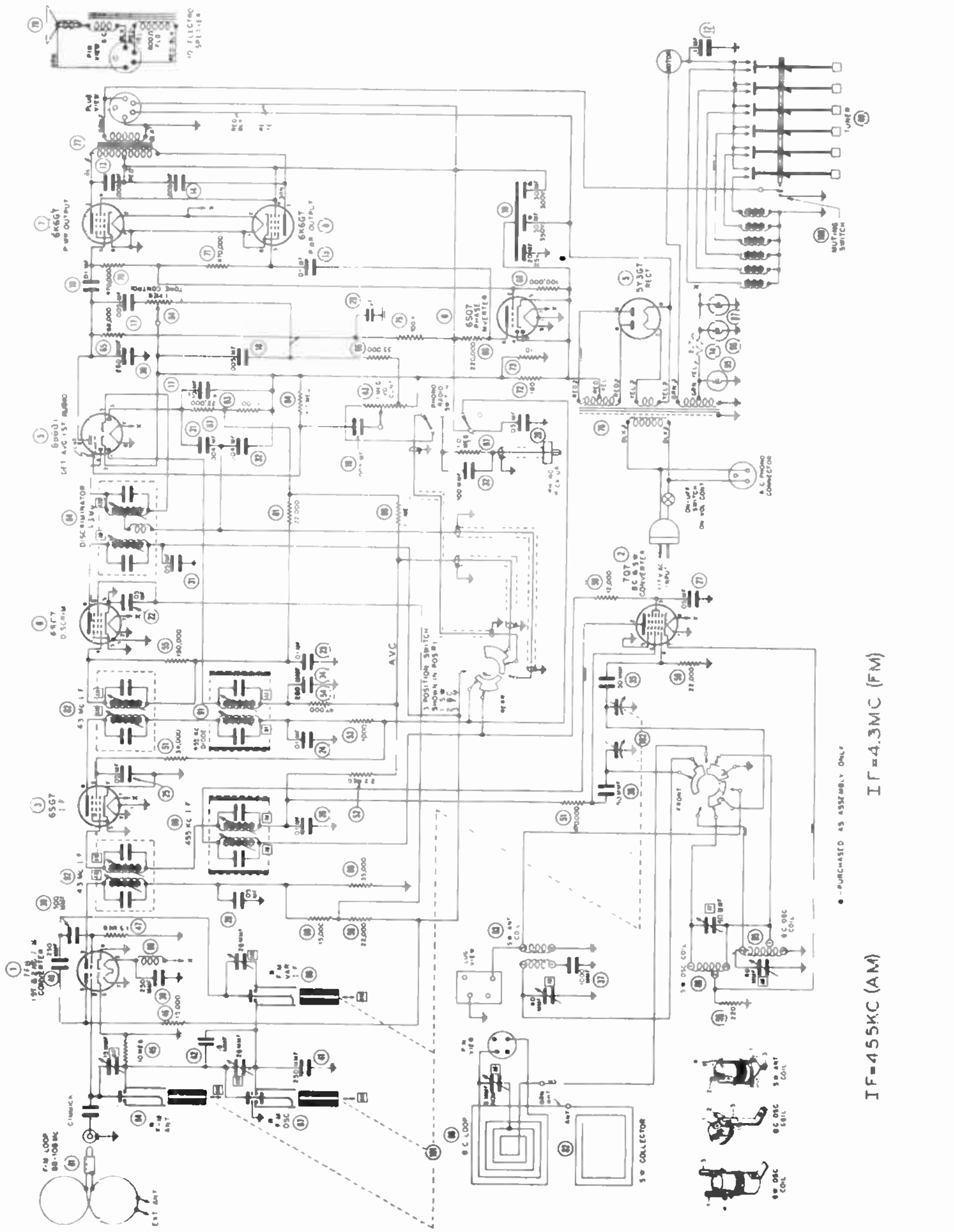
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SJ7GT	0V.	38V.AC	0V.	-.275V.DC	0V.	88V.DC	27V.AC	47V.DC
2	12SA7GT	0V.	12V.AC	88V.DC	88V.DC	-4V.DC	0V.	27V.AC	-.225V.DC
3	12SK7GT	0V.	38V.AC	0V.	-.2V.DC	0V.	88V.DC	52V.AC	88V.DC
4	12SQ7GT	0V.	-.175V.DC	0V.	-.4V.DC	-.4V.DC	46V.DC	12V.AC	0V.
5	35L6GT	0V.	52V.AC	80V.DC	88V.DC	0V.	0V.	85V.AC	5.15V.DC
6	35Z5GT	0V.	117V.AC	114V.AC	0V.	114V.AC	0V.	85V.AC	120V.DC

RESISTANCE READINGS

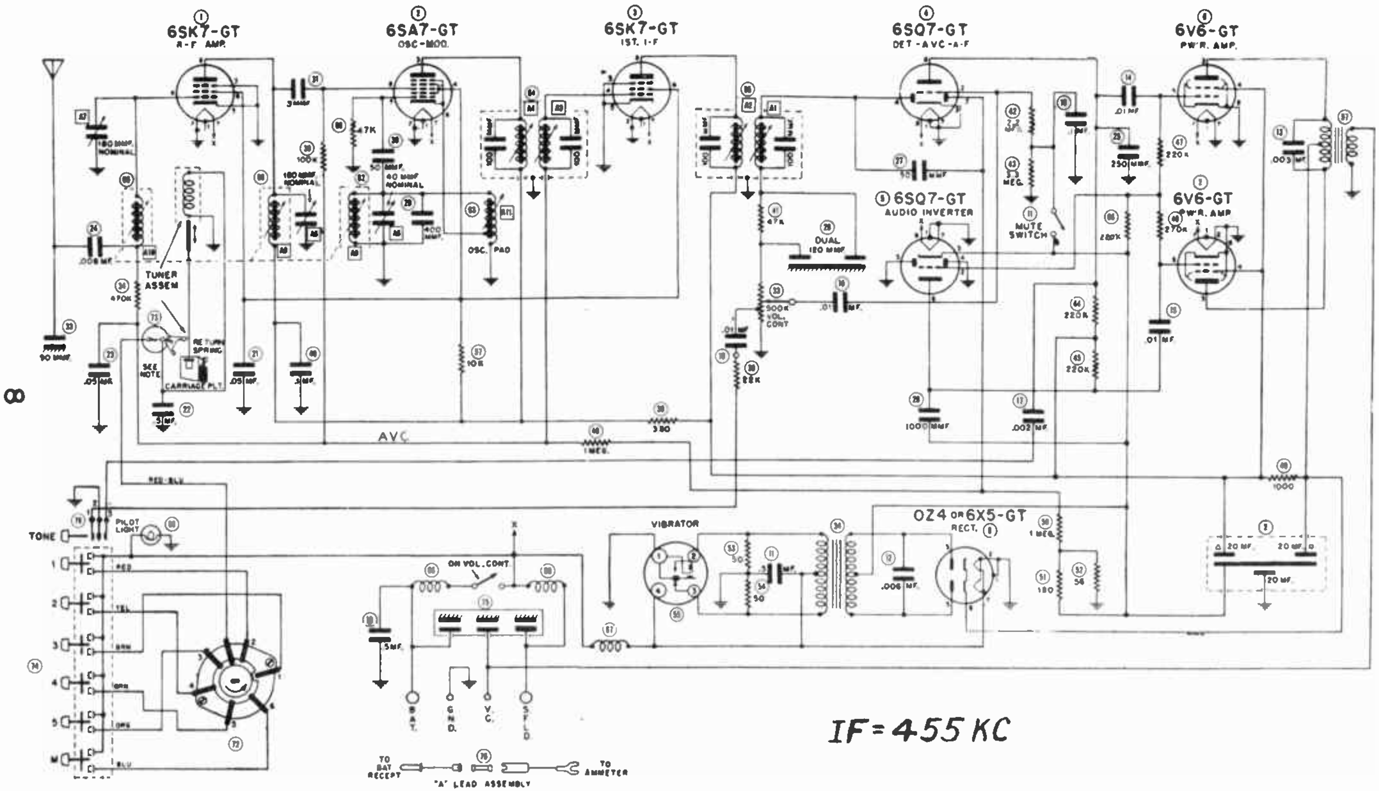
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SJ7GT	INF	38 Ω	0 Ω	700KΩ	0 Ω	120KΩ	27 Ω	130KΩ
2	12SA7GT	INF	14 Ω	120KΩ	120KΩ	19KΩ	1 Ω	27 Ω	720 KΩ
3	12SK7GT	INF	38 Ω	0 Ω	800KΩ	0 Ω	120KΩ	52 Ω	120KΩ
4	12SQ7GT	INF	3.25MEG	0 Ω	380KΩ	380KΩ	675KΩ	14 Ω	0 Ω
5	35L6GT	INF	52 Ω	120KΩ	120KΩ	470KΩ	INF	85 Ω	140 Ω
6	35Z5GT	INF	115 Ω	110 Ω	INF	110 Ω	INF	85 Ω	120KΩ

MODELS 95F31 95F31B
CHASSIS HS-39
MODEL 95F33
CHASSIS HS-38

MOTOROLA



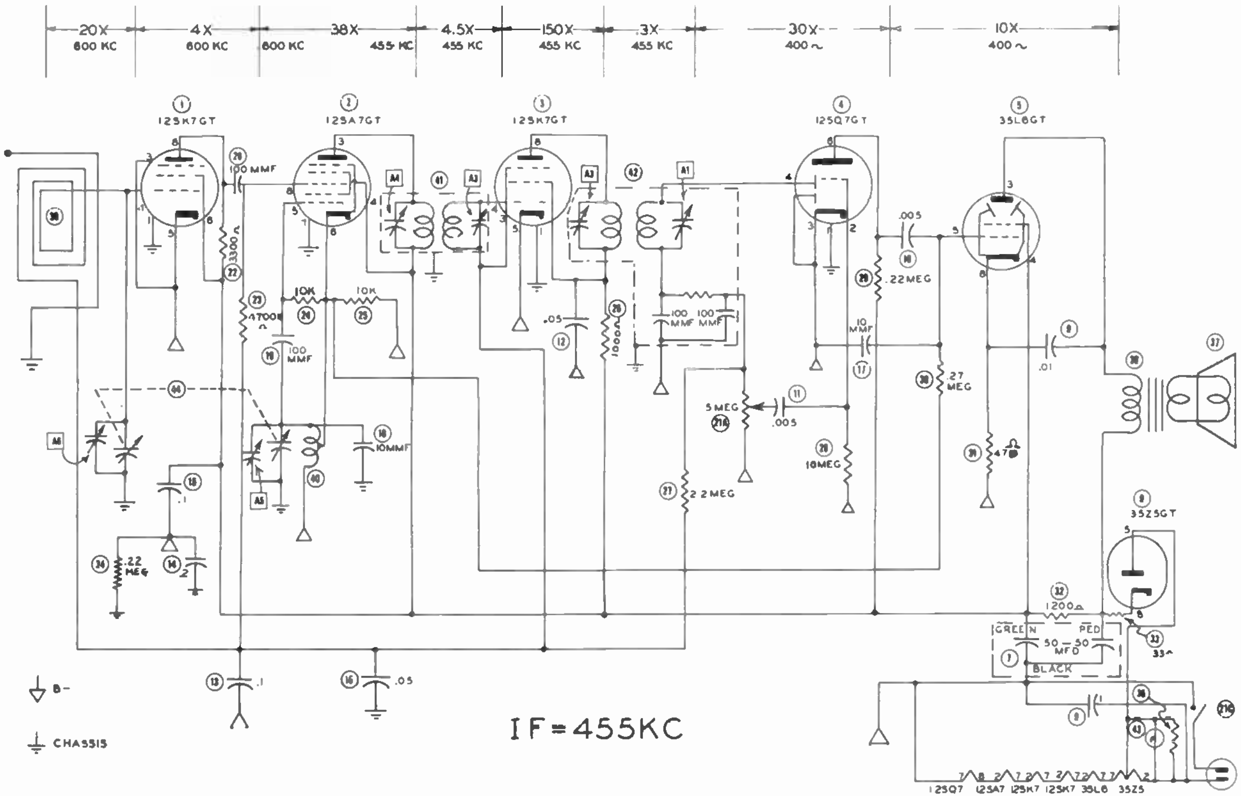
MOTOROLA



MODEL CR 6

NATIONAL UNION

MODEL G-619



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VOLTAGE READINGS

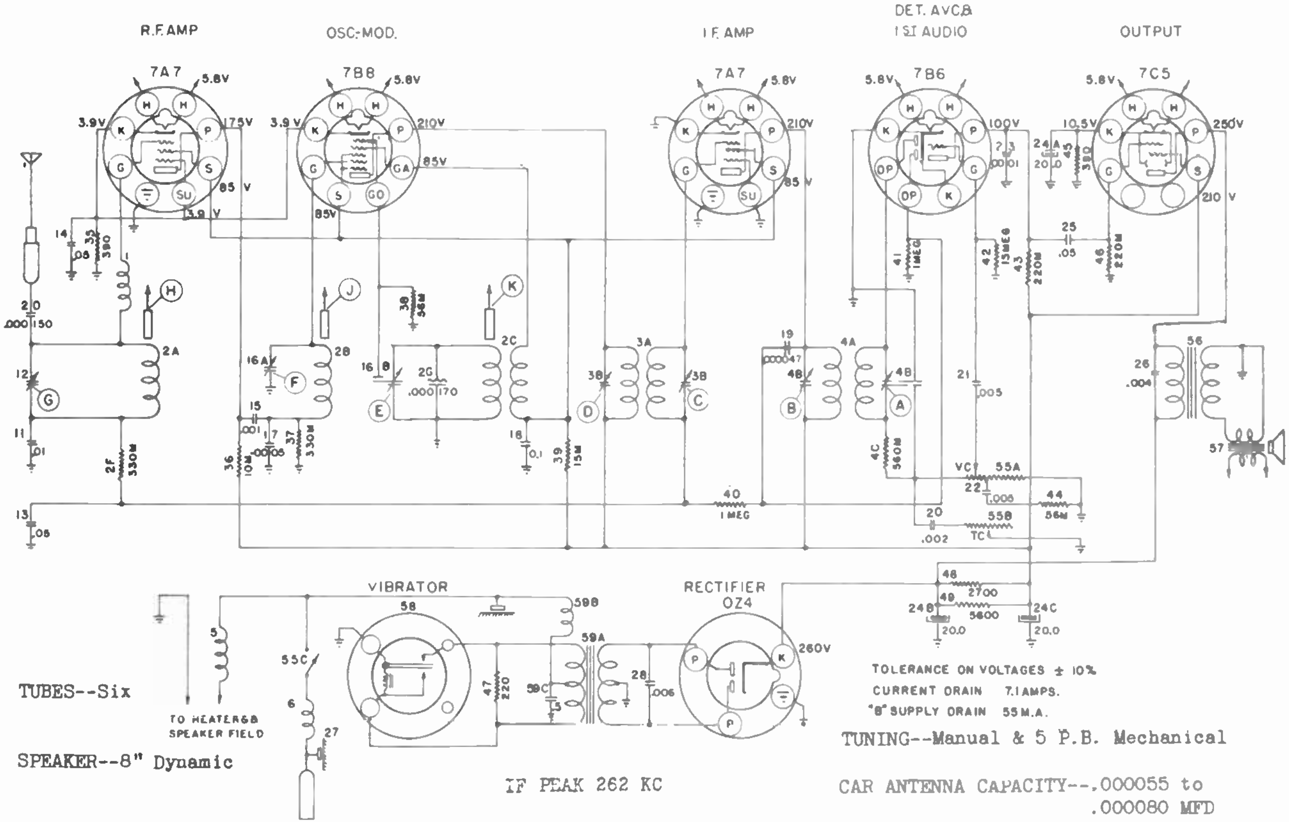
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7GT	0V.	26.5V.AC	0V.	-.82V.DC	0V.	71V.DC	39V.AC	44V.DC
2	12SA7GT	0V.	13V.AC	71V.DC	71V.DC	-4.4V.DC	0V.	26.5V.AC	-.82V.DC
3	12SK7GT	0V.	39V.AC	-.82V.DC	.82V.DC	0V.	62V.DC	52V.AC	62V.DC
4	12SQ7GT	0V.	-.9V.DC	0V.	-.5V.DC	0V.	55V.DC	0V.	13V.AC
5	35L6GT	0V.	52V.AC	105V.DC	71V.DC	-1V.DC	-2.2V.DC	87V.AC	1.45V.DC
6	35Z5GT	0V.	117V.AC	114V.AC	0V.	114V.AC	0V.	87V.AC	112V.DC

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7GT	215KΩ	23Ω	0Ω	2.6MEG.	0Ω	35KΩ	34Ω	38KΩ
2	12SA7GT	215KΩ	12Ω	35KΩ	35KΩ	18.5KΩ	.5Ω	23Ω	2.6MEG.
3	12SK7GT	215KΩ	34Ω	2.6MEG.	2.8MEG.	0Ω	36KΩ	45Ω	36KΩ
4	12SQ7GT	215KΩ	10MEG.	0Ω	550KΩ	0Ω	255KΩ	0Ω	12Ω
5	35L6GT	INF.	45Ω	35KΩ	35KΩ	330KΩ	9.6KΩ	73Ω	45Ω
6	35Z5GT	INF.	100Ω	97Ω	INF.	97Ω	INF.	73Ω	35KΩ

OLDSMOBILE

MODEL 982283



TOLERANCE ON VOLTAGES ± 10%
CURRENT DRAIN 7.1 AMPS.
"B" SUPPLY DRAIN 55 M.A.

TUBES--Six

SPEAKER--8" Dynamic

IF PEAK 262 KC

TUNING--Manual & 5 P.B. Mechanical

CAR ANTENNA CAPACITY--.000055 to .000080 MFD

TUNING RANGE--540-1600 K.C.

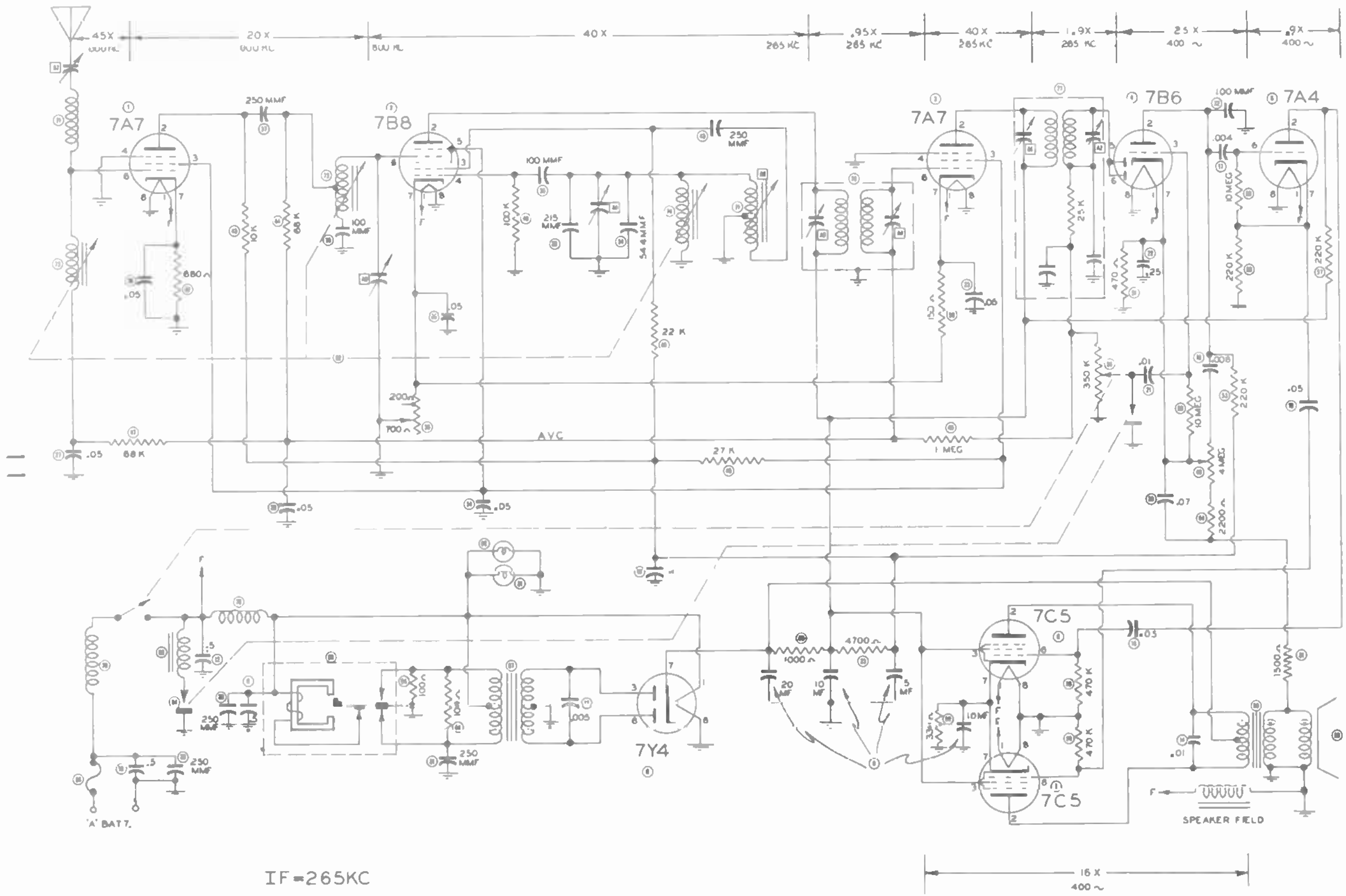
MOUNTING--All 1942 Oldsmobile Cars

PUSH BUTTON SET-UP

Push button in and latch. Allow to return to normal position. Turn button until desired station is brought in. Do not hold button in while adjusting.

MODEL PACKARD PA 382042

MODEL PHILCO P 4635



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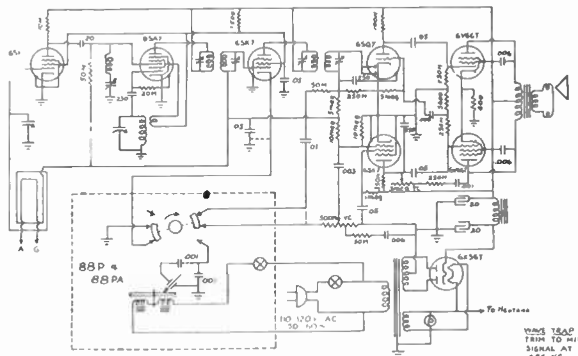
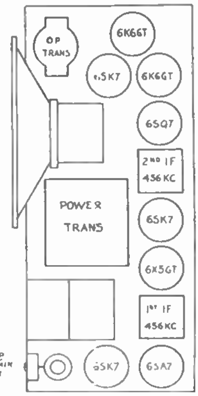
PACKARD-PHILCO

PACKARD BELL

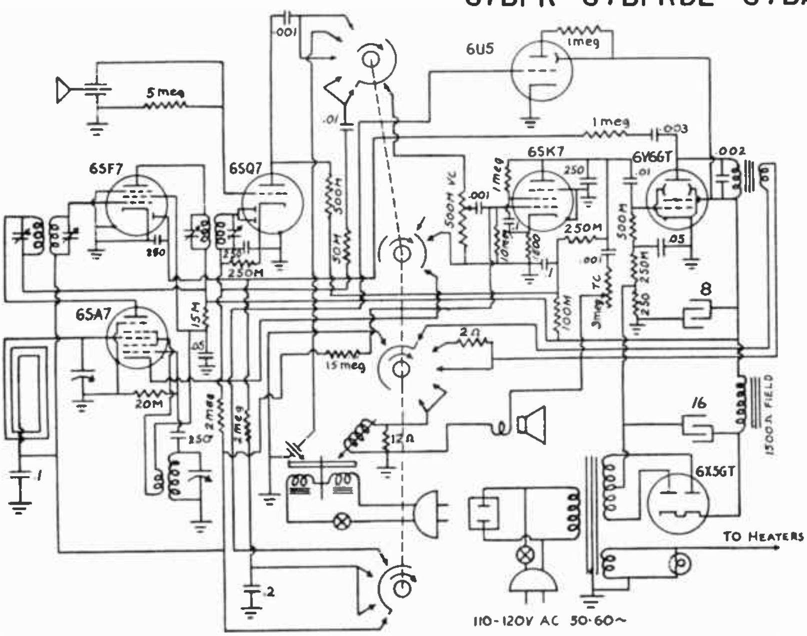
MODELS 88 88P 88PA

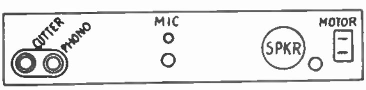


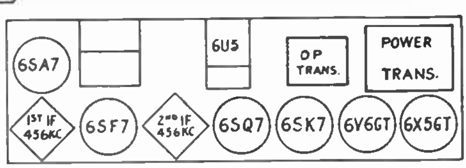


IN MODEL 88 DOTTED LINES IN MAIN DIAGRAM ARE CONNECTED AS SHOWN PHONOGRAPH SWITCH IN BOX SHOWN IN RADIO POSITION

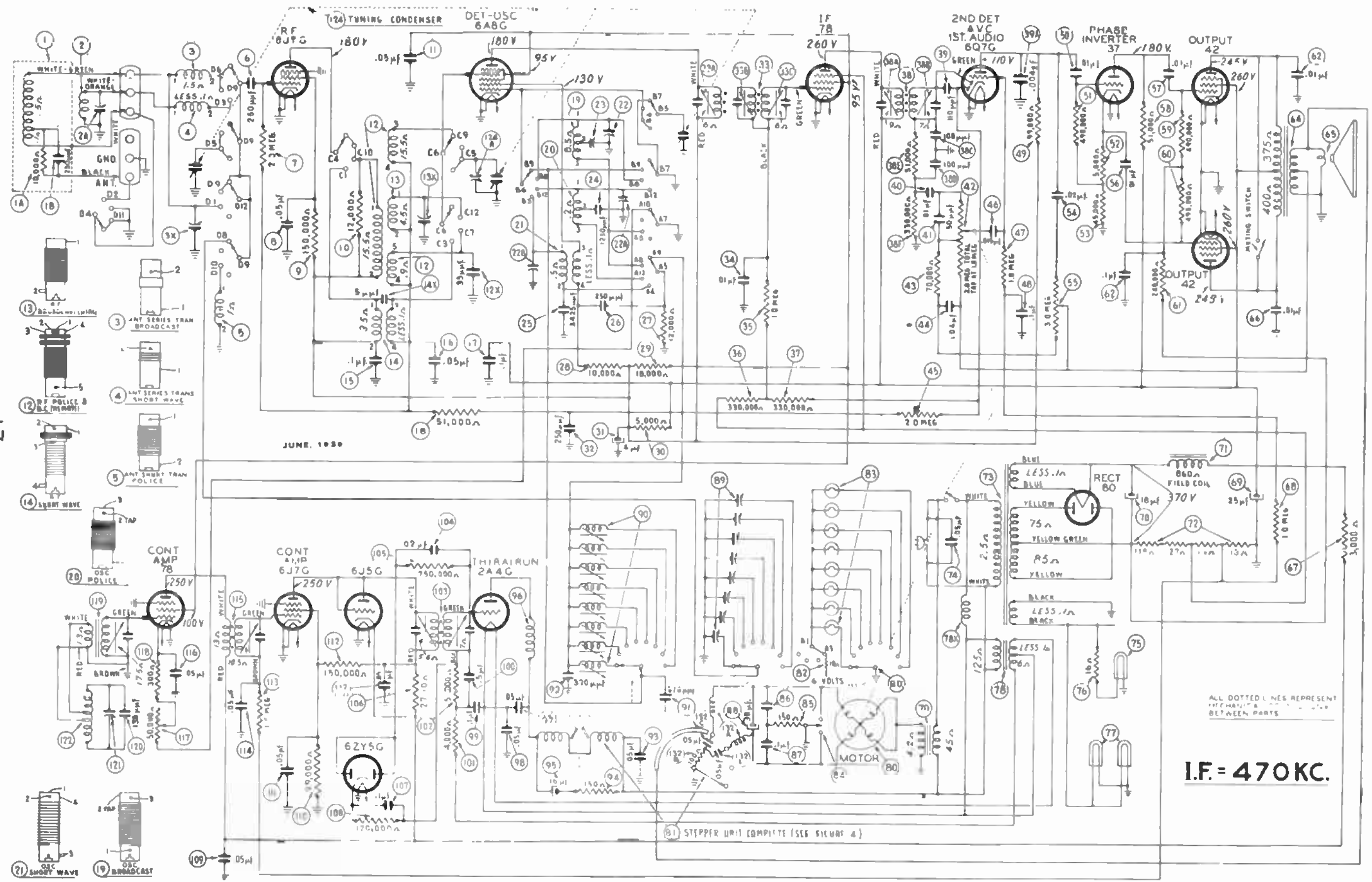
MODELS 67B 67BR 67BK 67BKA 67BPR 67BPRDL 67BA



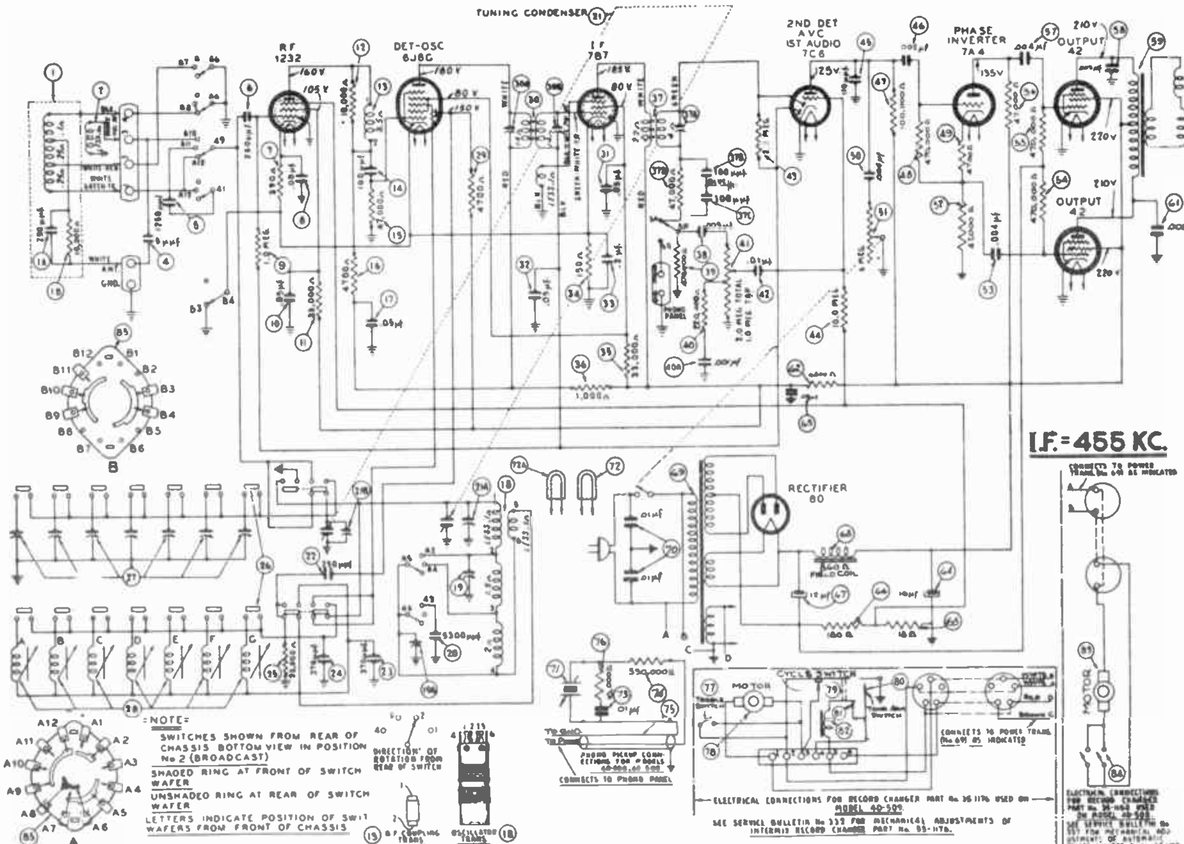




MODEL 40-216



PHILCO

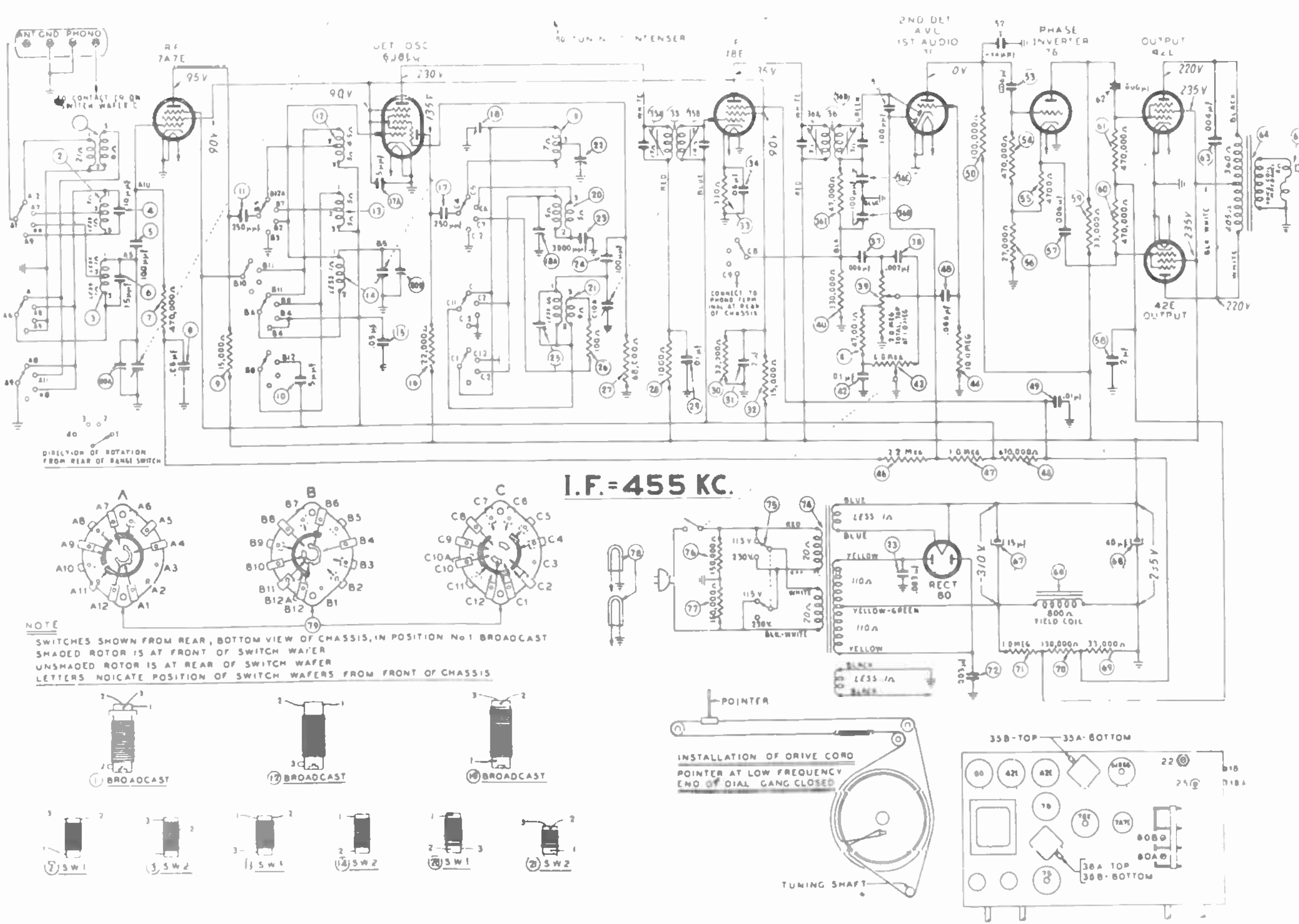


MODELS 40-508, 40-509

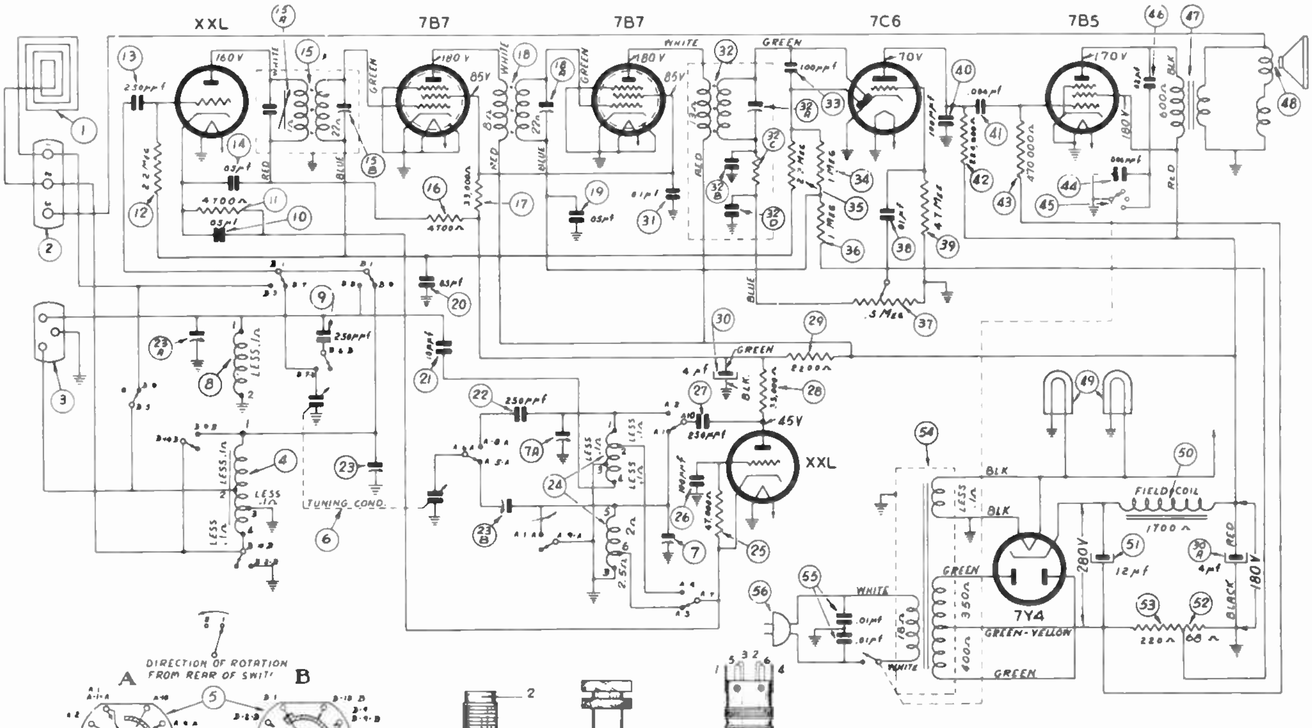
Beginning with Run "5" receivers, the converter tube is changed from a type 6J8G octal to a 7J7 loktal. The tube sockets are changed from Part No. 27-6120 to Part No. 27-6129.

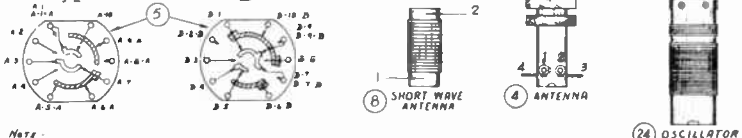
The 2nd I. F. transformer (37) beginning with Run "6" receivers was changed from Part No. 32-3246 to Part No. 32-3383.

PHILCO MODEL 41-758



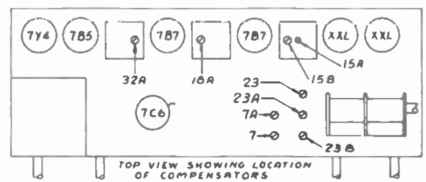
PHILCO MODEL 42-340



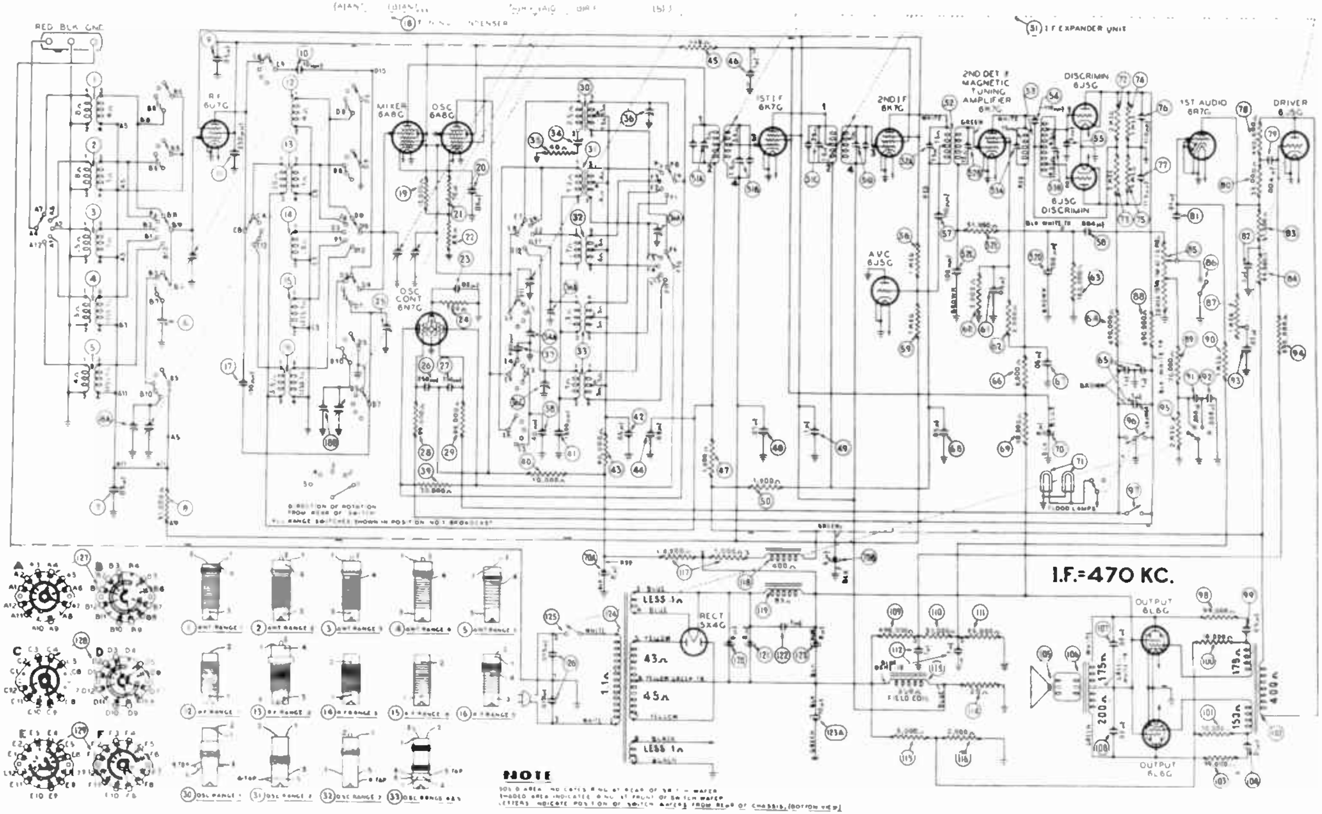


Note - Switches Shown, Rear Of Chassis, Bottom View, In Position No1 (Broadcast). Letters Indicate Position Of Switch Wafers From Front Of Chassis, Bottom View. Shaded Ring Is At Rear Of Switch Wafer And Solid Ring Is At Front Of Switch Wafer. Letter "A" After Lug Number Indicates Lug For Shaded Ring.

I.F. = 455 KC.



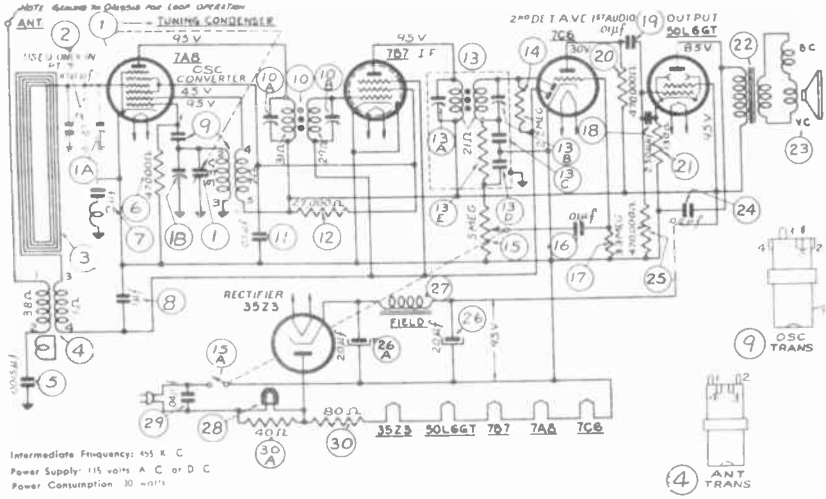
TOP VIEW SHOWING LOCATION OF COMPENSATORS


RED BLK GND
R F 6U7G
MIXER 6A8G
OSC 6A8G
OSC CONT 6N7G
1ST I F 6K7G
2ND I F 6K7G
2ND DET & MAGNETIC TUNING AMPLIFIER 6K7G
DISCRIMIN 6J5G
6J5G DISCRIMIN
AVC 6J5G
1ST AUDIO 6R7G
DRIVER 6J5G
RECT 5X4G
OUTPUT 6L6G
OUTPUT 6L6G
I.F.=470 KC.
FIELD COIL
LESS 1Ω
43Ω
45Ω
175Ω
200Ω
400Ω
DIAL LAMPS
I F EXPANDER UNIT
NOTE

PHILCO

MODELS 42-PT-2 42-PT-4 42-PT-7

CODE 121 122

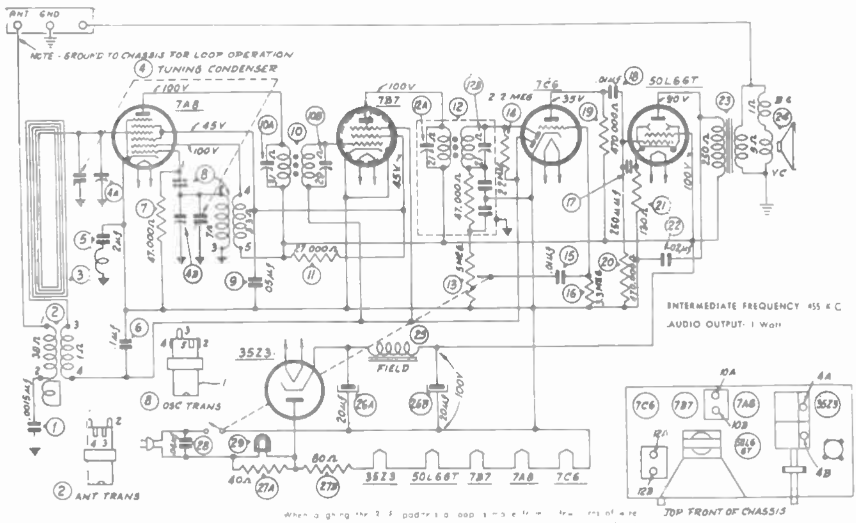


Intermediate Frequency: 455 K C

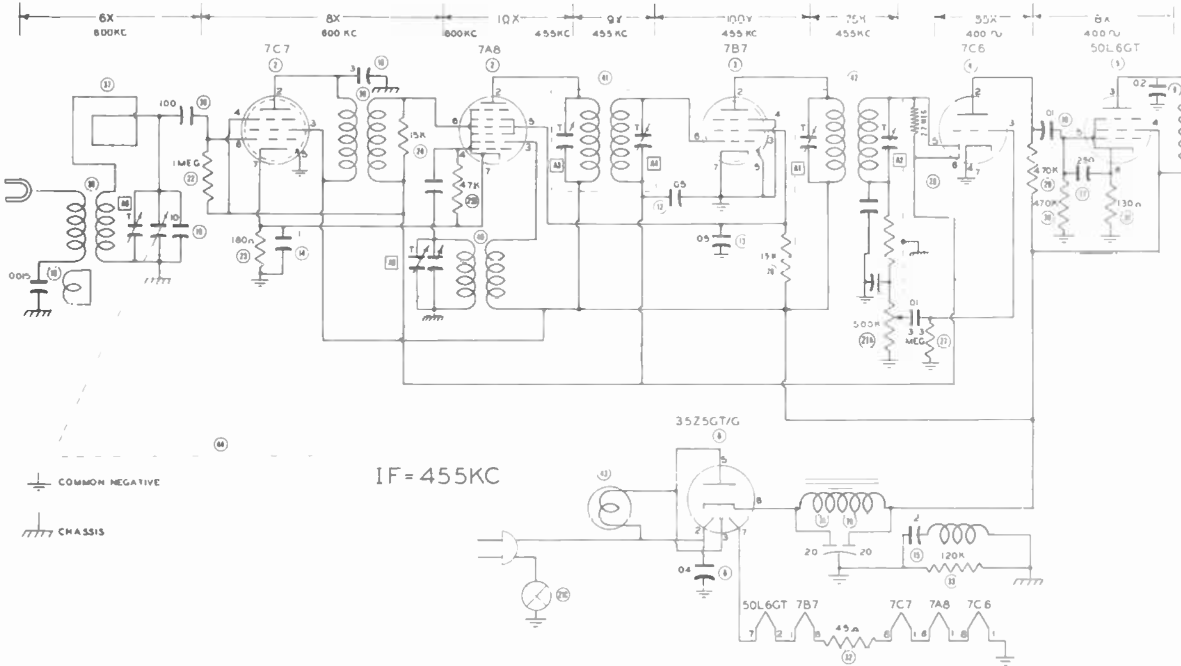
Power Supply: 115 volts A C or D C

Power Consumption 30 watts

MODELS PT-91 PT-92 PT-93 PT-94 PT-95 PT-96



POWER SUPPLY 115 V AC or DC



VOLTAGE READINGS

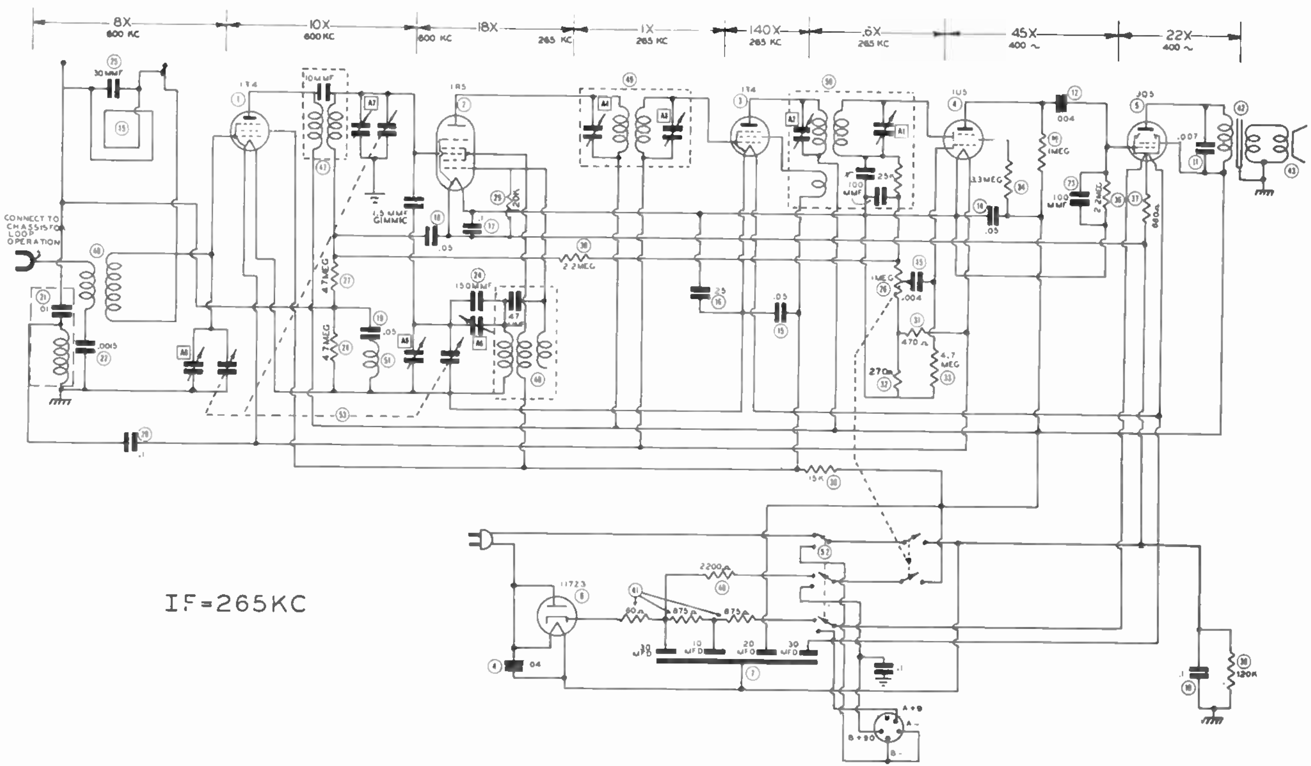
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	7C7	14V.AC	87V.DC	87V.DC	-.8V.DC	0V.	0V.	4.3V.DC	21V.AC
2	7A8	6.5V.AC	87V.DC	87V.DC	-2V.DC	50V.DC	-.8V.DC	1.3V.DC	14V.AC
3	7B7	35V.AC	87V.DC	50V.DC	0V.	0V.	-.8V.D	0V.	28V.AC
4	[illegible]	0V.	[illegible]	[illegible]	0V.	.4V.DC	-.8V.DC	0V.	6.5V.AC
5	50L6GT	0V.	35V.AC	80V.DC	87V.DC	0V.	0V.	87V.AC	5.7V.DC
6	35Z5GT	87V.DC	117V.AC	1.3V.AC	87V.DC	113V.AC	87V.DC	87V.AC	1.5V.DC

RESISTANCE READINGS

Item	Tube	1	2	3	4	5	6	7	8
1	7C7	13.5Ω	00KΩ	00KΩ	3 MEG	0Ω	MEG	75Ω	20.5Ω
2	7A8	8Ω	00KΩ	00KΩ	5KΩ	5KΩ	3 MEG	75Ω	3.5Ω
3	7B7	7Ω	100KΩ	15KΩ	0Ω	0Ω	3 MEG	0Ω	64Ω
4	7C6	0Ω	570KΩ	3.3 MEG	0Ω	540KΩ	3 MEG	0Ω	6Ω
5	50L6GT	NF	71Ω	100KΩ	100KΩ	480KΩ	0Ω	19Ω	140Ω
6	35Z5GT	00KΩ	145Ω	142Ω	100KΩ	142Ω	100KΩ	119Ω	100KΩ

PHILCO

MODEL 46-350



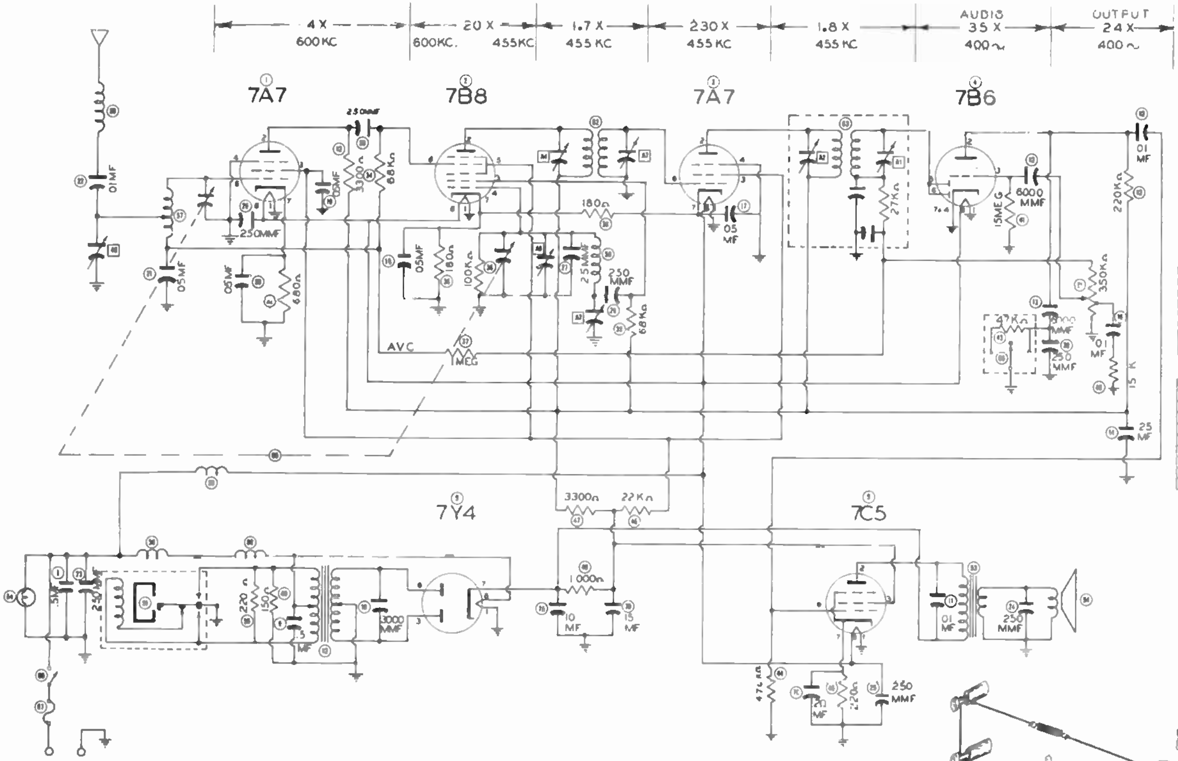
NOTE VOLTAGE AND RESISTANCE READINGS TAKEN IN AC-DC POSITION.
• DO NOT USE OHMMETER TO MEASURE FILAMENT RESISTANCE.

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	1T4	2 V.DC	80 V.DC	45 V.DC	0V.	2 V.DC	.2 V.DC	2.9 V DC	
2	1R5	0V.	80V.DC	45 V.DC	0V.	0V.	2 V.DC	1 V.DC	
3	1T4	2.9 V.DC	80 V.DC	45 V.DC	5.8 V.DC	2.9 V DC	2 V.DC	3.8 V DC	
4	1U5	1 V.DC	12 V.DC	17 V.DC	.4 V.DC	0V.	0V.	2 V.DC	
5	3Q5	1 V.DC	5.2 V.DC	78 V.DC	80 V.DC	.1 V.DC	102 V.DC	3.8 V DC	4.4 V.DC
6	723	0V.	0V.	117 V.AC	0V.	1 7 V.AC	107 V.DC	0V	

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	1T4	•	3900Ω	19KΩ	INF.	•	2.7 MEG.	•	
2	1R5	•	3900Ω	19KΩ	106KΩ	•	2.3 MEG.	•	
3	1T4	•	3900Ω	19KΩ	890KΩ	•	54Ω	•	
4	1U4	•	1 MEG.	3.3 MEG.	950KΩ	INF.	5 MEG.	•	
	3Q5	•	•	4200Ω	3900Ω	2 MEG.	1640Ω	•	•
6	117Z3	INF.	INF.	450Ω	0Ω	450Ω	1700Ω	INF.	

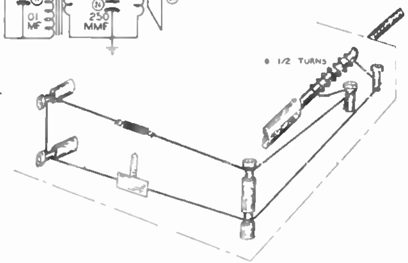


IF=455KC

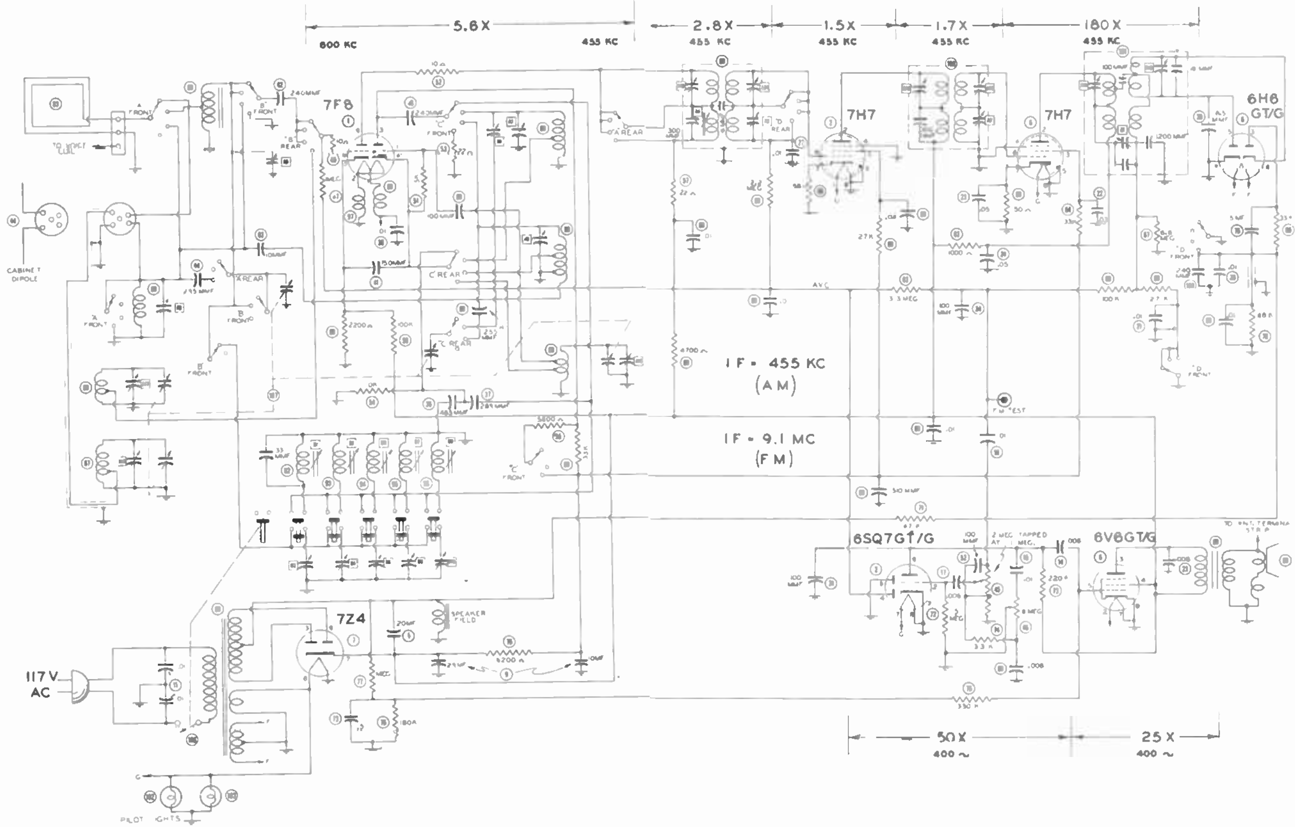
Pin	7A7		7B8	
No	Volt	Res	Volt	Res
1	0 V.	0 Ω	0 V	0 Ω
2	180 V.DC	290K Ω	180 V.DC	290K Ω
3	83 V.DC	510K Ω	87 V.DC	380K Ω
4	0 V	0 Ω	-.17 V.DC	83K Ω
5	0 V	0 Ω	83 V.DC	310K Ω
6	-17 V.DC	1.2 MEG	-.05 V.DC	1.2 MEG
7	3.4 V.DC	890 Ω	2.4 V.DC	180 Ω
8	5.8 V.DC	.1 Ω	5.8 V.DC	.1 Ω

Pin	7A7		7B6	
No	Volt	Res	Volt	Res
1	0 V	0 Ω	0 V.	0 Ω
2	[illegible]	[illegible]	82 V.DC	600K Ω
3	83 V.DC	310K Ω	-.5 V.DC	1.5 MEG
4	0 V.	0 Ω	0 V	0 Ω
5	0 V	0 Ω	[illegible]	[illegible]
6	0 V.	44 Ω	-.3 V.DC	315K Ω
7	3.4 V.DC	310 Ω	0 V.	0 Ω
8	5.8 V.DC	.1 Ω	5.8 V.DC	.1 Ω

Pin	7C5		7Y4	
No	Volt	Res	Volt	Res
1	0 V.	0 Ω	5.8 V.DC	.1 Ω
2	218 V.DC	290K Ω	0 V	INF
3	208 V.DC	290K Ω	280 V AC	450 Ω
4	0 V	INF	0 V.	INF
5	0 V.	INF	0 V	INF
6	0 V.	470K Ω	272 V AC	500 Ω
7	6.3 V.DC	210 Ω	232 V.DC	290K Ω
8	5.8 V.DC	.1 Ω	0 V	0 Ω



PHILCO



VOLTAGE AND RESISTANCE READINGS TAKEN IN BROADCAST POSITION

VOLTAGE READINGS

[illegible]	Tube	[illegible]	[illegible]	Pin 3	[illegible]	Pin 5	Pin 6	Pin 7	Pin 8
1	7F8	[illegible] DC	0V.	90V. DC	0V.	V. DC	200V. DC	6.3V. AC	[illegible]
2	7H7	[illegible]	[illegible]	120V. DC	[illegible]	0V.	0V.	[illegible]	[illegible]
3	7H7	0V.	[illegible]	[illegible]	[illegible]	[illegible]	0V.	[illegible]	6.3V. AC
4	6H6GT/G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0V.
5	6SQ7GT/G	[illegible]	[illegible]	0V.	[illegible]	[illegible]	125V.	6.3V. AC	0V.
6	6V6GT/G	[illegible]	[illegible]	[illegible]	320V. DC	[illegible]	0V.	0V.	0V.
7	7Z4	[illegible]	0V.	330V. AC	[illegible]	[illegible]	[illegible]	[illegible]	6.3V. AC

VOLTAGE AND RESISTANCE READINGS TAKEN IN BROADCAST POSITION

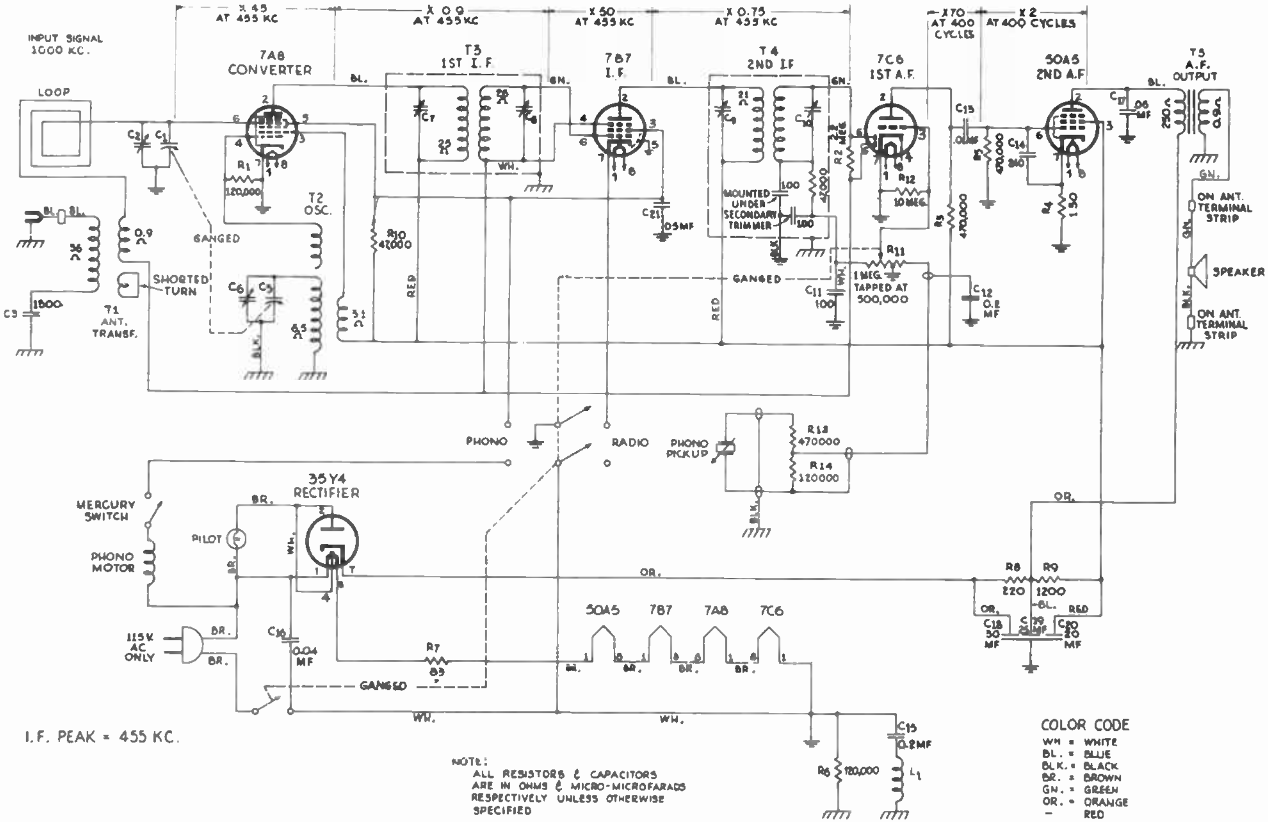
RESISTANCE READINGS

[illegible]	Tube	[illegible]	[illegible]	Pin 3	[illegible]	Pin 5	Pin 6	Pin 7	Pin 8
1	7F8	[illegible]	[illegible]	[illegible]	.8 Ω	2000 Ω	[illegible]	[illegible]	[illegible] MEG.
2	7H7	[illegible]	[illegible]	110 K Ω	0 Ω	[illegible]	[illegible] MEG.	[illegible]	[illegible]
3	7H7	0 Ω	[illegible]	125 K Ω	0 Ω	0 Ω	[illegible]	30 Ω	[illegible]
4	6H6GT/G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	6SQ7GT/G	[illegible]	[illegible] MEG.	0 Ω	[illegible]	0 Ω	[illegible]	[illegible]	0 Ω
6	6V6GT/G	0 Ω	[illegible]	80 K Ω	[illegible]	[illegible]	[illegible]	0 Ω	0 Ω
7	7Z4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MODEL 46-480

PHILCO

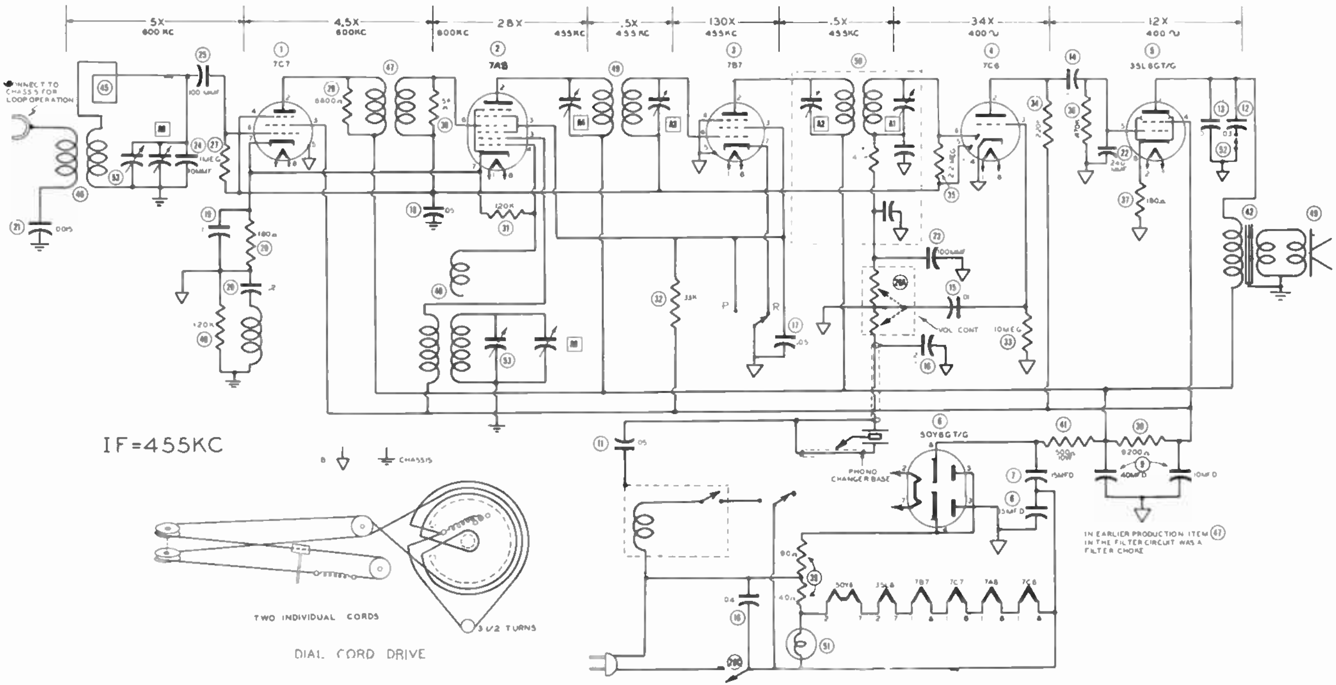
MODEL 46-1201
CODE 122



I.F. PEAK = 455 KC.

NOTE:
ALL RESISTORS & CAPACITORS ARE IN OHMS & MICRO-MICROFARADS RESPECTIVELY UNLESS OTHERWISE SPECIFIED

COLOR CODE
WH. = WHITE
BL. = BLUE
BLK. = BLACK
BR. = BROWN
GN. = GREEN
OR. = ORANGE
– RED



DIAL CORD DRIVE

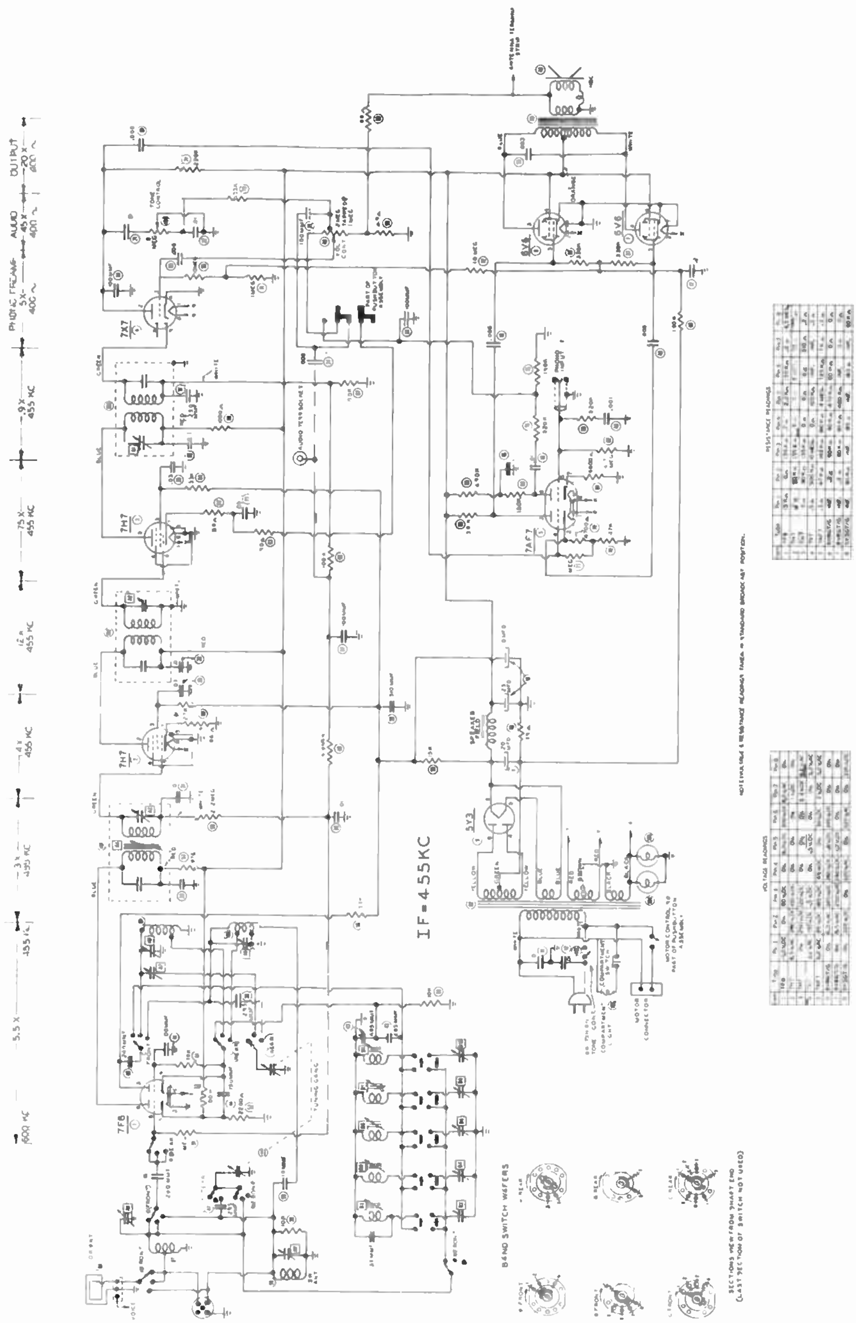
NOTE: FILAMENT STRING MEASURED FROM LOW END OF STRING, NOT MEASURED FROM B.

VOLTAGE READINGS

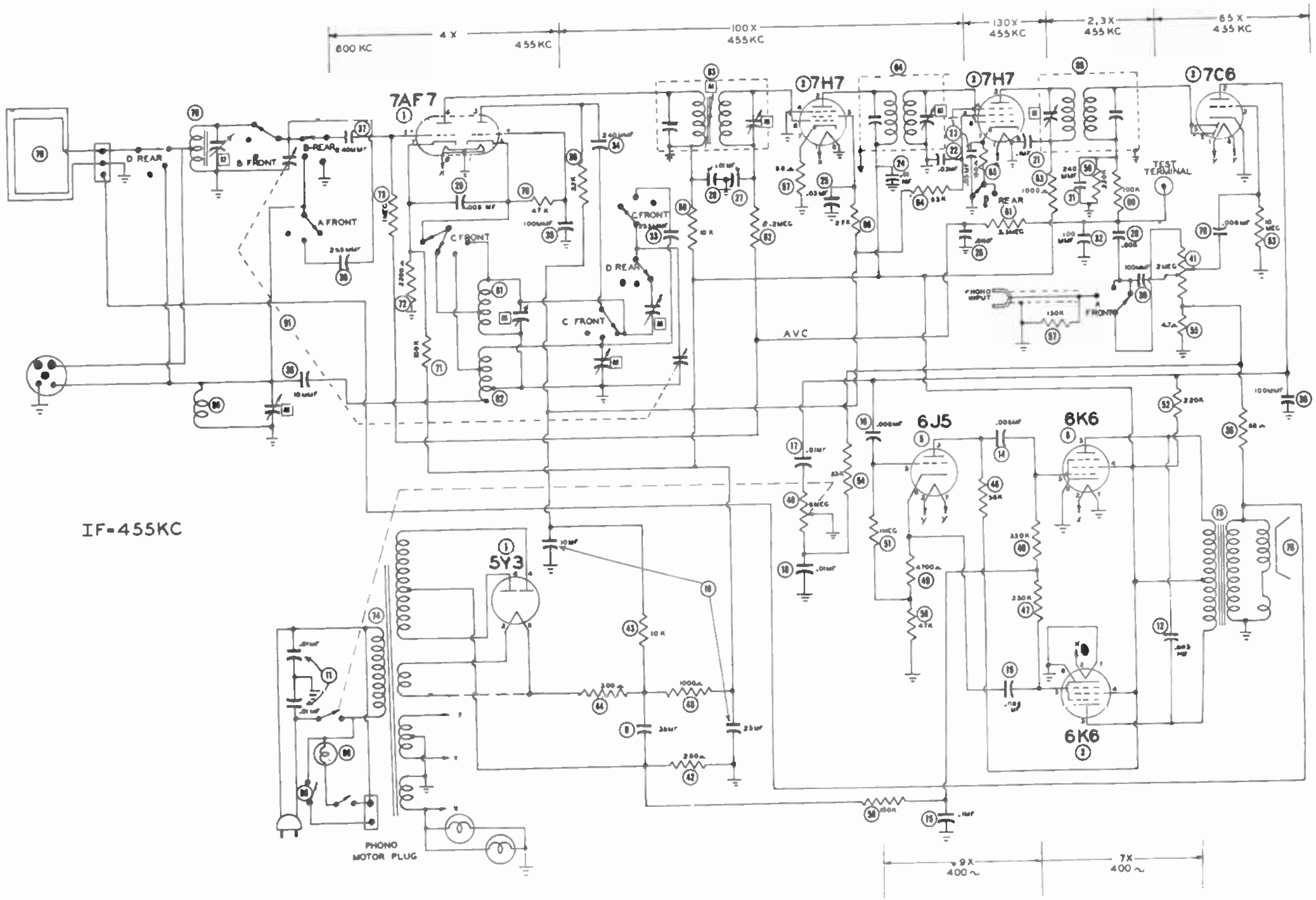
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Cap
1	7C7	18.5V AC	163V DC	107V DC	.35V DC	0V	-.02V DC	1.4V DC	12.6V AC	
2	7A8	12.6V AC	163V DC	107V DC	-2.45V DC	48V DC	.35V DC	1.4V DC	6.5V AC	-2.45V DC
3	7B7	24.3V AC	163V DC	48V DC	0V	0V	-.35V DC	0V	18.5V AC	0V
4	7C6	0V	50V DC	.45V DC	0V	-.35V DC	.25V DC	0V	6.3V AC	
5	35L6GT	0V	58V AC	145V DC	107V DC	0V	163V DC	24.5V AC	7V DC	
6	50Y6GT	181V DC	58V AC	0V	94V DC	94V DC	107V DC	107V AC	187V DC	7A8

RESISTANCE READINGS

Item	Tube	P	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	7C7	17 Ω	52K Ω	82K Ω	2.9MEG	0 Ω	4 MEG	133 Ω	2 Ω
2	7A8	12 Ω	52K Ω	82K Ω	123K Ω	95K Ω	2.9MEG	160 Ω	6 Ω
3	7B7	22 Ω	52K Ω	95K Ω	0 Ω	0 Ω	2.9MEG	0 Ω	19 Ω
4	7C6	0 Ω	280K Ω	11 MEG	0 Ω	2.9 MEG	540K Ω	0 Ω	6 Ω
5	35L6GT	0 Ω	45 Ω	52K Ω	82K Ω	450K Ω	49K Ω	22 Ω	160 Ω
6	50Y6GT	49K Ω	45 Ω	0 Ω	125K Ω	125K Ω	59K Ω	70 Ω	52K Ω


7X7
7H7
7H7
7F8
5Y3
6V6
6V6
7AF7
IF=455KC
BAND SWITCH WAFERS

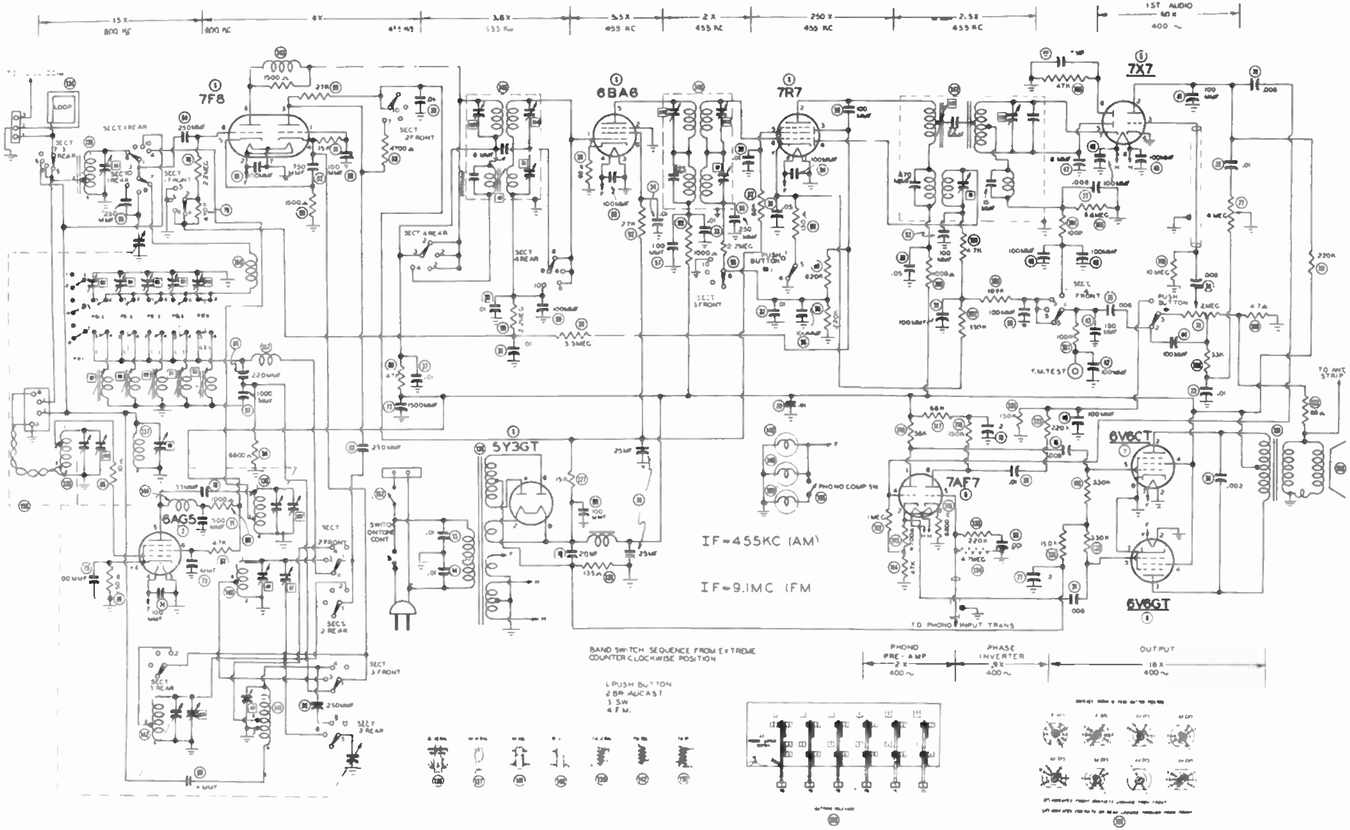
PHILCO

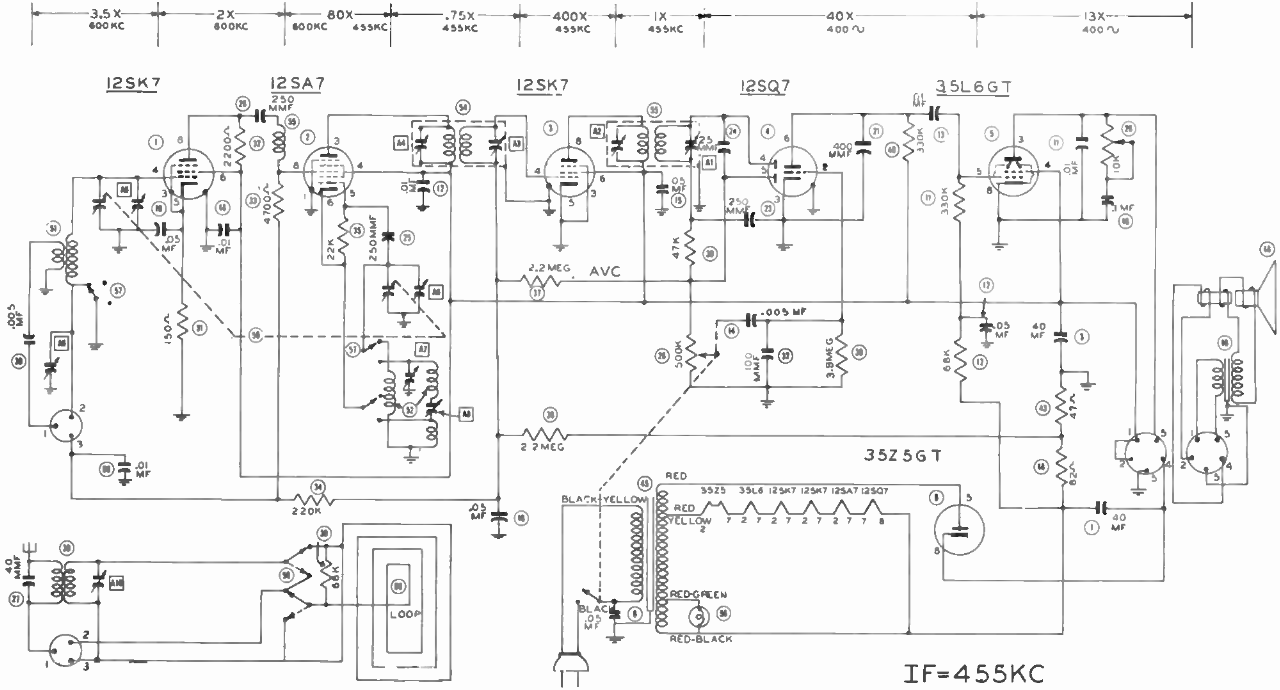


IF=455KC

MODEL 46-1226

PHILCO MODEL 47-1230





NOTE: VOLTAGE & RESISTANCE TAKEN IN BROADCAST POSITION.

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7	0V.	*37V.AC	2.5V.DC	-2V.DC	2.5V.DC	120V.DC	*24V.AC	100 V.DC
2	12SA7	0V.	*64V.AC	120V.DC	0V.	-8V.DC	0V.	*72V.AC	-2 V.DC
3	12SK7	0V.	*50V.AC	0V.	-5V.DC	0V.	120V.DC	*37V.AC	120V.DC
4	12SQ7	0V.	-5V.DC	0V.	-2V.DC	0V.	72V.DC	*12V.AC	* 0V.
5	35L6GT	0V.	*85V.AC	115V.DC	120V.DC	-10V.DC	-10V.DC	*50V.AC	* 0V.
6	35Z5GT	0V.	*117V.AC	0V.	0V.	*150V.AC	-12V.DC	*85V.AC	150V.DC

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SK7	0 Ω	* 28 Ω	140 Ω	1.2 MEG.	140 Ω	30 K Ω	* 20 Ω	30K Ω
2	12SA7	0 Ω	* 20 Ω	30 K Ω	0 Ω	20 K Ω	0 Ω	* 11 Ω	1.2 MEG.
3	12SK7	0 Ω	* 35 Ω	0 Ω	1 MEG.	0 Ω	30 K Ω	* 28 Ω	30K Ω
4	12SQ7	0 Ω	3.7MEG.	0 Ω	480 K Ω	19 Ω	320 K Ω	* 11 Ω	* 0 Ω
5	35L6GT	INF.	* 40 Ω	30 K Ω	30 K Ω	385 K Ω	115 Ω	* 35 Ω	0 Ω
6	35Z5GT	INF.	* 35 Ω	INF.	INF.	160 Ω	115 Ω	* 40 Ω	30 K Ω

* MEASURED FROM PIN NO.8 OF 12SQ7.

PONTIAC MODEL 984171

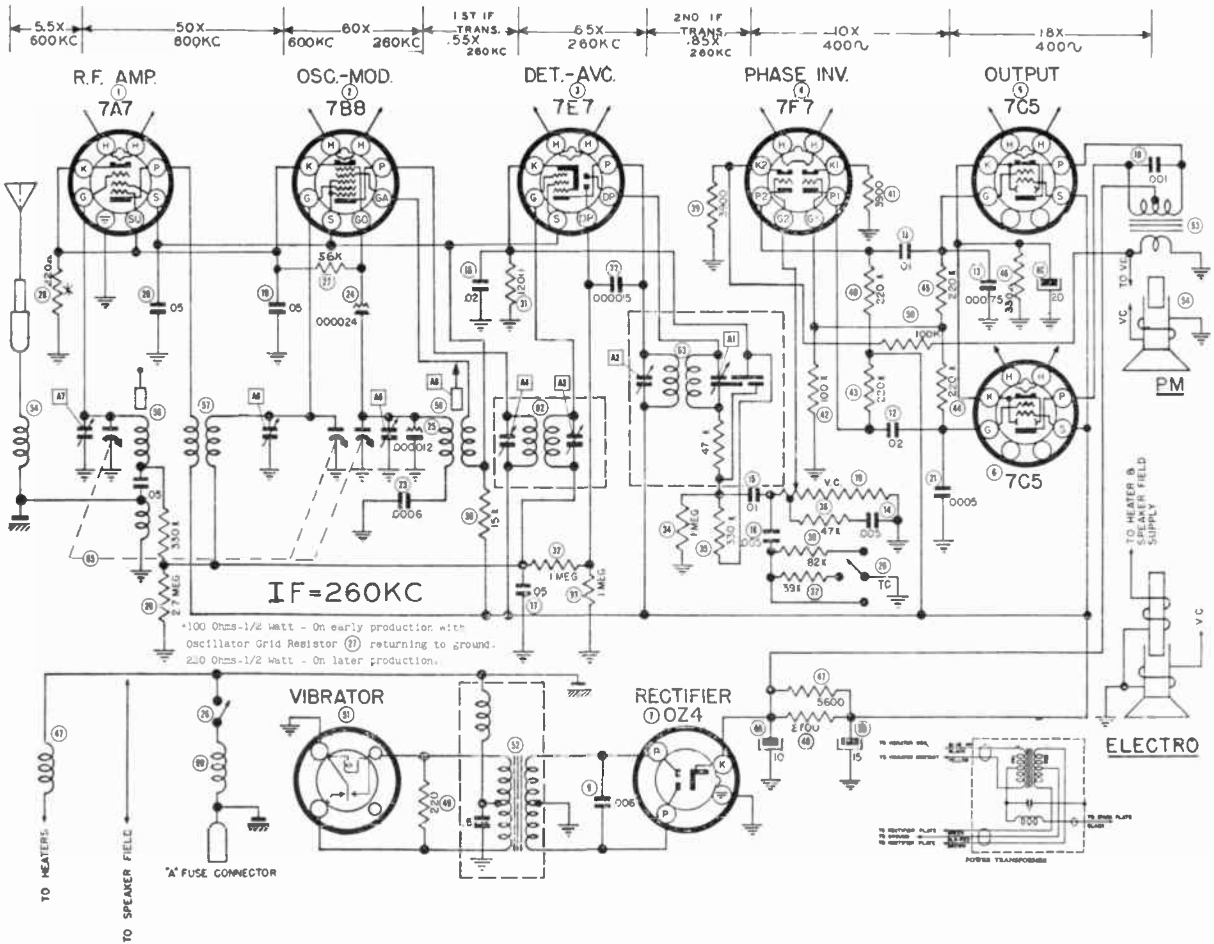


Photo-Electronics

LESSON ND-34

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

CHICAGO, ILLINOIS

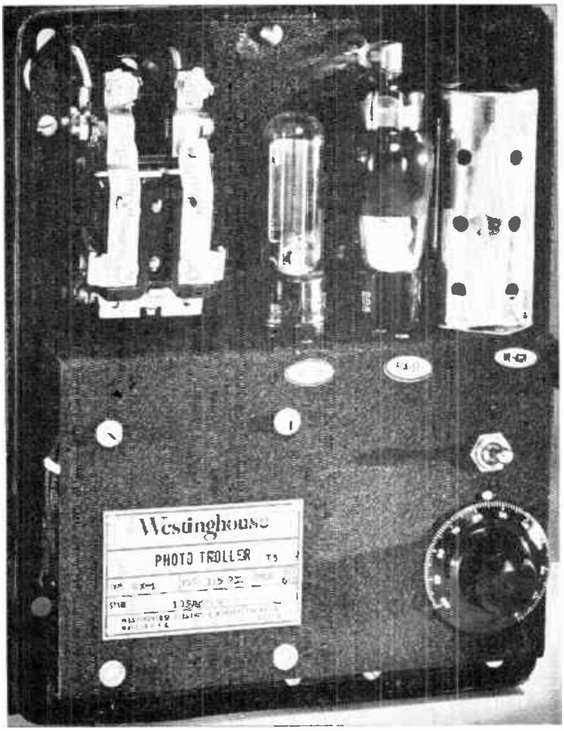
MIDWAY

Have you ever gone on a long journey that lasted several days or weeks? If you have, you will probably realize the similarity between such a journey and a course of instruction.

While packing for the journey, deciding where to go, how to get there, arranging for the tickets or having your auto checked for the trip, you experienced a thrill of excitement and anticipation. As the moment for leaving on the trip approaches, the anticipation gets stronger and stronger, until it is difficult to contain oneself. The climax comes when you have settled in your seat and enjoy to the fullest extent the getting under way. After a while the newness wears off, the scenery seems to appear all the same, mile after mile, and interest lags. This decline continues until you have passed the mid-point. Then the thoughts of your destination come into mind, stronger and stronger as you come nearer. Another climax is reached as you arrive, knowing that you have completed the journey successfully.

When you first decided upon a career of radio and television repair, there was great anticipation, much excitement as you choose which school you felt could give you the best education. This was climaxed with the arrival of your first lessons, and the thrill of sending your first answer sheet. Then, no doubt, the newness began to wear off. You knew that you had to continue the study that you had chosen, because it alone could bring you to your destination. Now, you have just about reached the mid-point, and you can begin looking forward to the final lesson, the completion of a task which you have undertaken. Your interest will quicken as you approach the end—your destination. Your enthusiasm will build and build, and you will find yourself studying harder and longer as each lesson is put behind you. Then, as a reward for all of the hours that you have spent at this work, you come to the point which you have had in mind as you studied each lesson—the diploma indicating that you have completed this course of instruction, and have qualified as an accomplished technician, ready to enter the radio and television field with the confidence that becomes second nature to the man who knows what he is doing and why he is doing it.

O'B 3-56 2M



The above shows a Westinghouse type RX1 Photo-Troller. This is a photocell unit commonly used in industry. It may be used in paper mills for a break indicator, for automatic weighing, oscillating grinder belt, paper and celophane bag machines, registering wrapper trade mark on packaging machines, stopping mechanical devices at accurate positions, liquid level control, door opening and for various counting operations.

PHOTO-ELECTRONICS

LESSON ND-34

Perhaps you have heard of photo-electric cells and the almost unbelievable results obtained from these units. Most people, unacquainted with this device, look upon the Electric Eye, as it is often called, as a miraculous and mysterious invention—the principles of which can only be understood by a well educated scientist. However, you will find as this lesson is studied that photo-electric cells involve primarily, only the basic principles of radio which you have studied in your preceding lessons. As a matter of fact, it has been because of discoveries in the field of radio that photo-electric devices are fast coming to wide use in industry.

Many years ago, scientists discovered the ability of certain chemicals or chemical compounds to change their electrical properties when exposed to light. It has only been since radio development has given a means to utilize this property, that light sensitive cells have gained popular use.

Before studying the different

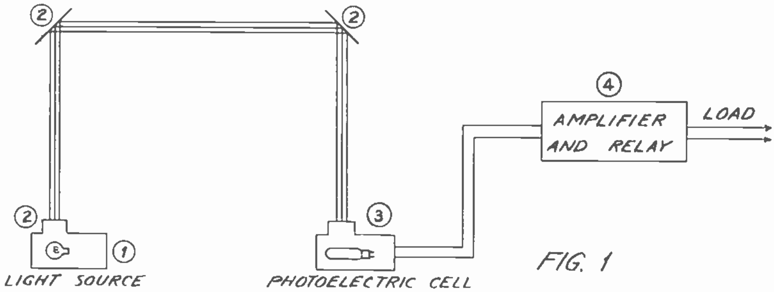


FIG. 1

types of photo-electric cells and their characteristics, it will be to your advantage to study a typical installation of a photo-electric cell and its associated equipment. A simple set-up of this type is shown in Fig. 1. An explanation follows:

(1) Light Source: The source of light, depending upon the application in which the equipment is being used, may be natural sunlight or some artificial source, such as incandescent lamps, arc lamps or even the light given off by a flame of fire.

(2) Light Transmitting Equipment: This equipment in general is the means by which light rays are transmitted from the light source to its ultimate goal, the photo-electric cell. In more detail this includes any and all reflectors, lens, mirrors or other apparatus which reflect or focus the light beam in its path between the light source and the photo-electric cell.

(3) The Photo-electric Cell: This may be of any type, depending upon the particular application in which it is used. Its purpose is to interpret the changes in light upon its active surface in terms of electrical response. These electrical responses must be in exact accordance with the changes in light, and the cell must respond practically instantaneously.

(4) Amplifier and Relay: As the output of most photo-electric cells is too small to be of any practical value, it is necessary to amplify the electrical impulses produced by the cells. The amplifier used may be a single tube unit or a multi-tube unit, depending upon the strength of the impulses from the photo-electric cell. A relay is usually placed in the plate circuit of the amplifying tube, the contacts of which are in turn connected to a suitable alarm or counter. In some cases, a meter is used in the plate circuit in order to take direct readings of the plate current flowing.

The preceding description covers, of course, a single installation. But fundamentally, the parts covered are required in all installations. The extent to which these parts are necessary depends entirely upon each individual installation, and you will be able to judge what equipment is needed after studying this and the following lesson.

In order to better understand the principles of photo-electric cells some knowledge of the theory of light is essential. The amount of light available at the photo-electric cell is an important factor, and a great many manufacturers speci-

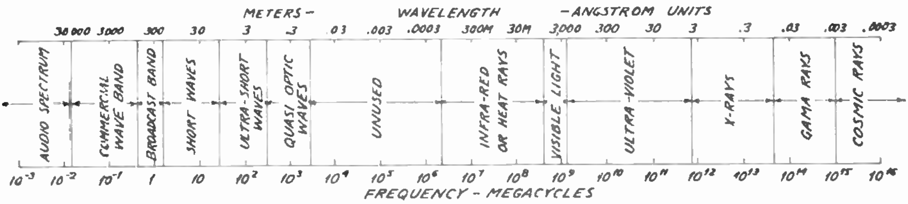


FIG. 2

fy the minimum amount of light to which their cell will respond.

You have studied how radio broadcasting is accomplished by an actual disturbance of the ether at a certain specified frequency. The transmission of light is basically done by the same principle with the single exception that the disturbance of the ether is at a higher frequency. This extremely high frequency is of such a nature that the disturbance is visible to the eye. Also, the frequency of this visible disturbance determines the color which registers itself upon the eye.

By referring to Fig. 2, you will see the relationship between radio broadcasting frequencies and the frequencies in the *visible light spectrum.* Radio as a rule uses frequencies from 10^4 cycles per second to 10^{10} cycles per second. The visible frequencies fall between 10^{14} and 10^{15} cycles per second. In photo-electric work frequencies from 10^{14} to 10^{16} cycles per second are used, the visible frequencies in the ultra-violet and the infra-red spectrum being used where it is necessary for the light beam to be invisible.

The frequency is so high in the visible spectrum that its rotation numerically would be an unwieldly set of figures, so the *wavelength* of light is used as a basis of measurement. Here the dimensions are so small that the ordinary metric system of measurement is unsatisfactory. A very small unit of length called the Angstrom Unit is extensively used in the measurement of the wavelength of light.

This is really too small a length or dimension for the imagination to grasp but a comparison may be made which will help you to understand the size. An ordinary newspaper sheet is about .002 inch thick. This in turn is equal to about 500,000 angstrom units. When you realize that ordinary visible light wavelengths fall between 4,600 and 6,800 angstrom units you can begin to have some idea of its size.

Figure 3 will help to give a clear picture as to the frequencies visible to the human eye. As can be seen, the eye does not follow a straight line but is most sensitive to frequencies in the green spectrum.

As previously mentioned, photocells as a group respond not only to the visible frequencies of light,

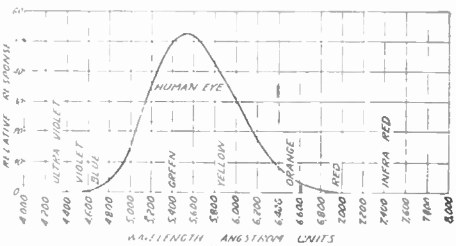


FIG 3

but also to frequencies both lower in the infra-red region and higher in the ultra-violet region. Later on in this lesson you will find, however, that no one type of cell will respond to all light frequencies. When a certain installation necessitates the use of a certain frequency, it is necessary to choose a cell which is sensitive to that frequency.

LIGHT MEASUREMENTS

The basic unit of light measurement is commonly known as a candle. This is not to be confused with the ordinary candle, but is a special unit designed by scientists, and arbitrarily chosen as a basic unit. As new light devices were developed, it was natural that they were compared with this basic unit and so the term *candle power* naturally followed.

You have undoubtedly noticed that as you move an object such as a book or picture away from a source of light the illumination of the book or picture lessens rapidly as you move away. This change in illumination is actually diminishing at a rate equal to the square of the distance from the lamp. Thus the illumination on a picture one foot from a lamp is four times as great as when the picture is two feet from the lamp.

In photo-electric work the unit of illumination intensity used is the foot candle. The foot candle is a measurement of light intensity, and is generally defined as the amount of light falling on a surface perpendicular to the light rays and one foot from a light source of one candle-power. Another unit of light measurement used in photo-electric work, is the lumen. A lumen is a measurement of quantity of light and is defined as the amount of light falling on a surface one foot square, each point of which is one foot from a light source of one candlepower. It is also the product of the area of the surface illuminated and the intensity of light thereon in foot candles. That is, foot candles times area in square feet gives a result in lumens.

One candlepower consists of 12.6 lumens. The number of lumens of light falling upon a surface from a point source of light may be expressed as follows:

$$L=\frac{CA}{d^2}$$

Where L is equal to lumens; A is area of surface in square centimeters; d is equal to the distance from the surface upon which the light falls to the light source, expressed in centimeters.

To better understand these light measurements, refer to Fig. 4. Here there is a source of light at A of one candle-power and a surface at B of one square foot. Then the intensity of light at B is one foot candle, and the quantity of light falling on the surface at B is one lumen. But, if these same light rays are extended to another surface at C which is two feet from the source of light, the area

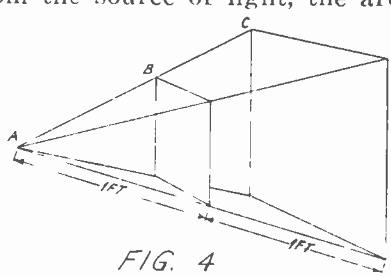


FIG. 4

illuminated is now four square feet. As before the quantity of light falling on the surface at C is one lumen but the light intensity at C is only one quarter (.25) foot-candle.

LIGHT SOURCES

Now, having learned the nature of light and how it is measured, you will be able to understand the action of light in its use in photo-electric cell application.

Light sources of nearly all commercial types, use a source similar to a common automobile headlamp as the illuminating unit. This type of lamp has been chosen for several reasons. Primarily because it has a small concentrated filament which is practically a *point source* of light. The advantage of a point source of light will be shown in the study of light transmitting equipment. The size of the light source is such that it may be mounted in a very small space. The filament of this lamp may be energized from a 6 volt battery, from a 110 volt line by means of a step-down transformer or from a 110 volt DC line by means of series resistors.

There are some cases where some other source of light waves is used. In many applications, signs and kindred equipment are turned on by the action of sunlight. That is, when the sun goes down in the evening and light from the sun begins to fade, the photo-cell reacts accordingly and turns on the sign. In the morning when the sun comes up the reverse action takes place and the sign is turned off. Also many applications use actual flame from unwanted fires to energize a photo-cell, ringing an alarm and even ringing a fire alarm at central fire headquarters.

LIGHT TRANSMITTING EQUIPMENT

As stated before, the ability of a photo-cell to operate depends entirely upon the amount of light falling upon the sensitive surface of the photo-cell.

Consider Fig. 5 for a clarification of this principle. You will note that the photo-electric cell at A receives only a very small portion of the total light rays emitted by the light source. If the photo-cell at B is the same type of cell as that at A and is twice the distance from the light source at the cell at A, the amount of light falling on its sensitive surface is one fourth (.25) of that at A. Obviously, in order to work at any distance from a light source without using an extremely strong light source, some system must be installed to utilize as many of the rays from the light source as possible. In photo-electric work a system of lenses or lenses and reflectors are used.

The simplest form of light transmitting equipment is that in which the light rays travel in a straight line between the light source and the photo-electric cell. In such a system, two lenses are used, one at the light source and one at the photo-electric cell.

The study of lens and reflectors, more commonly known as the science of optics, will not be

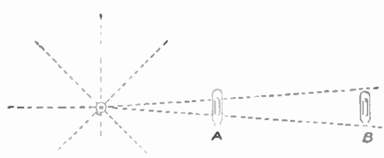


FIG. 5

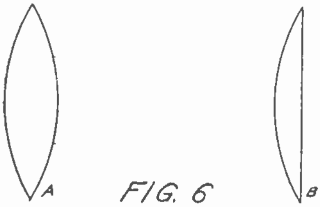


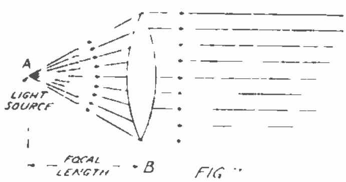
FIG. 6

treated here to any great extent. Some statements made will be made as true without any attempt to prove them to you.

Lenses used in photo-electric work are usually of the double convex type (see Fig. 6A) or of the plano-convex type (see Fig. 6B).

Lenses when properly made actually have the property of *bending or changing the direction of a beam of light.* Thus, if there is a source of light as at A in Fig. 7, a portion of the light ray falls upon the lens and after leaving it, the light rays part as shown by the arrow lines.

This distribution of light is assumed to be from a point source. Actually, however, a point source of light cannot be realized, and there are therefore, some diverging beams as shown by the dotted lines in Fig. 5. These diverging beams are also caused by the fact that commercial lenses are not absolutely true, and do not transmit the beams true to theoretical calculations. This stray light is never great enough to cause any difficulty in photo-electric work. Referring again to Fig. 7, the distance between the light source A and the center of the lens at B is known as the focal length of the lens, and every lens is identified by this measurement. Obviously, the closer the lens is placed to the light source, or in other words, the shorter the focal length of the lens, the more light will be collected from the light source and transmitted to the photo-electric cell in a parallel beam. Now, if an identical lens is placed at the photo-electric cell end of the beam, the beam of parallel rays will be focussed again to a point. However, the photo-electric cell is not placed at exactly the focal point of the lens. If it were, only a point of light would be projected on the sensitive surface of the cell. For this reason, the photo-electric cell in Fig. 8 is placed either slightly closer to the lens at A or slightly farther away at B from the lens than its focal point. This distance is just sufficient to completely illuminate the active surface of the photo-electric cell. The entire system is then shown in Fig. 8. Note as stated, that the photo-electric cell may be placed at either A or B with the same results.



FIG

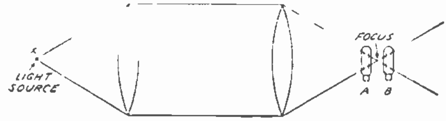


FIG 8

In some cases a parabolic reflector is used in back of the light source in place of a lens in front of it. This reflector reflects the light rays in a parallel beam as shown in Fig. 9. This has the faculty or property of using a higher percentage of the available light rays, and for that reason is more efficient than the lens. It takes somewhat more space for mount-

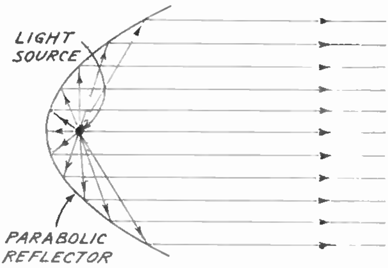


FIG. 9

ing and for that reason, as well as its higher cost, is seldom used in commercial light sources.

The use of two lenses is the simplest form of light transmitting equipment. However, in many cases the space available, or the particular object of the photo-electric installation requires a light beam which is reflected by one or more mirrors. For instance in the case of burglar alarms, it is possible to protect an entire room by reflecting a light beam across the room several times. In one commercial application, an irregular room was protected from floor to ceiling by a beam of light reflected 27 times between the light source and the photo-electric cell. For the purpose of this study a single mirror will be used inasmuch as all plane mirrors, which are usually used, follow the same principles.

By referring to Fig. 10, you will note parallel rays, from a light source and lens, falling on a mirror and reflected to another lens and in turn focused on a photo-electric cell. The light beam from

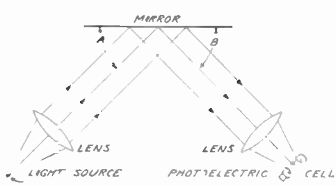


FIG 10

the light source falls on the mirror at an angle A, known as the ***angle of incidence***. It is reflected from the mirror at an angle B, known as the *angle of reflection*. In all cases, for plane mirrors, the angle of reflection is equal to the angle of incidence. This is true regardless of the position of the mirror or the position of the light source. Thus in all photo-electric installations requiring the use of a mirror, you can calculate the position of the mirror and construct supports for it without tedious trial and error methods.

Having some knowledge of light principles and also a knowledge of how light is transmitted to the photo-cell, you are now ready to study the photo-electric cell itself. Almost all photo-electric cells or light sensitive cells made commercially can be divided into three general classes. These are as follows:

(1) Photo-conductive Cells: These cells are of a type in which the light sensitive material changes its electrical resistance in proportion to the changes in the light falling on it. As Selenium is nearly always used in this type of cell it is commonly called the *selenium cell*.

(2) Photo-emissive cells: These light cells are those in which the light sensitive material, mounted on a cathode, emits electrons in proportion to the amount of light falling on this light sensitive material. The electrons so emitted are collected by an anode which is held at a potential higher than the cathode. These cells consist of two electrodes mounted in a glass envelope or tube and in turn mounted on a regular vacuum tube

base. These cells may either be evacuated or be gas filled.

(3) Photo-voltaic Cells: These cells are of the type which generate an EMF within themselves, which is in proportion to the light falling on their active surface. These are also known as self-generating cells and are the type used in photometers common to photographic work.

PHOTO-CONDUCTIVE CELLS

The photo-electric properties of selenium were discovered by Willoughby Smith and a Mr. May in 1873. Selenium was being used by these men as resistors in an electrical circuit. They noticed that when the sun was in a position to shine on the various elements of these circuits, meters connected in the circuits flickered. By shielding various parts of the circuit from the sun with their hands, they found that the selenium resistors were causing the flickering of the meters.

As the name of this type of cell indicates, it changes the electrical resistance of its active element in accordance with changes of light falling on its active surface. From this principle it follows that it is at all times necessary to use an external source of voltage to take advantage of this effect. The resistance of these cells is always the greatest when not illuminated and the resistance decreases as the amount of light falling on the active surface increases. By means of a suitable amplifier circuit, this effect can be utilized to control many other operations.

Basically all photo - conductive cells or selenium cells as they are commercially called are more or

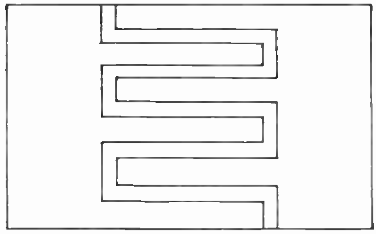


FIG. 11

less the same. Selenium is deposited between two metal electrodes. The metal electrodes may be of practically any metal, even gold having been used satisfactorily in experimental cells. These electrodes are supported on insulating material such as glass, quartz, bakelite or any similar material. These electrodes are formed commercially in several ways. One of these is shown in Fig. 11 and another in Fig. 12. The element of Fig. 11 is constructed by forming the selenium *grid* in a die. The grid is then assembled by cementing it to its insulating support and trimming the excess foil. The element of Fig. 12 is constructed by winding two separate wires around an insulating support. In other cases, metal is deposited on the insulating support by electrolytic action, and the grid is formed by scratching this metal to form the open spaces. The spacing of the electrodes is an important factor, as it controls not only the resistance of the cell, but its operating voltage. Molten selenium is then placed on these electrodes, and spread by pressing a protecting cover of glass or quartz over the

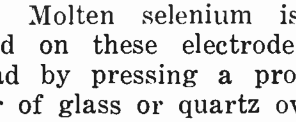


FIG. 12

selenium. This spreads the selenium over and between the electrodes, and the glass cover acts as a window to admit light to the active surface of the cell. The selenium may also be deposited by chemical action or by vaporizing and condensing the vapor on the electrode assembly. However, in all cases the selenium and electrode assembly is given an annealing treatment to change the selenium into its light-sensitive form.

After this preparation, all types of cells are hermetically sealed from atmospheric moisture which has a very undesirable effect upon the sensitive selenium. The selenium quickly loses its light sensitive properties under humid conditions.

Selenium cells have certain properties which in some types of photo-electric work are objectiontionable. These may be specified as *time lag and fatigue.* Time lag may be explained as the property of selenium cells of not responding immediately to changes in light. This time lag is only a small fraction of a second, the current rising rapidly the first instant the cell is illuminated and more slowly reaching a final value. Fatigue may be explained as that property of selenium cells of dropping off in output when continuously exposed to strong light. The current after reaching a maximum value will slowly decrease, returning to its original value only after illumination has been removed for a short time from the cell.

Both of these properties are shown graphically in Fig. 13. From time T to T1 note the current rises sharply and then slowly reaches a maximum. Although

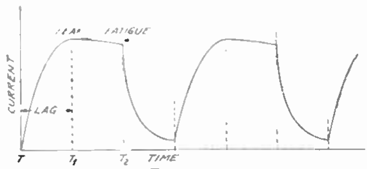


FIG. 13

the time period from T to T1 is only a fraction of a second, it is sufficient to make this type of cell unsatisfactory for talking motion picture and television work. The property of *fatigue* is illusrated by the current path between T1 and T2 in Fig. 13. Under continued light this output will gradually decrease until it reaches a steady value. Although these two objections are detrimental to the use of this type of cell, they offer no obstacle in most photo-electric installations. The low cost, the small size and ruggedness of this cell makes it ideal for most practical use.

Figure 14 shows the current-illumination curve for a typical selenium cell. You will note that the current does not increase in a straight line. The increase for each foot-candle increase of illumination is greater at low intensities than at

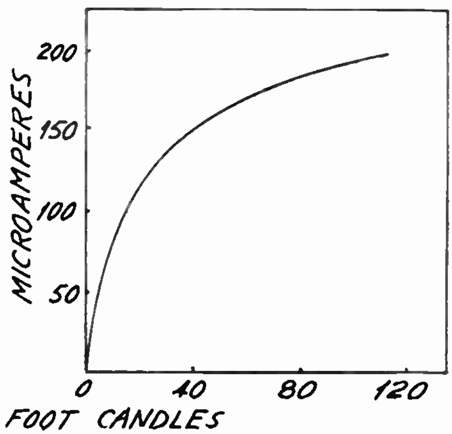


FIG. 14

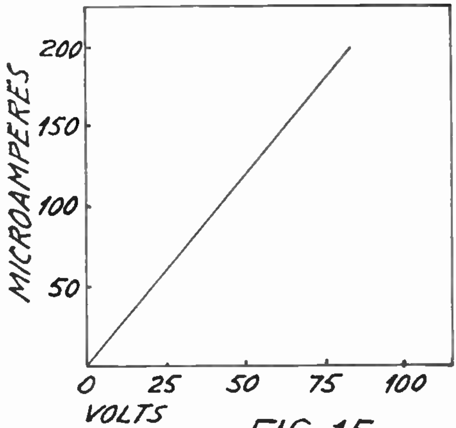


FIG. 15

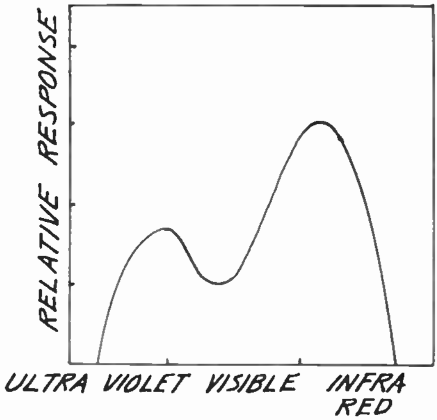


FIG. 16

higher intensities of light. You will note that the current does not drop to zero. It can only drop to a value in line with the dark resistance of the cell. The measure of sensitivity of selenium cells is indicated by the ratio of dark resistance to light resistance. In this particular case the sensitivity of the cell is approximately 10 to 1. Some commercial cells have a sensitivity as high as 50 to 1.

When the illumination is held constant on a selenium cell and the voltage is varied, the cell reacts exactly as a resistor. This variation is shown in Fig. 15. The current varies in direct proportion to the voltage variation and the straight line shown holds true.

Referring to Fig. 16 you will see one of the advantages of the selenium cell. It definitely responds to the invisible spectrum, especially in the lower infra-red region. This is a decided advantage as all burglar alarms and similar devices are more satisfactory where an invisible ray can be used.

Nearly every commercial selenium cell requires an amplifier of some type, depending upon the particular application. Obviously the current output is not sufficient to operate a relay direct. Consequently, in order to operate a relay, a vacuum tube amplifier is used. The grid of the vacuum tube is controlled from the photoelectric cell and the plate current of the vacuum tube operates the relay.

Figure 17 shows a typical circuit of a single stage amplifier. Referring to this circuit, when the selenium cell is dark, the grid of the vacuum tube is held at a negative cut-off potential by battery C and no plate current flows. When the cell is illuminated, the grid becomes more positive, allows plate current to flow and closes the relay in the plate circuit of the tube.

In the use of selenium cells certain precautions must be taken, to

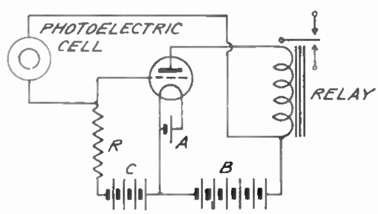


FIG. 17

insure correct operation and long life.

(1) Under no conditions should selenium cells be operated in a temperature exceeding 125 dgrees Fahrenheit. Due to the nature of the selenium used, any temperature exceeding this value will cause serious damage.

(2) Selenium cells must never be exposed to direct sunlight or to lights of great intensity. Due to the *fatigue* factor of the cell, such exposure causes temporary and sometimes permanent loss of sensitivity.

(3) When not in use, selenium cells should be kept in an enclosed box. Light of any kind, even though of low intensity, reacts on the active surface the same as if the cell were in actual use.

(4) Selenium cells should always be kept dry; especially those which are not hermetically sealed in bakelite or some similar material. Moisture of any kind, reacts with sensitive selenium causing loss of sensitivity and eventually complete deterioration.

PHOTO-EMISSIVE CELLS—VACUUM TYPE

As the name indicates, photo-emissive types of photo-cells operate upon the principle of the emission of electrons from a cathode. coated with a light sensitive material, when light strikes this cathode.

Figure 18 shows a sketch of a common type of photo-emissive cell and its construction. The cathode and anode are connected to a standard tube base. The envelope is usually of glass, although sometimes quartz is used because of its property of transmitting a greater

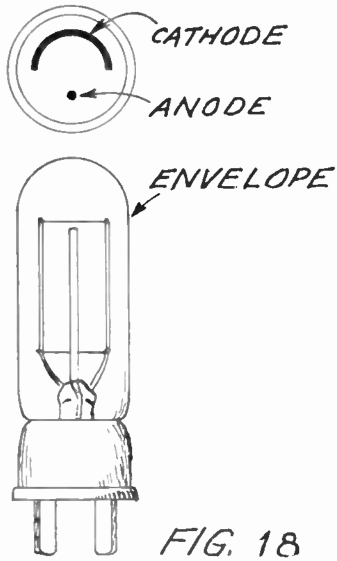


FIG. 18

band of light spectrum, especially in the ultra-violet region.

As this cell is similar to a diode type vacuum tube, its action is practically instantaneous. It is able to respond to extremely high frequencies making it ideal for use in talking motion picture and television work. The only limit upon its use is its capacity between electrodes. In most cases this is so small a value that it does not seriously alter the circuits in which it is used.

Since the principle of the photo-emissive type of photo-cell was discovered, much experimental and research work has been carried on by the leading industrial concerns to discover the most satisfactory metal or compound to use in this type of cell. Figure 19 gives the graphical form of the results of this work. Potassium was long used by these firms as the light sensitive material. However, it was later discovered that caesium deposited over a thin layer of silver, gives far better results. Now, except in

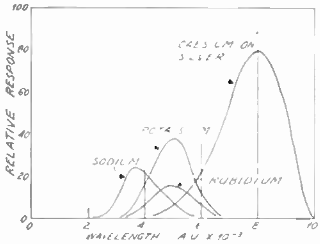


FIG 19

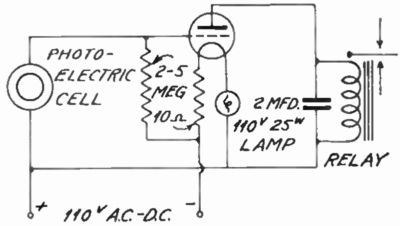


FIG. 21

special cells for particular applications, this is used entirely for commercial cells.

The action of a photo-emissive cell is exactly like the action of a diode vacuum tube. Electrons are emitted from the cathode by the action of the light on the cathode (see Fig. 20). The electrons are attracted to the anode, as it is held at a potential positive with respect to the cathode by an external battery. This action, as stated before, is exactly as in a vacuum tube. The cathode corresponds to the filament or cathode of the vacuum tube, but electrons are emitted by the light striking the cathode rather than by the heating as in the vacuum tube. *No grid, however, exists in a photo- electric cell.* Control of the electrons is dependent only upon the amount of light striking the cathode.

The current passed by this type of cell is necessarily small. In most cases, an amplifying circuit is necessary to operate an auxiliary relay. Such a circuit operating direct from a 110 volt AC source is shown in Fig. 21. The 25 watt, 110 volt lamp is placed in the filament circuit to reduce the line voltage to a value suitable for the amplifying tube.

The tube is normally biased so that the plate current is zero. When light falls on the cell, the grid of the amplifier tube is made more positive by the photo-electric cell current flowing through the grid resistor. Plate current then flows and the relay contacts close.

The voltage applied across a photo-electric cell of this type is not critical. Under constant illumination, however, a saturation point is reached after which no additional current flows even though

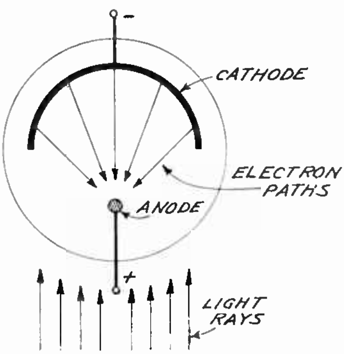


FIG. 20

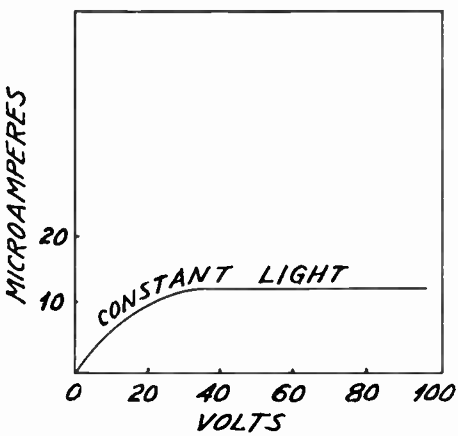


FIG. 22

the applied voltage be increased. This characteristic is shown in Fig. 22.

In this type of cell the current in the photo-electric cell varies directly with the amount of light falling on the cathode. This is illustrated in Fig. 23. You will note also that in this type of cell, the current goes to zero at zero illumination. As no electrons are emitted from the cathode when no light strikes it, this is necessarily true.

Figure 24 shows the response of a typical vacuum type photo-emissive cell over the light spectrum. The response in the visible spectrum is less than in the ultra-violet and infra-red bands. This makes it ideal where invisible light is to be used for operation of the equipment.

In construction, a gas filled photo-emissive cell is identical with the vacuum type photo-emissive cell. A cathode, which emits electrons upon the application of the light rays and an anode for the collection of these electrons are sealed in a glass or quartz envelope. However, in the gas filled tube, after evacuation and before sealing off, a small quantity of some inert gas is liberated within the tube. Argon gas is usually used, although helium or neon gas can also be used.

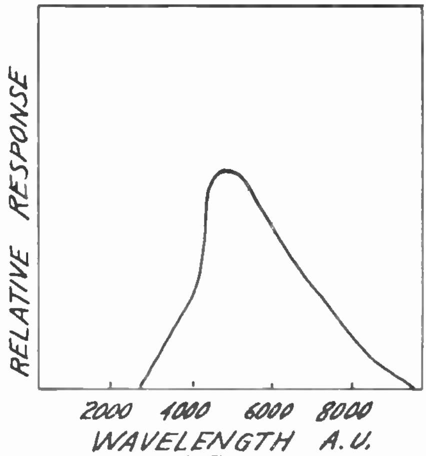


FIG. 24

In operation, however, there is a big difference between the two types of cells. The electrons emitted from the cathode by the action of the light, travel toward the anode at high speed. In this travel they collide with atoms of the gas with great force *ionizing* them. That is, the atoms are split up into positive ions and free electrons. The electrons thus liberated are also attracted to the anode and help increase the total current in the cell. The positive ions move close to the cathode forming a space cloud. It is possible, in gas filled cells, to obtain a cell current 8 to 10 times as great as in a corresponding vacuum type cell.

In Fig. 25 note the relative tube current in respect to the illumination applied to the cathode. This curve is taken with constant voltage applied to the cell. As in the vacuum type cell, the current

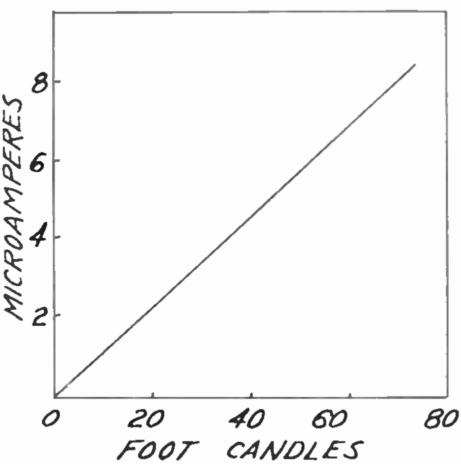


FIG. 23

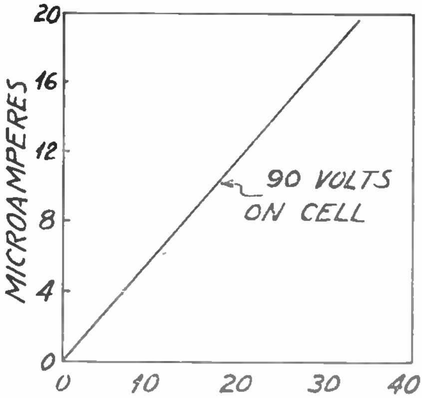


FIG. 25

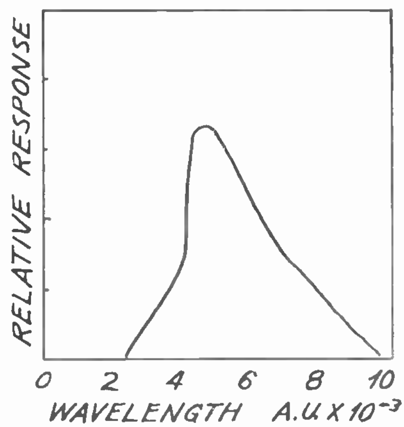


FIG. 27

varies directly as the voltage. However, for the same voltage, the output current is far greater than in the vacuum type.

The action of the gas is shown clearly in Fig. 26 which gives the voltage current relationship of the gas filled cell. You will note that the current follows the same curve as the vacuum type cell up to about 30 volts. At that point the gas action starts and the current increases rapidly. The voltage applied to this type of cell *is very critical.* If the applied voltage is too great, ionization reaches the point of *glow breakdown* and further current increase would be independent of light intensity. The excessive current flow accompanying this breakdown would cause damage to the tube. A resistance is usually used in series with the phototube to prevent ionization from reaching the point of *glow breakdown.* Proper limitation of the applied plate voltage of the phototube to within the range specified by the manufacturer is imperative.

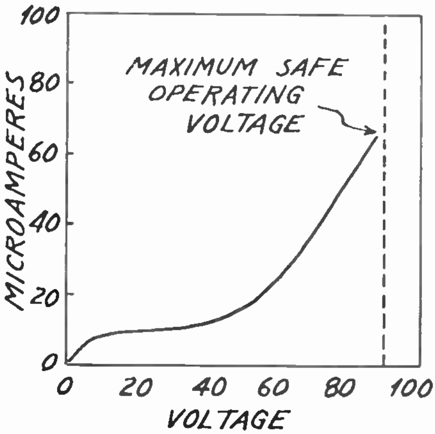


FIG. 26

Figure 27 gives the color response curve for the gas filled cell. This is practically identical with that for the vacuum type cell.

PHOTO-VOLTAIC CELLS

Photo-voltaic cells, are simply small batteries, which generate by electronic and chemical action voltage and current. Photo-voltaic cells take their name from the fact that when their active surface is exposed to light rays they generate a voltage within themselves.

The resulting current varies according to the amount of light falling on the cell. The current is small but in most cases is great enough to operate a super-sensitive relay without using any auxiliary equipment such as batteries or amplifiers.

Photo-voltaic cells fall into two classes, the dry type which may be called an electronic type and the wet type which may be classed as an electrolytic type. The dry or electronic type is in commercial use. For that reason consideration will be given to that type in detail.

Most commercial dry photo-voltaic cells are constructed in the same manner. A disc of steel is coated with a photo-sensitive material, usually selenium. This is spread and annealed. An extremely thin layer of gold, silver or platinum is placed over the selenium and the whole is protected by a glass window. This assembly is sealed in an insulating case and leads are brought out from the steel and the thin silver or gold layer on top of the selenium.

One of the commercial type of photo-voltaic cells now on the market uses a copper base with a coprous oxide coating in place of selenium on iron. Figure 28 shows the construction and operating circuit of these cells.

The top layer of gold or silver must be extremely thin to allow the light rays to shine through onto the active material. It may be a sheet of *gold leaf*, or it may be sprayed or sputtered on to the active material. Light rays shining through the gold onto the active surface forces electrons to that surface. These are collected by the top foil and a collector ring and find their way back through the relay to the steel disc where the operation is repeated. In all cases the foil cover is at negative potential and the steel at a positive potential.

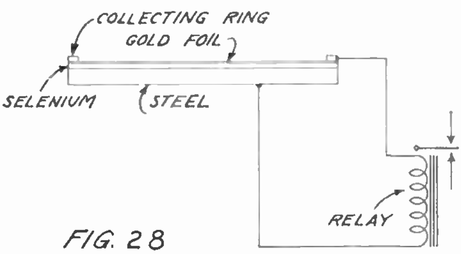


FIG. 28

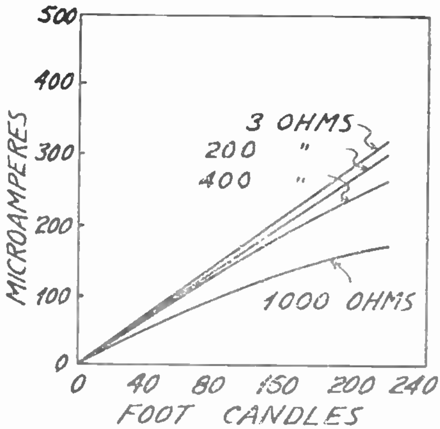


FIG. 29

Figure 29 shows the current output variation with respect to illumination changes for several values of external resistance. With low resistance loads, the output is practically a straight line, however, with high external load resistances, this is not true. This is due to the fact that the internal resistance falls lower with increase in illumination and acts as a shunt for the load resistance.

Figure 30 shows the generated voltage as it varies with illumination. This, you will note, is not a straight line and the voltages are very small. As a rule this type of cell is not used with a vacuum tube amplifier due to the relative high voltages required to get a usable change in plate current.

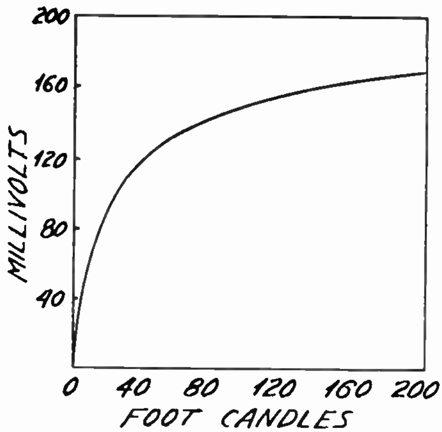


FIG. 30

Figure 31 shows the color response of a typical cell as well as the eye response. You will note the close relationship between these two curves. This property makes it ideal for use where the photocell replaces the human eye for color comparisons.

As stated, photo-voltaic cells as a rule are not used with amplifier tubes. The output of the cell is connected directly to a supersensitive relay whose contacts in turn control the operation to be performed. The super-sensitive relays are built much like a meter,

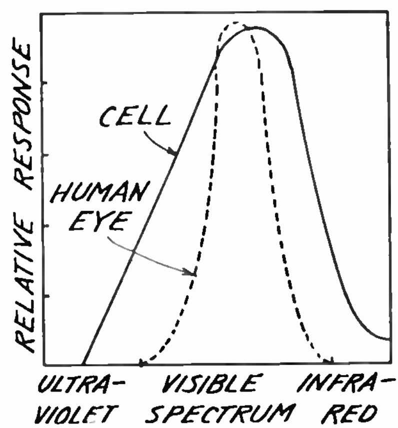


FIG. 31

the moving contacts being on the moving arm, and the stationary on the scale. These meter types of relays respond to extremely small currents and are quite expensive.

Although the action of these cells is practically instantaneous, they are not suitable for use in talking motion picture or television work. This is due to the high inter-electrode capacity which at audible frequencies acts as a shunt across the output of the photoelectric cell.

Wet photo-voltaic cells, due to their construction have not met with any commercial success. They consist of two metal electrodes immersed in an electrolyte. In some cases one of the electrodes is light sensitive and in another the electrolyte is the sensitive material. The former cell usually consists of one copper electrode and one having a coating of coprous oxide. As these cells sometimes form dangerous gases, they are not welcomed by the users of photo-electric cells.

RATINGS OF PHOTO-ELECTRIC CELLS

All types of photo-electric cells are rated by their sensitivity. In the case of the photo-conductive cells, this sensitivity is the ratio of dark resistance to light resistance. If the dark resistance is 50 megohms and the light resistance is 2 megohms the sensitivity is 25 to 1. In photo-emissive and photovoltaic cells, this sensitivity is rated as the current passed per lumen of light.

Other ratings on photo-cells which must be kept in mind by the user are:

(1) Maximum and operating voltages. The maximum voltage is

that voltage beyond which the tube will reach glow breakdown. The operating voltage is the voltage recommended by the manufacturer of the cell as a safe voltage to apply to the cell for normal operation.

(2) Maximum safe temperature limit. This rating is extremely important in both photo-voltaic and photo-conductive cells. If this temperature, recommended by the cell manufacturer, is exceeded, serious damage may be done to the cell.

(3) Maximum illumination rating. Most cells cannot be exposed to direct sunlight or intense light from other sources. Most suppliers specify the maximum limit of illumination that their cell can stand with no damage.

In this lesson one basic circuit for each of two of the three types of photo-cells has been given. Another circuit which is often used is shown in Fig. 32.

This circuit is used primarily where small changes in light are to be detected, and responds to slow variations in light. The circuits shown in Figs. 17 and 21 are known as impulse circuits and respond only to large sudden changes in light such as when the light beam is completely broken.

Referring to Fig. 32, when no illumination is on the cell, the potentiometer in the grid circuit is adjusted until the relay drops out (releases). Now when the cell is illuminated, the resistance of the cell is reduced, bringing the voltage of the grid nearer the plate voltage and allowing more current to flow, thus closing the relay.

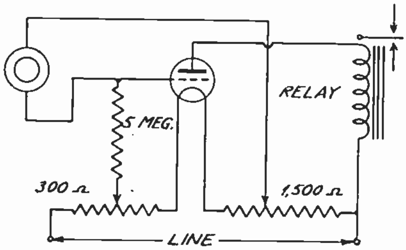


FIG. 32

In some cases it is possible to operate a power relay direct from a photo-cell and amplifying tube circuit. This is done by the use of a gas filled amplifying tube such as the thyratron or grid-glow tube, as it is sometimes known. These tubes, which are fundamentally triodes filled with an inert gas operate as follows:

When the tube has a definite grid bias and the plate voltage is gradually increased from zero, to a certain specified voltage, a large space current suddenly starts to flow through the tube. When this space current, which may be rated in *amperes* in some cases, once starts to flow, the grid loses control over the plate current, and it is necessary to reduce the plate voltage to a low value before the space current stops flowing. The higher the negative voltage on the grid, the higher the necessary plate voltage to start the space current. Mercury gas is used in tubes passing high current, but argon or neon gas tubes will pass as high as .5 ampere without any difficulty. This is sufficient for most power relay applications in photo-electric control work.

The thyratron tube has several applications other than for photo-electric control circuits as you will learn as you continue your study of radio. The thyratron tube might be defined as a *grid controlled rectifier* tube of the gas filled type. The action of the tube is determined as in any triode by the voltage on the grid and also that applied to the plate.

The action of the tube as the voltages on the plate and grid are varied is shown in Fig. 32A. At (A) the grid is negative and the plate is also negative. Thus no electrons flow through the tube due to the highly negative field (electrostatic) on both the grid and the plate. As the plate is made positive, Fig. 32A (B), the grid, remains negative. The negative field produced by the grid prevents a flow of electrons (because it is acting between grid and cathode) but as the grid is made *less negative* a point will be reached where the positive field due to the positive voltage on the plate is high enough to overcome the negative repelling field of the grid and the plate will then draw electrons from the cathode. (Fig. 32A) (C). These electrons in being drawn to the plate cause the gas inside the tube to become ionized and the positive ions thus formed are attracted to the cathode and as more electrons are emitted from the cathode, they neutralize these ions and in this way the ions reduce the negative *space charge of the cathode* and allow the emission of more electrons. This makes the tube a better conductor and will allow a heavy current to flow. Now when the grid is made more negative again, it will attract these positive ions and form a positive sheath around the grid. *Thus, the grid acts as though it were positive.* Therefore, it has no control upon the electron emission of the tube. This action is shown in Fig. 32A (D).

Before the grid can be made to control the tube action after the gas once becomes ionized, the plate and grid must be made negative as shown in Fig. 32 A(E), and the

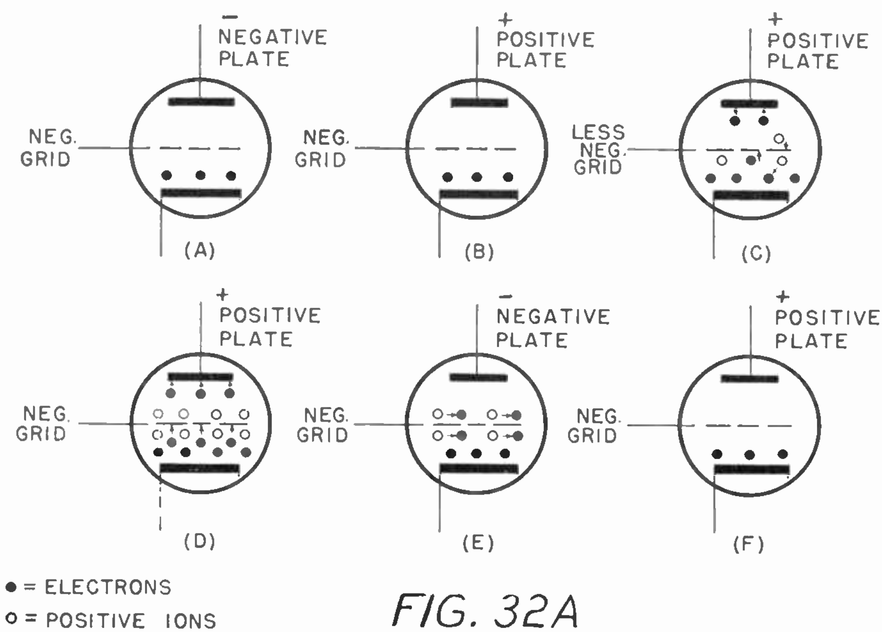


FIG. 32A

cycle is repeated as before and the grid is placed in control of the tube once again.

The ionization of the gas within the tube causes a glow inside the tube. The color of this glow is determined by the type of gas used. Because of this glow the tube is said to have fired and when the ionization is stopped by reducing the plate voltage to zero or making it negative it ceases firing and returns to normal.

Thyratron tubes are triode tubes, but they are not used to vary the plate current around a certain steady value as do other amplifying triodes, but they are made so that the grid voltage of the tube acts as a trigger allowing the tube to fire at the correct time, thus causing a heavy current to be drawn by the tube plate circuit. In photoelectric circuits the grid voltage is controlled by the photo tube and the heavy plate current is made to operate a relay which in turn may operate a number of different electrical machines.

RELAYS

When this type of tube is operated on DC, the circuit is self locking. Once the current starts flowing and the relay is closed, it is necessary to reduce the plate voltage by some mechanical method before the space current will stop flowing and the relay will open. However, on AC circuits, this is not true, as the plate current will be reduced to zero every cycle. For this reason this type of tube is used almost entirely on AC circuits. A circuit for such a control is shown in Fig. 33.

Mention has been made about relays but up to this point no special instructions have been given

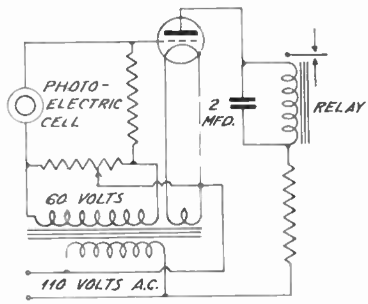


FIG. 33

as to their construction, their operation or their characteristics. Relays, as used in photo-electric work, can be divided roughly into three classes according to their application. These are the supersensitive relay, the sensitive relay, and the power relay. Further classification of the power relays can be made into AC and DC relays.

The subject of relays is one that cannot immediately be exhausted for there are numerous types and styles of relays. The relay operates upon the same principle as an electro-magnet that is as the coil of the relay is excited (voltage applied to it) it causes a magnet field to be set up. This field causes a movable iron core or arm to be attracted toward the center of this attracting force. The solenoid type relay is composed of a movable metal core which is suspended in the center of a coil of wire. The size and number of turns of this coil depends upon the use of the relay. If it is to operate from a high voltage, the wire is small and there are many turns. Arm type relays are used more commonly than the solenoid type. The relay and the controlling circuit act as an *automatic switch* which allows a voltage to be applied to some mechanism that is made to operate a certain definite piece of equipment.

In the next lesson, several practical uses of these controlling circuits as applied to industrial applications will be given to acquaint you with some of their possibilities in the industrial field.

Relays are the heart of all types of controlling circuits such as telephone switch boards, especially the dial system, alarm circuits, automatic heat controls and many other types of automatic controls. Practically all recent developments in the Army and Navy as well as industrial equipment and machinery uses relays in one form or another. Thus the relay today is one of the most important single units in modern electrical control equipment.

A special circuit set up by a leading telephone company which incorporates many relays and also a photoelectric tube circuit is one for automatically telling the time when a certain number is dialed. This system consists of a strip of film on which is recorded the time every minute in voice. This film is so synchronized with an electric timing system that the correct time is given when this number is dialed. The sychronizing pulse and the switch mechanism to start the system operating are all accomplished with relays. The sound is produced from the film with the aid of a photo tube and an electric amplifier.

It is quite obvious how complicated some of these systems must be and how accurately the relays must operate.

The mechanical construction of relays which are designed to operate from DC is such that a DC relay will not function properly on AC. This is due to the current and voltage reducing to zero when AC is applied. This causes a chattering or buzzing sound to emanate from the relay. It may also cause the relay contacts which operate the controlled mechanism, to spark as the contacts are opened and closed at the frequency of the AC applied to the relay. This will, of course, cause the contacts to burn or pit in a short time. With AC relays some method of preventing this chatter must be provided. There are several methods of preventing this chatter. Placing a metal ring so that the collapsing magnetic field caused by the current reducing to zero sets up a counter *emf* in this ring such that the magnetism is still retained in the core even though the current through the relay coil is zero is a common method of reducing the chatter. This ring is usually called a shading coil.

Another method is to actually wind a separate winding on the core and short the ends together. Or in other types of relays a split phase arrangement is used. By splitting the phase of the AC voltage applied to the relay the current flowing through the two windings of the relay can never drop to zero. Two windings are necessary to accomplish the phase shifting action.

The brief discussion given here concerning relays is to acquaint the student with the operation and use of relays. A more detailed description of some of the more sensitive relays which are used in conjunction with photo circuits will now be given.

SUPER-SENSITIVE RELAYS

Super-sensitive relays operate on the principle of a meter. Some of the better types have a sensitivity as low as 15 microamperes. A drawing of such a relay is shown in Fig 34.

Basically these relays are nothing more than a moving coil type microammeter. The pointer is replaced with a moving arm, carrying the moving contact. The stationary contacts are placed on the scale portion of the meter. The contacts of these relays are normally rated to handle currents not in excess of one quarter of an ampere and must be practically non-inductive to prevent arcing of the contacts.

Super-sensitive relays can be set for normal operation in any of three different positions. These are:

(1) With no current flowing, the moving contact is set midway between the two stationary contacts. If current flows in one direction, contact is made with one stationary contact. If current flows in the opposite direction, contact is made with the other stationary contact.

(2) The moving contact is set midway between the two stationary contacts for some predetermined value of current. If the current should increase from this value, contact is made with the right hand contact. If the current should decrease, contact is made with the left hand contact.

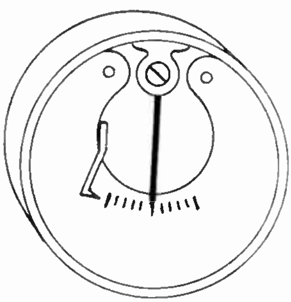


FIG. 34

(3) The movable contact is moved and made to touch the left stationary contact for zero current. As the current increases, the moving contact is made to touch the right hand contact.

In all these types of settings, the closer the stationary type contacts are together, the more sensitive the relay. This is due to the fact that the closer these stationary contacts are to each other the less current variation is required to move the movable contact between them.

Super-sensitive relays, due to the small current required to operate them, have one great objection to their use. When the current of the movable contact is just sufficient to cause it to touch one of the stationary contacts, any slight variation in current will cause the movable contact to make and break the circuit with the stationary contact. This is called *chattering*. To remedy this objection, some relays have a small permanent magnet incorporated in them. This is so placed that when a circuit is established between the moving contact and the stationary contact, the magnet holds the contacts together regardless of any current fluctuation thereafter. This type of relay, however, requires some manual or magnetic method of resetting.

Due to the small amount of power the contacts of a super-sensitive relay can handle it is nearly always necessary to use a sensitive relay and sometimes also a power relay in connection with them.

SENSITIVE RELAYS

Figure 35 shows a drawing of one of the commercial sensitive relays. This type of relay depends upon the familiar principle of electromagnetism for its operation.

When coil A is energized by direct current a magnetic field is set up through the iron circuit B and the armature C. The tendency of the magnetic field is to flow through the easiest path or the iron circuit. Thus the magnetic attraction pulls the armature up to the iron circuit and the contact is made. Contacts are placed on the armature and the two stationary terminals at D in Fig. 35. So that the force necessary to close the contacts will be as small as possible, the armature is made as light as possible, the spring tension is made as light as necessary to return the armature to its open position and the friction between the armature and its support is reduced to a minimum.

Sensitive relays operate on a comparatively low current, in the neighborhood of 1 to 3 milliamperes. To obtain sufficient magnetic force, therefore, it is necessary to have a large number of turns of very small wire in the operating coil of the relay. The steel used in the iron circuit and the armature must have the characteristic of high permeability. That is, it must give the highest possible magnetic field for a given number of ampere turns in the coil. Also it must have the property of losing its magnetism as rapidly as the current drops in the energizing coil. Practically, this is of course impossible, but this condition can be approached by some alloys of iron and silicon or of iron and nickel.

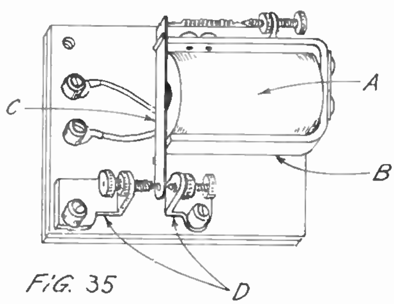


FIG. 35

The speed of sensitive relays depends entirely upon the mass of weight of the armature and the setting of the stationary contacts. If the armature is light—that is, if it is of thin material and the shortest possible length, and the armature has to travel only a few thousandths of an inch to close, it is possible to close a sensitive relay in less than one thousandth of a second.

Sensitive relays are used in plate circuits of vacuum tubes. In photo-cell work, these vacuum tubes are often operated directly from alternating current lines, which produce a pulsating current through the relay coil. To prevent chattering in this case, a capacitor of about 2 mfd. is placed across the relay coil. If a capacitor of too large a capacity is used it will act as a shunt across the relay coil and reduce the sensitivity of the system.

Some types of sensitive relays can be obtained to operate directly on alternating current. These are less sensitive than direct current relays because of losses due to eddy currents and hysteresis in the iron circuit. To reduce these

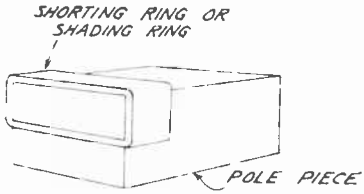


FIG. 36

losses to a minimum several modifications of the direct current relays are necessary. In some cases the core is laminated although the same results can be obtained by slotting a solid core along one side. Also a shading ring is placed on the end of the core nearest the armature. This ring splits the pole as shown in Fig. 36.

The principle of the power relay is identical with the principle of the sensitive relay. However, where the sensitive relay controls up to 250 watts on a coil current of from 1 to 3 milliamperes, power relays control power in kilowatts and operate on about one-tenth to one-half ampere. Alternating current power relays have the same modifications to prevent chattering as alternating current sensitive relays. Power relays often carry many contacts depending upon the switching operation or operations they are to perform.

In some cases it is necessary for power relays to be held in the closed position even when the photo-electric control circuit and sensitive relay have returned to normal position. *Latch-in* relays are used for this purpose. They may be released manually by simply pushing on the latch, or they may be released magnetically by means of a magnet or a relay whose armature is attached to the latching mechanism.

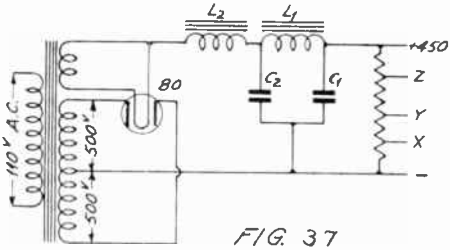


FIG. 37

POWER SUPPLIES

Photo-electric circuits may be designed to operate from practically any voltage source either alternating current or direct current. A great many simple circuits operate direct from the 110 volt alternating current line without the use of a transformer. Some circuits require a higher direct current voltage in which case a rectifier system as illustrated in Fig. 37 is used. Any voltage required can be picked off the voltage divider as at X, Y or Z.

Where 32 volts or 6 volts direct current is the supply to be used, two possible systems are available. First a motor generator unit, such as a dynamotor may be used. Secondly, a vibrator circuit may be used. This type of circuit gives a more flexible voltage supply than is available in the motor generator unit. Either the motor generator unit or the vibrator unit complete can be purchased from radio parts jobbers.

AMPLIFIED PHOTO CONTROL CIRCUIT

It often becomes necessary in special photo control applications to increase the sensitivity of the photo control circuit. Figure 38 shows a circuit where the voltage developed by the photo cell, which is of the photo-voltaic type, is amplified through a pentode tube amplifier and the output of this amplifier is made to control the firing of a thyratron trigger tube which in turn operates a relay. The operation of the control system is somewhat complicated as the thyratron is operated with AC on its plate.

The operation of this circuit is as follows: The photo tube as already mentioned is of the photo voltaic type. Thus, when light strikes the tube an *emf* (voltage) is produced across it. This circuit is adjusted in such a way that the normal light intensity applied to the tube causes a voltage to be developed which is greater than the negative voltage developed across the bias control resistor R2. This places a positive voltage upon the grid of the pentode tube V2, thus causing a large plate current to flow through the tube. This large plate current produces a large voltage drop across resistor R5 which is connected to the control grid of the thyratron trigger tube. The voltage drop across R5 is much greater than the voltage drop across R4 and as R4 is connected through R7 and through half the winding W2 to the cathode of the thyratron, the voltage on the cathode of the thyratron with respect to the thyratron grid is made positive and the reverse is true when the polarity changes. The grid is then negative with respect to the cathode. This keeps the thyratron from firing. Now if the light intensity which is normally placed upon the photo tube is interrupted. less light will fall upon the phototube. Therefore, less voltage will be developed reducing the voltage on the grid of V2. When this voltage is reduced

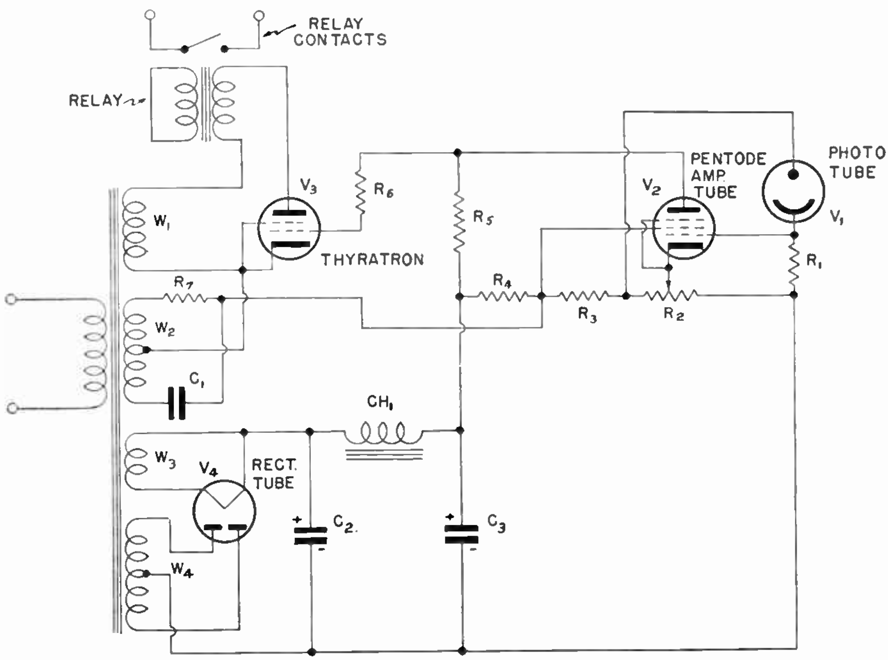


FIG. 38

the plate current is in turn reduced and a lower voltage drop appears across R5. This makes the control grid of the thyratron tube less negative allowing the tube to fire and so operate the relay.

As stated the voltage applied to the plate of the thyratron is AC. In order to produce the desired effect upon this system so that as the light intensity on the phototube is returned to normal the relay will also return to normal, there must be a phase shift between the voltage on the plate of the thyratron and that applied to the control grid. This is to insure that the DC bias (which is secured from the phototube and pentode amplifier) will be sufficient to cause the thyratron to cease firing. It is for this reason that an AC voltage is applied to the plate of the thyratron tube. It has already been mentioned that after a thyratron tube fires unless the plate voltage is reduced, it will continue to conduct current regardless of the voltage on the grid. Thus, with AC voltage applied to the plate it will be made negative on the reverse half cycle allowing the tube to stop firing. It is necessary for correct operation of this circuit that the bias voltage applied to the grid of the thyratron tube be made to follow an AC voltage. This will allow a bias voltage large enough so that when the plate voltage is maximum positive, it will keep it from firing. This phase change is accomplished through the phase shifting network consisting of R7 and C1 which is placed across the winding W2 in Fig. 38. The windings W1 and W2 are wound in the same direction upon the iron core, and hence will be in phase with each other.

Now by placing the network consisting of R7 and C1 across the winding W2, the voltage across C1 and the centertap of the winding W2 will be 90° (leading) out of phase due to the phase relationship between the current and voltage across a condenser. Now as this voltage is 90° (leading) out of phase with the voltage across W2, it is also 90° out of phase with W1. Now by connecting the centertap of winding W2 to the cathode of the thyratron and connecting the lead from the phase shifting network R7 and C1 through R4, R5 and R6 to the grid of the thyratron, the bias upon this tube will be made to increase in the right phase to keep the thyratron from firing when the DC bias voltage is applied to the grid of the thyratron from the phototube and amplifier. Resistor R6 is a current limiting resistor to protect the thyratron tube. With the use of the AC on the plate and a phase shift of the voltage applied to the grid, a photo control system which will operate with a light intensity of one foot candle or less is obtained. Further it does not require any mechanical means of stopping the thyratron action after the light beam has been interrupted and then returned to its normal operation. The shorted winding on the relay in Fig. 38 is to prevent relay chatter caused by the AC applied to it as explained earlier in the lesson.

MULTIPLIER PHOTOTUBES

One other type phototube which was recently developed and is much more sensitive than the ordinary tube is called a multiplier phototube. The basic operation of this tube is the same as the operation of the photo emission type cell and the principle of *secondary emission* from targets (plates) bombarded by high speed electrons is used. As you have already studied the principle of secondary emission, the principle of operation of this tube should be easy for you to understand.

As you recall from the study of secondary emission, one high speed electron upon striking a metal target may liberate a number of secondary electrons from this target. It is on this principle along with the principle of photo emissive type phototube that the multiplier tube operates.

Figure 39 gives a clear picture of the construction of the electrodes within this type tube. The arrows indicate the paths taken by the electrons as they pass through the tube. The electrode marked O is the cathode which is coated with the photoelectric substance and is so placed that light can shine upon it causing electrons to be emitted. Electrodes 1, 2, 3, 4, 5, 6, 7, 8 and 9 are called dynodes and have a progressively higher positive voltage placed upon them. The electrons from the cathode O are drawn to the first dynode because of the positive potential placed there. These electrons are accelerated to a high velocity and upon striking the dynode 1, cause secondary emission to occur, liberating more electrons than it received from the cathode. In turn these electrons are accelerated towards dynode No. 2 and the process repeated. This same procedure is carried out throughout the other 7 dynodes and then the final amplified electron stream is collected by anode 10 which consists of a wire grid which allows the electrons from 8 to reach 9. Dynode 9 is shaped in such a way as to act as a shield for anode 10 as shown on the diagram.

The placement of so many electrodes in one tube envelope requires very special design as can be seen from the diagram of Fig. 39. Each electrode is shaped to give the correct bending of the electron beam with a maximum of electrode surface.

With the RCA phototube, number 931, an increase in emission up to 230,000 times the weak emission resulting from the emission due to the incident light falling on the photoelectric cathode O can be realized. The voltage between each

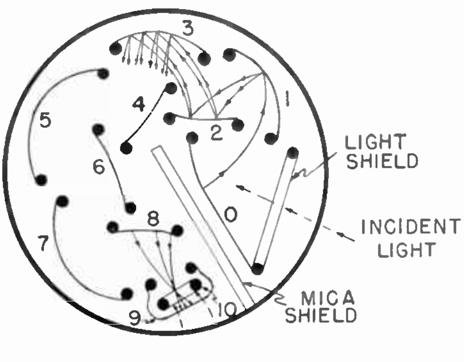


FIG. 39

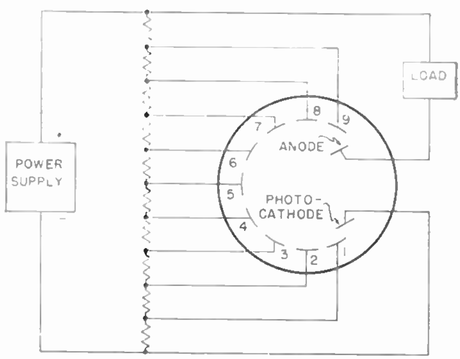


FIG. 40

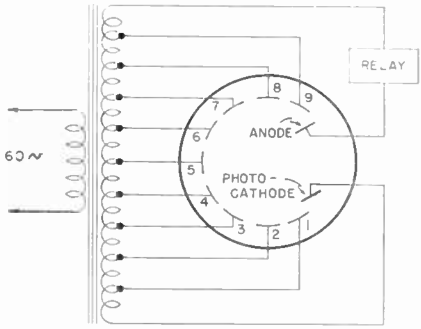


FIG. 41

dynode is spaced in equally increasing steps until the 9th dynode is reached. The voltage on the anode 10 is not critical, however. The value of the voltage applied to the various electrodes determines the amplification obtainable from the tube. A gain control can be placed so that the voltage on any one of these dynodes can be varied, making the voltage gain on this electrode uneven, thus reducing the amplification of the tube.

The application of this tube is much broader than for most phototubes. Figure 40 shows how the DC voltage may be distributed for using this tube. The load which is to be controlled may be an amplifier or a relay circuit, etc.

The voltage for each dynode is secured from the taps of the voltage divider in such a way that the voltage is increasingly higher and the voltage between each consecutive pair is the same. Voltage as high as 1250 volts can be applied to the RCA 931 photo multiplier tube.

Figure 41 shows a circuit using a multiplier tube operating from an AC source. The voltage for each dynode is secured from evenly spaced taps upon the secondary of a *high voltage* transformer. This circuit is suitable for relay operation and is a very convenient and sensitive photo control circuit.

Figure 42 shows another circuit using a photo multiplier tube. This circuit is useful in some audio frequency applications. Due to the characteristics of this multiplier tube any variation in the voltage between the different elements will cause an appreciable change in the output of the tube. Thus, it is necessary in many installations to use some type of automatic stabilization control. Figure 43 shows a circuit using a tube of this sort in a sound-on-film recorder. There are two stabilizing features incorporated with this circuit—one to stabilize the output when the power supply voltage varies and one to stabilize the output when the light source varies due to fluctuation in the voltage applied to the light. The first stabilizer operates as follows:

A glow tube which changes resistance as the current through it changes is placed across the output in series with resistors R1 and R2. The values of these are chosen so that the voltage on the dynode number 7 is correct when the applied voltage is correct. As the voltage is increased which would

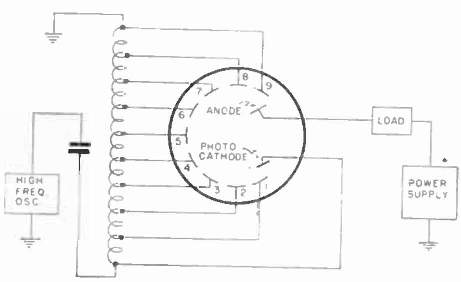


FIG. 42

ordinarily cause an increase in the output of the tube, the glow tube resistance changes. This causes the voltage applied to dynode number 7 to change. Thus the output is changed approximately the same amount as the increase in the supply voltage. This keeps the output of the tube constant. When the supply voltage drops below the correct value, the glow tube again changes in resistance, causing the voltage applied to dynode number 7 to change in such a way as to bring the amplitude of the phototube back to normal although the supply voltage in reducing tends to reduce its output.

The second stabilizer in Fig. 43 is that of correcting for variations of the intensity of the exciter lamp. This is done with the aid of a second phototube not of the multiplier variety. The output of this second tube is resistance coupled to the number 3 dynode of the multiplier tube. Thus as the light intensity of the exciter lamp, which would ordinarily cause an increase in the output of the phototube, reduces the amplification of the multiplier tube, when the light intensity of the exciter lamp increases. On the other hand, the voltage applied to the number 3 dynode from the controlling phototube is changed in such a way as to increase the amplification of the multiplier tube to compensate for any reduction in the intensity of the exciter lamp. These two stabilizing circuits of Fig. 43 as described improve the operation of the circuit considerably, making for a better reproduction of the sound recorded on the film.

The application of these multiplier tubes is unlimited. The few circuits shown here are some of the typical circuits using these tubes.

COMMON CAUSES OF PHOTO CIRCUIT FAILURE

There are a few precautions that should be observed when constructing or repairing these circuits. Dust is one of the worst enemies of the operation of a photo electric circuit, not only because it may form an opaque shade over the phototube light window, but also because of the high resistance of

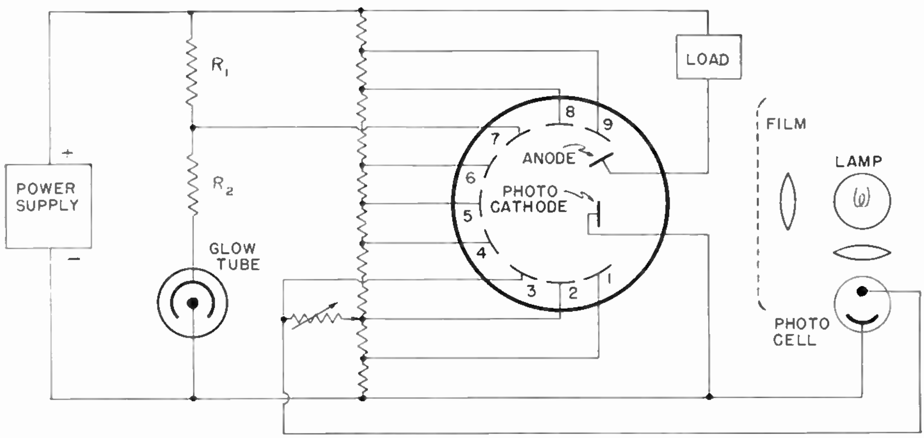


FIG. 43

some of the circuit components, dust will make a lower resistance path which may make the circuit partially or entirely inoperative. Thus in any photo electric installation where dust is present in any quantity, a dust proof hood as recommended by the manufacturer of the installed equipment should be employed.

Wherever dust is found to be gathered upon this type of equipment and the operation of the equipment is hampered because of it, it should, of course, be removed. Do not use a liquid type cleaner to remove this dust because the cleaner will allow a thin film of the dust to be formed which cannot be removed. To remove this dust, use a stiff bristled brush and dust it very thoroughly, removing all trace of the dust without leaving a film of dust for a leakage path to ground.

Circuits such as the one in Fig. 38 often cause trouble due to defective tubes. If the pentode amplifier tube is any way defective, it may cause the thyratron to fire at the wrong time, causing untold trouble in the controlled circuit.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1 Are photo-cells limited in their use by the wavelength boundaries of the human eye?

No. 2 Name two devices which will focus parallel light rays to a point.

No. 3 Name two objectionable properties of the Selenium cell.

No. 4 How many elements has a photo-cell, and what are they?

No. 5 By what means may the emission of a photo-cell be controlled?

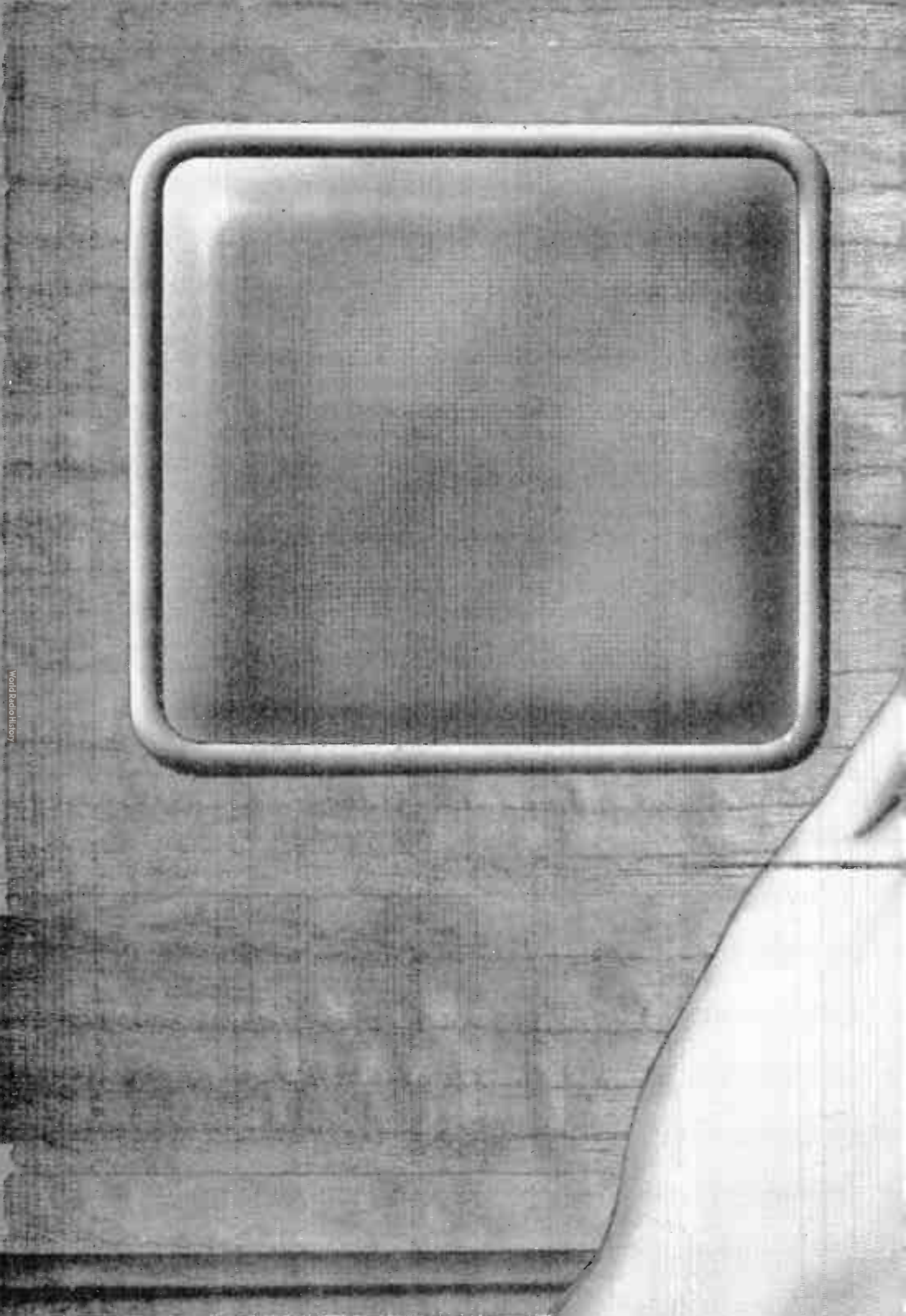
No. 6 What kind of a photo-cell will operate a relay directly without any external voltage source?

No. 7 In a photo emission cell, what relation has the generated current to the light impressed?

No. 8 What is the main difference between a sensitive relay and a power relay?

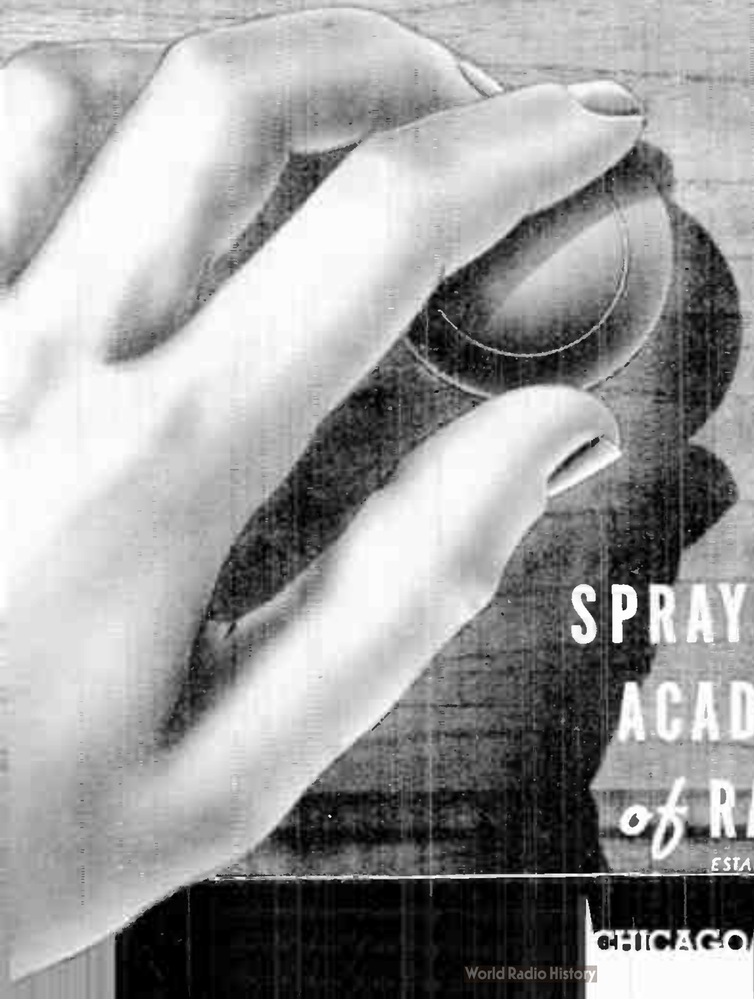
No. 9 For the same applied voltage and light, would the high vacuum or gas filled photo-cell allow more current to flow?

No. 10 Why must AC be used to supply the photo-cell relay as shown in Fig. 33?



Practical Applications Of Photo-Electronics

LESSON ND-35



SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

CHICAGO, ILLINOIS

FRANK CONRAD

As our character sketch for this lesson, an outstanding personality was chosen because of the effect he has had on the radio industry. As you have repeatedly seen, no person does a complete job in this field; he merely adds his touch to the general knowledge, then passes it on for the use of men working on the same problems or men who will follow in his footsteps.

Mr. Frank Conrad did not discover basic principles or propose new theories in radio. He was professionally employed as an electrical engineer, and rose to be assistant chief engineer at the Westinghouse Company. His inventions number over two hundred and are used today in almost every type of electrical appliance. In radio, however, Mr. Conrad participated as an amateur—that is he did it as a hobby and because of his love for radio.

In the early 1920's radio was used only as a means of communication. The telegraph key was the sending device. The transmission of speech had not been perfected and was not seriously considered. Mr. Conrad, operating an amateur's radio transmitter put his voice and recorded music on the air. He soon had a large following of amateurs who listened in regularly. Since it was not coded, uninitiated people could appreciate these brief messages and his audience built up constantly until it came to the attention of his superiors at Westinghouse. They cooperated in a project to build a large transmitter to be operated by Westinghouse. Conrad built the station and the first election returns (1920) were heard over the radio, from a station called KDKA.

The result of this broadcast was a mad scramble by people all over the country to build receivers: In these early days each person built his own or had it custom built.

Thus Conrad's greatest contribution has directly related to you. Home radio and television receivers constitute a great majority of electronic sales and servicing, and without this pioneer to show the way to use the new device of radio for entertainment as well as communications, the present state of the art might well have been delayed.

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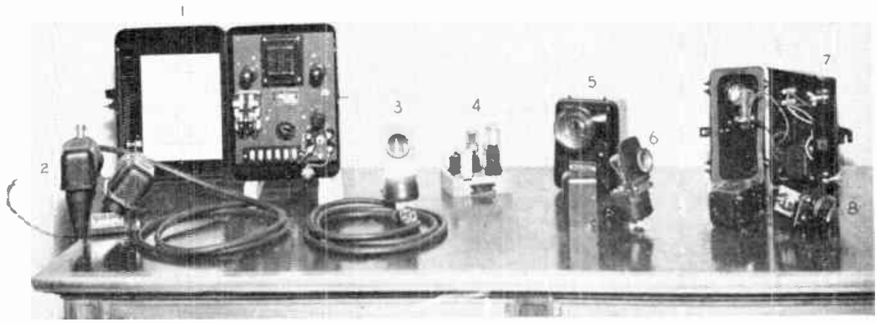


This view shows several General Electric photoelectric control parts. The parts are (1) photoelectric relay (2) scanning head (3) phototube holder (4) photoelectric relay without case (5) auxiliary cover with lens (6, 7 and 8) light source. Such a unit can be used for many of the photoelectric functions described in this lesson.

Practical Applications of Photo-Electronics

LESSON ND-35

Although the photoelectric cell is a fairly recent discovery, it is today one of the most useful developments in the field of electronics. The extent to which this simple device can be used is unlimited. In the industrial field there are numerous applications of these photoelectric circuits. Some are used to speed up production while others are used as safety devices to protect machinery from being damaged or to protect the operator from injury.

In order to acquaint the student with some of these photo-control systems, a detailed description of a number of applications of these systems will be given. The installations considered in this lesson were chosen so that the student could get a general picture of the applications of these photoelectric circuits.

COLOR SORTING

It was pointed out in the preceding lesson that phototubes can be made which are more sensitive to one color than another color. It is upon this principle that color sorting operates. A diagram of a color sorting system is shown in Fig. 1. The system itself, of course, is much more elaborate than this rough sketch indicates, but the essential components of the system are illustrated. This sketch gives the fundamentals of the actual setup and allows for a complete description of the operation of the system.

The light source as shown on the diagram is made to shine upon the object which is to be sorted in such a way that only the reflected light from this object is allowed to reach the two color sensitive phototubes.

One particular application of this system is for sorting beans in a canning factory. The beans are fed to a vacuum wheel as indicated in the diagram, Fig. 1, and as each bean comes within the range of the light source light is reflected

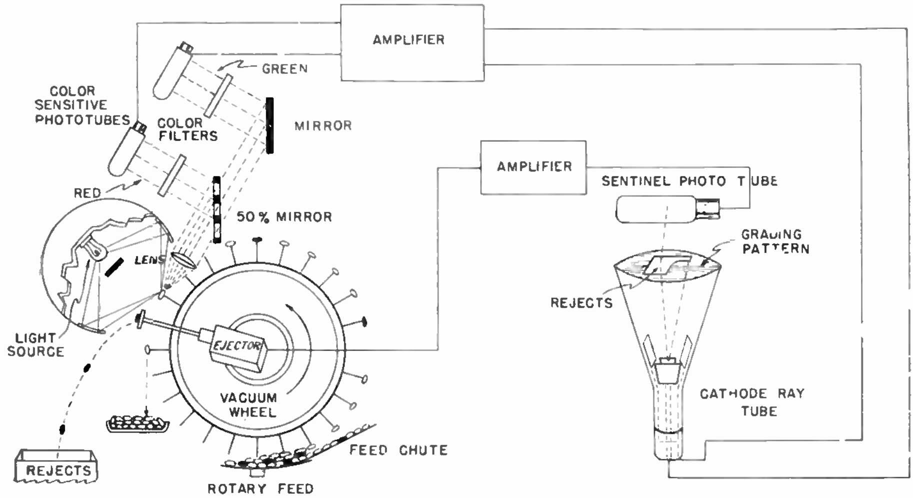


FIG. 1

from the bean onto the two phototubes. One tube is sensitive to red and the other to green. The reflection is equally divided between the two tubes by the use of a 50% reflection mirror which is placed so that 50% of the reflected light from the bean is reflected onto the first phototube due to the 50% mirrored surface. The other 50% of the light reflected from the bean is allowed to pass directly through this partially reflecting mirror on to a second mirror which reflects all of this light onto the second phototube.

In the path of the light beam focused on the first phototube which is sensitive to red is a light filter which eliminates all colors but red from the beam. In the path of the light beam focused on the second phototube which is sensitive to green is a green filter allowing only the green to reach this tube. The output from these two tubes is fed into dual amplifiers and from there to opposite deflection electrodes of a cathode ray tube. You will learn more about cathode ray tubes in other SAR Lessons, but to make the explanation of this color sorting system complete a brief explanation will be given in this lesson. You have, no doubt, become familiar with the electric tuning eye tube which is used as an aid to tuning a receiver to the proper resonance point when a signal is brought to resonance. This electric eye is a form of the cathode ray tube. The electrons from the cathode of the tube are allowed to strike a fluorescent screen which gives off visible light when bombarded by high speed electrons. In the cathode ray tube of an oscilloscope which is the same as the cathode ray tube of this system, a beam of electrons is formed by an electrostatic field within the tube. This beam of electrons can be deflected in any direction by an electric or magnetic field. Thus by placing electrodes inside the tube two of which are in the horizontal plane and two in the vertical plane, a potential placed upon these plates will then control the direction in which this beam will move.

Referring to the sorting system of Fig. 1 as the output of the two amplifiers are fed to the cathode ray tube, the beam of electrons within the cathode ray tube will be controlled by the output of these two amplifiers. As the front of this cathode ray tube is coated with a fluorescent material (screen) when the electron beam strikes the screen a visible light or image will be produced on the end of the tube. When the color reflected from the bean is of the correct quality the output of the two amplifiers will be such as to deflect the electron beam within the cathode ray tube in a certain pattern, depending upon color variations of acceptable beans. Now when a reject bean comes within the light source, the light reflected from this bean will throw the electron beam in the cathode ray tube out of the accepted pattern. By placing a *mask* over the front of the cathode ray tube which is shaped to fit the accepted bean pattern, when the electron beam strikes this area, the light from the fluorescent screen of the tube is shaded and no light emanates from the front of the tube. On the other hand, when a reject bean comes along the electron beam is deflected out of this accepted pattern and as this area outside of the grading pattern is not shaded, light will emanate from the face of the tube. Now by placing a third phototube in front of the cathode ray tube the light produced by the reject because of its color being wrong will cause the cathode ray tube screen to fluoresce and this will excite the phototube in front of the cathode ray tube. The output of this third phototube is fed through an amplifier, the output of which operates an ejector and the rejected bean is removed from the vacuum wheel into the reject bin. By placing the correct grading mask over the screen of the cathode ray tube all inferior beans will be rejected. This system as you can see not only speeds up the process of sorting but reduces the possibility of inferior beans from being canned, thus improving the quality of the product.

RESISTOR SORTING

This process should be of special interest to the student of radio because he is so familiar with resistors. The sketch shown in Fig. 2 gives a simple picture of the main components of this system. The operation of this system is very simple and easy to understand. The bridge circuit is set up to measure the resistance of any resistor. The indicating instrument for indicating bridge balance is a light beam galvanometer. A light beam galvanometer is a sensitive type instrument which causes a light beam to be reflected from the surface of a mirror which is attached to the moving coil of a meter. This type of instrument is very sensitive because the light beam moves through twice the angle of the rotating mirror. This is due to the fact that the angle of reflection is always equal to the angle of incident. Thus, when the coil is forced to move one degree the light beam is moved through two degrees.

In the rejector system of sort-

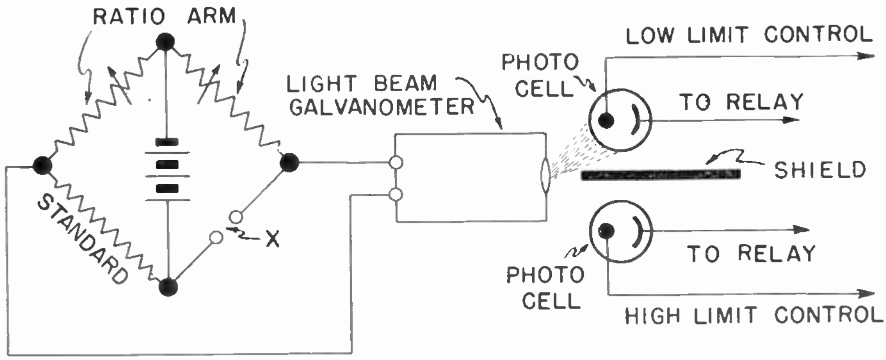


FIG. 2

ing resistors as shown in Fig. 2, the resistors are brought to the bridge upon a conveyor belt, contact is made for each resistor across terminals marked *X*. When contact is made the bridge circuit will be completed and current will be caused to flow in the circuit. The current flowing through the galvanometer will be proportional to the unbalance of the bridge. That is, if the bridge is so arranged that it is in perfect balance, when the correct resistor is placed across terminals X, the galvanometer coil will not move from its stationary position but if the resistor placed across terminals X is higher or lower than the value of that to which the bridge is balanced the galvanometer coil will move from its stationary position in a direction depending upon the resistance value of the resistor under test.

Now as a mirror is attached to the coil of the galvanometer and a light beam (not shown in diagram) is focused upon this mirror, this light beam will be deflected twice the angle of the coil rotation. Thus, when a resistor is lower than the value for bridge balance, the light beam will be deflected up as indicated on the diagram and if the resistor is higher the beam will be deflected down. By adjusting the spacing of the two phototubes indicated and connecting them to amplifiers which will operate relays, this movement of the light beam from the galvanometer can be made to reject resistors that fall short of the tolerance rating specified for the resistor. For a 20% tolerance the phototubes will be much farther apart than for a 10% or 5% tolerance and as the one relay rejects resistors lower than the correct value and the other higher, this same system can be used to sort the resistors into separate bins, one for correct values within the tolerance rating, and one for lower and one for higher than the accepted tolerance rating.

With the aid of such a system resistors can be checked very rapidly, increasing the production rate appreciably. It is devices of this sort which reduce the price of such products because of the increase in production per day.

COUNTING

Perhaps the best known use of the photo-electric cell in the com-

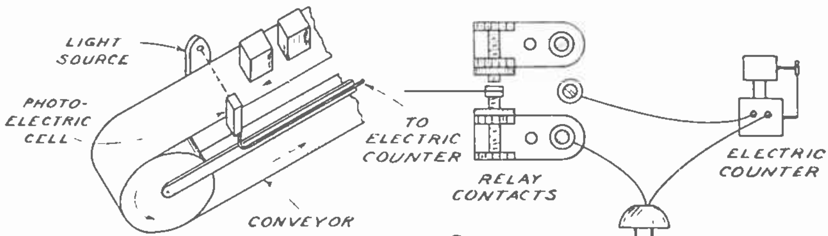


FIG. 3

mercial field is for counting purposes. This counting may be done on objects moving along a conveyor belt or on any other straight line movement. Figure 3 shows a typical installation on a conveyor belt.

In this case, as the light is either on or off, an impulse type amplifier is used. The complete connections of the relay contacts, counter and power line are shown in Fig. 3. As the objects move along the conveyor belt they intercept the beam of light and operate the relay and counter. The speed with which the objects may be counted depends on the counter itself. Counters may be obtained to operate either on AC or DC. They usually will operate at about 600 counts per minute maximum. These counters can be obtained to count up to 9999 or even to 999,999. When they reach this point however, they automatically reset themselves to zero. Counting of persons is done in much the same manner. A passage way is constructed so that people pass through single file. In order to get the necessary spacing between each person, a turnstile is installed. The beam of light is passed across the passage immediately after the turnstile. Later on the details of a system for people passing through a door in one direction will be given. People going through the door in the opposite direction do not operate the counting mechanism.

In cases where high speed counters are necessary, often times a meter type counter is used. This is actually an impulse motor geared to an indicating dial. Another system used for high speed counting is the *memory circuit.* This circuit operates a counter periodically depending upon the number of tubes used. If four tubes are used the counter indicates one for every four impulses. This circuit is shown in Fig. 4. The tubes used are small size gas triodes.

The operation of the circuit is as follows. The value of the voltage applied to the plates and the grid bias value (obtained from batteries) is so chosen that no tube can carry plate current when these voltages are applied, even when impulses come through. The circuit must therefore be set to start counting impulses. This is done by throwing the switch to position 2, placing zero bias on tube 1 and it carries plate current (it is said to *fire* as when a gun fires). The switch is then thrown to position 1 where it remains. With the switch in this position (No. 1), the first tube has normal bias voltage applied. With the first tube passing current the voltage drop in the lower part of the potentiometer R1 opposes the bias voltage on tube 2,

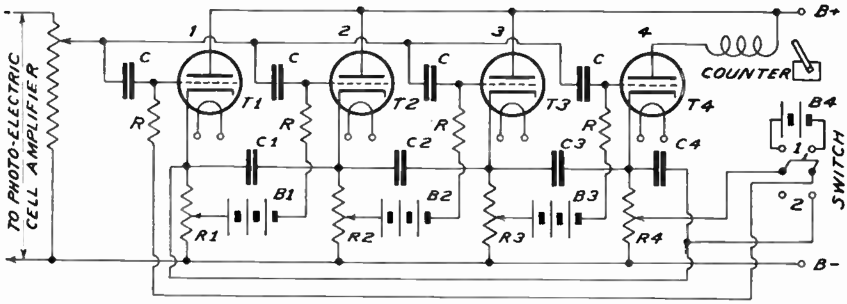


FIG. 4

and the net bias on that tube is made less. When a signal impulse comes through from the photo-electric cell unit, it will *fire* tube 2, but will not affect tubes 3 or 4, due to their high bias, or tube 1 which is passing current. The firing of tube 2 causes the condenser C1 to take a large charging current, drawing this current through R1. This causes a high voltage drop across R1 so that the voltage between plate and cathode of tube 1 is sufficient to maintain ionization and the tube is extinguished. This action causes tube 3 to be set to be fired. The next signal impulse will fire this tube, set-up tube 4 and extinguish tube 2. This keeps up and when tube 4 fires it advances the counter. This continues and *the counter only indicates once for every four signal impulses.*

WEIGHING

Another common use of photo-electric control equipment is in the control of automatic weighing operations. In this system a set-up is used as shown in Fig. 5.

In this case a direct coupled circuit is used and in place of one relay, two relays are used in series in the plate circuit of the amplifier tube. One of these relays is set to operate at a low value of plate current and the other at a higher value. Material is fed onto the scale platform by two spouts, one at a rapid rate and the other at a slow rate. As the scale comes down, interrupting the light, the plate current is reduced and the relay set for high plate current releases, shutting off the rapid flow of material. The slow speed spout fills the scale platform more slowly until the light beam is entirely shut off. This opens the second relay, which in turn shuts off the remaining spout. This allows for very accurate weighing.

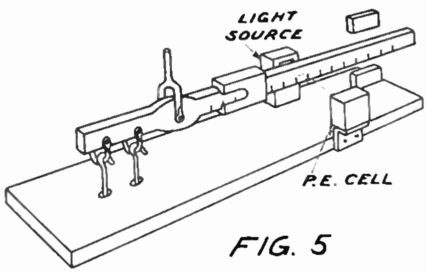


FIG. 5

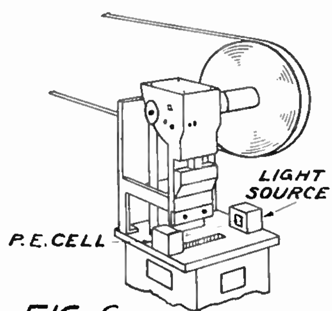


FIG. 6

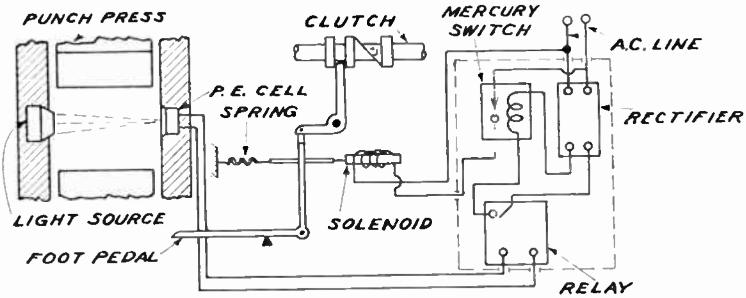


FIG. 7

MACHINE GUARDS

There are several methods of guarding punch presses, and other heavy metal working machinery. The basic installation of the light source and photo-electric cell and amplifier are shown in Fig. 6.

The impulse circuit is used in this application almost entirely. The output of the relay may be connected in several ways to control various operations of the press. In some cases, the foot control lever is held away from the punch press trip by a spring. Opposite this spring a solenoid is also connected to the foot control lever. As long as the light beam is not interrupted the solenoid is energized and pulls the foot lever over so it will engage the punch press trip. However, if the operator's hands intercept the beam, the solenoid is released, the spring pulls the foot lever away, and even if the foot lever is pressed, the punch press cannot be operated. This system is shown in Fig. 7.

Another method used to protect the operator by the photo-electric cell control is to connect the output of the relay contacts to a solenoid. The plunger of the solenoid engages a stop on the trip lever of the punch press. If the operator's hands interrupt the light beam, the solenoid is energized and the stop hits the solenoid plunger preventing the punch press from operating. This set-up is shown in Fig. 8.

In the manufacture of paper and in the weaving of cloth similar problems are presented in rolling of the finished product. To compensate for the difference in speeds of the manufacture of the material and the take up roll, a loop of material is left. To keep this loop approximately the same at all times a set-up as shown in Fig. 9 is used.

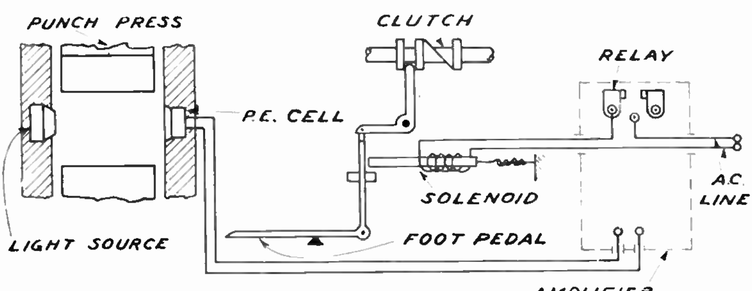


FIG. 8

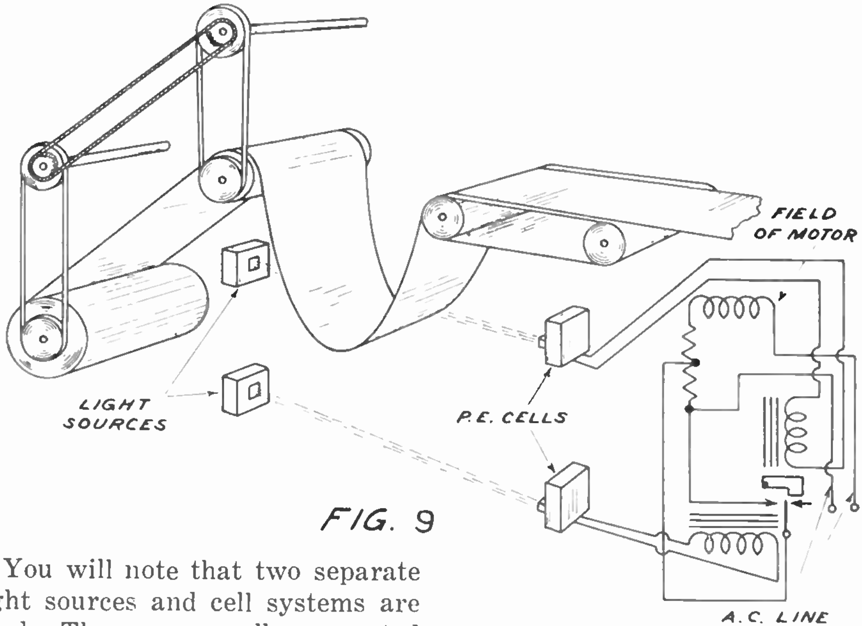


FIG. 9

You will note that two separate light sources and cell systems are used. These are usually connected in the impulse circuit. The upper one functions to slow up the speed of the take up mechanism when the loop is short. The lower system acts to speed up the take up mechanism when the loop becomes too long. The control may be by any one of several different methods. The most common method for DC control is the insertion or shorting out of resistance in the field circuit of the DC motor. When resistance is added to the circuit, the speed of the motor is increased. For that reason the relay of the lower photo-electric cell amplifier is connected so that resistance is added to the field circuit. The relay of the upper photo-electric cell amplifier is connected to short out resistance in the field circuit. In this system, of course, the speeding up or slowing down of the take up system is not effective while the loop is somewhere between the two levels.

PAPER BREAK INDICATOR

In wrapping machines which use large rolls of paper, and in newspaper printing presses, a system is sometimes used to indicate when the paper breaks or the end of the roll is reached. In this application the component parts are set up as shown in Fig. 10.

In this case also an impulse circuit is used. When the paper breaks or the end of the roll is reached, the light from the light source falls on the photo-electric cell. This closes the relay and the

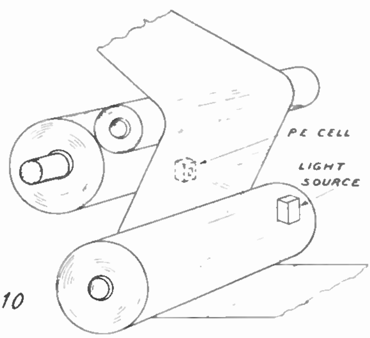


FIG. 10

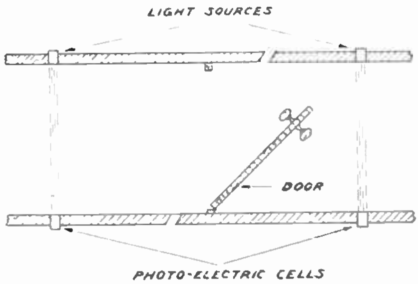


FIG. 11

relay in turn either rings an alarm, or in most applications, stops the machinery. This same set-up is often used in those printing machines designed for printing colored designs on fabric or cloth of all kinds.

DOOR OPENING MECHANISMS

The automatic control of doors by the use of photo-electric cells is one of the most spectacular as well as one of the most useful applications to be found today. Doors in garages, hospitals, restaurants, factories or other public buildings can be controlled by the approach of persons or vehicles. The door opening mechanism itself may be one of two types depending upon the application. These are (1) those operated by electric motors in conjunction with pulleys, cables, worm gear drives, or similar mechanical means and (2) those operated pneumatically in which pistons operated by compressed air open the door through a link mechanism.

The electric motor type of control is mostly used in the opening of garage doors, where it is not necessary that the door also close automatically. In this case the motor mechanism may be started by a car interrupting a beam of light or by the beam of the headlights of the car striking the photo-electric cell and thus starting the door opening mechanism. The objection to the former system is that pedestrians can also set the motor in motion. Inasmuch as the driver must leave the car anyway, there is no objection to the turning of a switch to close the doors.

In the case of doors in homes, restaurants, and hospitals, faster action of the door is required. Inasmuch as pneumatic openers are quick in action as well as silent in operation they are used almost entirely. Also the door must close automatically after the person passes through. This is accomplished in one of two ways. A time delay unit may be installed which holds the door open for a predetermined time. In this case, of course, if two or more persons follow through the door together, each person resets the time delay action. Or the door may be held open until the person passing through the door intercepts another beam of light on the opposite side of the door. This system is shown in Fig. 11. A person approaching the door from the left interrupts the light beam, causing the door to open. It will close when the beam at the right is interrupted.

AUTOMATIC DRINKING FOUNTAIN

The installation of photo-electric equipment for the control of

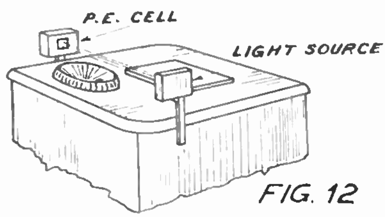


FIG. 12

drinking fountains is becoming quite extensive. As before, the impulse type of circuit is used. The light source and the photo-electric cell are placed so that the person leaning over the fountain to take a drink intercepts the beam of light with their head. When this is intercepted, the relay operates a solenoid valve in the water line supplying the drinking fountain. Such a set-up is illustrated in Fig. 12.

In some installations the beam of light extends vertically from above and in front of the drinking fountain to the photo-electric cell mounted on the fountain itself. In this case, it is not necessary for the person wanting a drink to bend completely over the fountain to start the flow of water.

AUTOMATIC CUT-OFF

Another application using the impulse type of circuit is the automatic cut-off of material of various types. Such a system for the cut-off of steel to pre-determined lengths is shown in Fig. 13.

You will note that as the end of the steel breaks the beam between the light source and the photo-electric cell, the relay operates the cut-off knife automatically. This same system stops the motor which drives the feed rolls. This system may be used for any material. It is often used in wrapping machinery to insure that printing on the wrapping paper or cellophane, appears in the proper place on the finished wrapped product. Of course, in the case of wrapping paper where the material is not transparent, a reflecting system is used. As the printed portion of the paper comes under the light beam, no light is reflected to the photo-electric cell and the relay opens. This in turn operates the cut-off knife at the same point at all times.

ELEVATOR CONTROL

Photo-electric cells are used in several different ways in elevator control work such as for (1) Limit control, (2) Location indication, and (3) Door controls.

You have often noticed in riding in elevators that as you approach the top floor or the basement levels, the elevator slows. This slowing of the elevator is not done by the operator. On the contrary it is really used as a signal to the operator that he is approaching the limit of travel in the elevator shaft. This prevents jamming of the elevator in either end of the shaft. Photo-electrically, this is accomplished by the placing

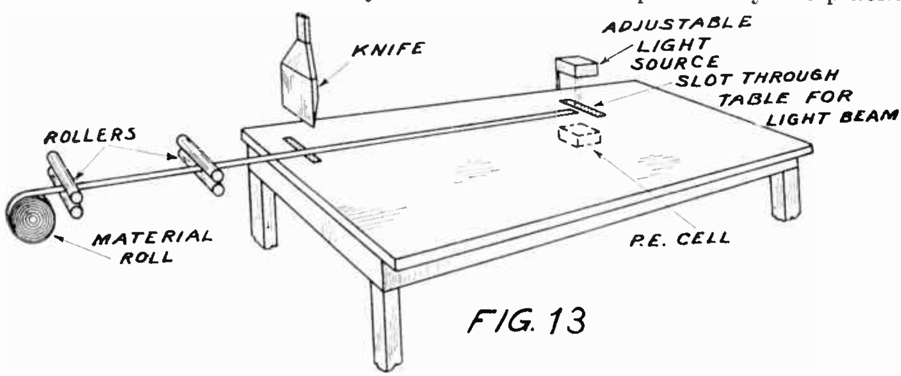
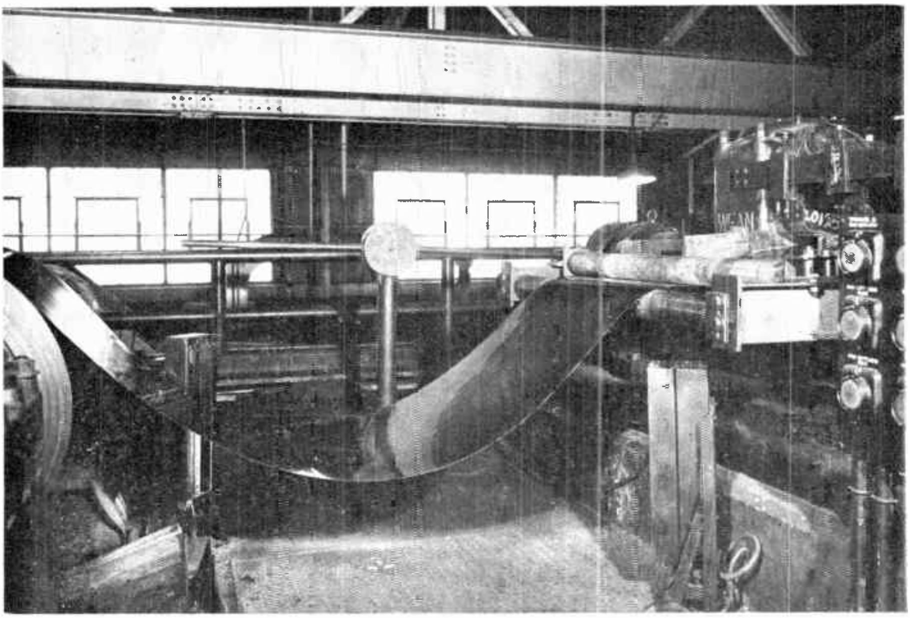


FIG. 13



Here is shown an actual photoelectric installation for controlling the loop in a sheet of metal as it is rolled through the large rollers in a steel factory. The photocells are located at the left and the light source at the right. This installation is similar to the one illustrated in Fig. 9.

of a light source and a photo-electric cell and amplifier at the top and bottom of the elevator shaft. These are arranged so that the elevator car intercepts the light beam when the car is approximately one-half floor from its limit of travel. When the beam is broken by the car the sensitive relay operates a power relay which in turn slows the elevator motor to about half speed.

The use of the photo-electric cell as a location indicator is twofold. In one case, a light source and a photo-electric cell are mounted on opposite sides of the elevator shaft. One system being installed at each floor level. The output of each relay is connected to the floor indicator located over the elevator on each floor of the building.

The other application is the indication within the car itself as to the floor level being passed at any time. This is accomplished by placing a row of photo-electric cells along the side of the elevator. These photo-electric cells are numbered in accordance with the number of the floors at which the elevator stops. At each floor level a light source is installed in such a manner that it will illuminate only the photo-electric cell on the elevator car which is numbered for that floor. In this way an indication is given within the elevator car itself as to its location at any time.

Many hotels, public buildings and similar locations have experienced the loss of large amounts of money in damage suits due to the injury of passengers in elevators. This injury is caused in most cases by the inadequate closing of the doors. A system of a light source and a photo-electric cell operating across the door opening prevents the door from closing if

FIG. 14

the light beam is obstructed. This control is made possible by the use of a solenoid in the door operating mechanism. Even though the doors have started to close, if a person steps into the light beam the action of the solenoid immediately stops the closing of the door and pulls it open again.

In all elevator control work as outlined, the impulse type of circuit is used.

BURGLAR ALARMS

One of the best known uses of photo-electric cells is for burglar alarm systems. The installation of these systems is extremely simple. The light source is placed on one side of the opening to be protected with the photo-electric cell on the opposite side of the opening. They may be built in or mounted away from the surface depending upon the nature of the particular application. Naturally it is nearly always required that the light beam be invisible. For that reason a filter is placed over the light source which filters out all frequencies of light except the infra-red. The photo-electric cell amplifier is always of the impulse type circuit. A typical installation is shown in Fig. 14.

The relay contacts may be connected to any type of alarm. They may be even hooked into a circuit which signals an alarm remotely situated from the opening being protected.

There is one objection to this type of burglar alarm installation. That is the fact that a complete system of light source, photo-electric cell amplifier and alarm are required for each opening. When a large number of openings in one room are to be protected the cost of such installations becomes prohibitive.

Figure 15 shows a typical set-up for reflecting light beams around a room in such a way that only one light source and two photo-electric cells and amplifiers are used.

The light source is housed in A, and the light rays are divided into two different groups. This is accomplished by two reflectors set at different angles behind the lamp. The rays from these reflectors are focused by a condensing lens onto the mirrors of M1 and M4. These mirrors are arranged at different heights from the floor in order to make it impossible to enter the doors D and E without interrupting one of the light beams. The windows B and C are also protected in the same manner—the mirrors M2 and M5 are mounted higher, consequently it can readily be seen by following the light beams A1 and A2 through their reflected courses that it would be impossible to enter the room and proceed very far in any one direction without intercepting at least one of the light beams. These light beams may be either visible or invisible. If an invisible beam is desired, an infra-red ray filter is used—all of

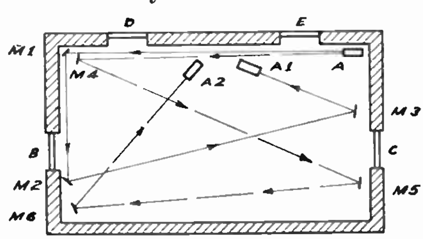


FIG. 15

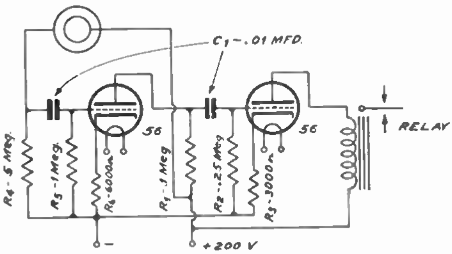


FIG. 16

the equipment is set and focused, with the visible light first—the infra-red filter is then slipped into place.

A1 and A2 in Fig. 15 are the photo-electric cell, amplifier and relay housing—the diagram shows two photo-electric cells operating independent of each other, but if it is so desired, the angle of the mirrors M6 and M3 may be slightly changed so that both beams A1 and A2 meet at a common point which is the cathode of the photo-cell.

It is good practice to feed the photo-cell and amplifier from the 110 volt power lines through a relay—that is, when the alarm system is turned on for the night, the solenoid of the relay pulls up the armature which energizes the amplifier and photo-cell with the supply current—but across the off position of the relay a set of dry A and B batteries are connected. These batteries are an emergency in case the lighting circuit is out or disconnected—the alarm will still be sounded. The batteries and the system should be tested out periodically.

From your studies in the previous lesson you have found that the further the photo-electric cell is from the light source, the more sensitive must be the photo-electric cell amplifier. Accordingly a single stage amplifier will not operate satisfactorily in this installation due to the distance traveled by the light beams before reaching the photo-electric cell. For that reason, a two or three stage amplifier is used. These amplifiers may be either resistance coupled or transformer coupled. Typical circuits for these two types of amplifiers are shown in Figs. 16 and 17.

A transformer circuit, although perhaps the most sensitive, is subject to distortion and oscillation. These conditions are very undesirable and must be eliminated before stability in the amplifier can be

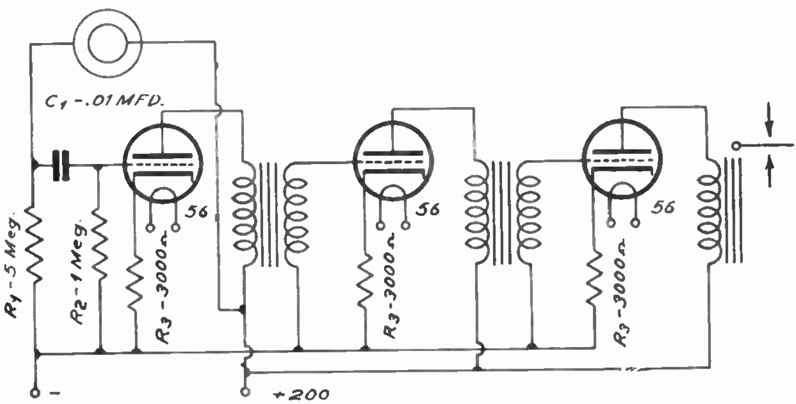


FIG. 17

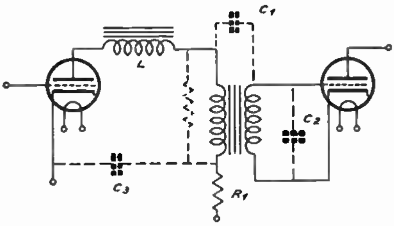


FIG. 18

maintained. Methods of elimination are hard to foretell. However, Fig. 18 shows possible means of eliminating these objectionable features. The value of resistors and condensers can be determined by trial.

CONTROL OF MATERIAL IN HOPPERS OR BINS

A great deal of labor, and costly delays have been eliminated by the use of photo-electric cells to control the level of material in storage bins. Figure 19 shows the details of such an installation.

When the material in the bin or hopper falls below a certain level, the lower light beam falls on its corresponding photo-electric cell. The relay closes and starts the filling mechanism. By means of a solenoid releasing lock-in relay the filling mechanism is not shut off when this lower light beam is again broken by the material in the bin. The material pours into the bin until the top light beam is broken. This opens the relay which opens the lock-in relay and stops the falling mechanism. When the material falls below the top light beam, the system is again ready for operation as the lock-in relay releasing solenoid is deenergized.

DAYLIGHT CONTROLS

The changes in daylight—that is, at morning and night are used for controlling several different operations. Among these are—

1. Illumination control. The control of artificial illumination depending upon the amount of sunlight in rooms in public buildings, schools, etc.

2. Signboard control. The turning on of artificial lighting on advertising signs at night and turning them off in the morning.

3. Venetian blind control. The adjustment by means of a motor of venetian blinds so that only a certain amount of illumination is present in a room.

4. Lighting of safety lights on antenna towers.

All of these systems use the direct coupled type of circuit as they must respond to gradual changes in light.

In those applications controlling illumination of buildings, etc., the photo-electric cell is usually placed outside the building in such a position that no direct sunlight falls on the cell. As the amount of power controlled is quite high, auxiliary power relays are used to control the lighting circuit. Figure 20 shows such an installation.

You will note that two series of relays are used. This is done in some installations for one or two reasons. In large buildings which are also surrounded by other large buildings, the lower floors require artificial illumination before the upper floors. By setting one of the

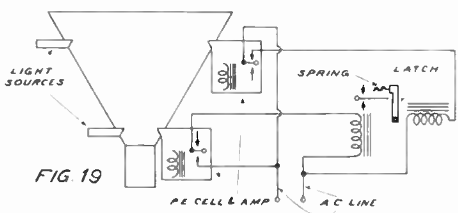


FIG. 19

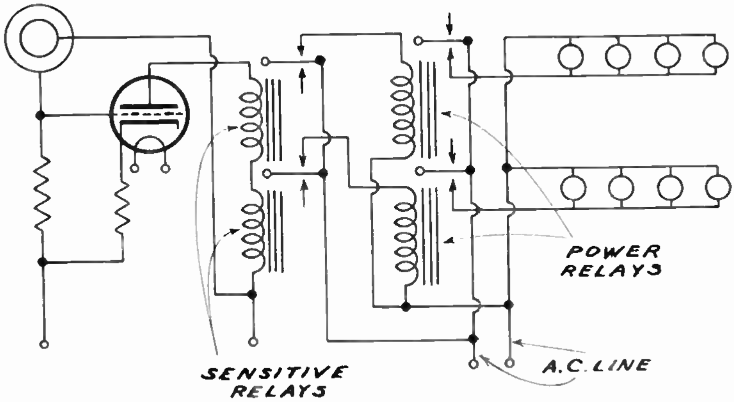


FIG. 20

relays to release on a higher current than the other, the lights on the lower floors can be turned on before those on the upper floors.

In other cases, the first relay is used to turn on only half of the lights as shown in Fig. 20. When the outside light falls to a lower value, the remaining lights are turned on. In small buildings where such control is not necessary, only one relay is used.

The same circuit as is shown in Fig. 20 is used for sign board control except only one relay is used. When natural illumination falls to a certain predetermined level, the relay operates, turning on the sign board lights. They remain on until the natural illumination again rises to a level which will release the relay system. In these installations care must be taken to see that no light from the sign board falls on the photo-electric cell.

SMOKE DETECTORS

The purpose of smoke detectors is two-fold. First it is an indication of improper burning of fuel and second, it is useful in communities where there are rigid *no smoke* ordinances.

The light source and photo-electric cell are mounted on opposite sides of the smoke stack about half way between the bottom and top. In this position there is no great danger of the surface of the lens in the light source and the protective glass cover over the photo-electric cell becoming covered with soot. Inasmuch as gradual changes in light are to be detected, the direct coupled circuit is used. An alarm located in the boiler room of the building is connected to the relay contacts. In some cases, a recording milliammeter is placed in the plate circuit of the amplifier tube. The plate current as recorded on the meter of course is an indication of the amount of light falling on the photo-electric cell which in turn is dependent on the amount of smoke going through the stack. By taking samples of the smoke in the stack for various milliameter readings, it is possible to calibrate the recording meter in terms of gas content.

Figure 21 shows a typical installation of a smoke alarm. You will note that both a recording meter and a relay are shown. Either or both of these units can be used.

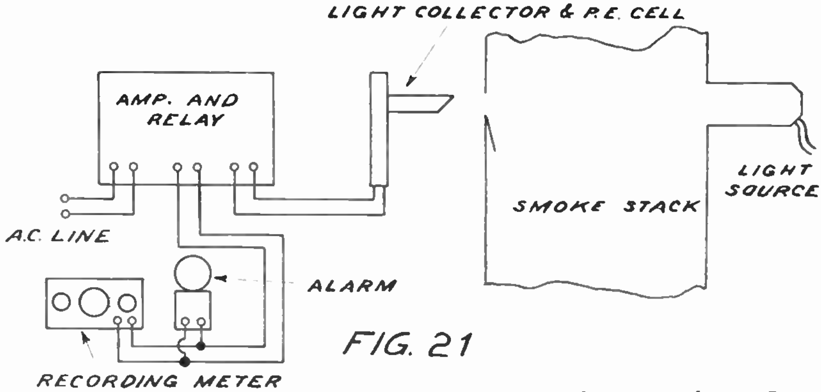


FIG. 21

PHOTO-METERS

Due to the fact that they require no external batteries or other sources of power, photo-voltaic cells are used entirely in photo-meters. A typical photometer is shown in Fig. 22.

Photo-meters are used for checking the intensity of natural or artificial light in schools, libraries and offices as a means of reducing eye strain. In this case, the meter is calibrated in foot-candles and with the aid of a chart which gives ideal light conditions for various eye requirements, it is possible to determine whether sufficient illumination is present. Another application is the use of a photo-meter in photography. In place of being calibrated in foot-candles, the photo-meter is calibrated in camera diaphragm openings. This application has become so advanced that in some very expensive cameras a photo-voltaic cell is included in the camera and automatically adjusts the diaphragm opening with no manual operation.

The circuit of the photo-meter is simply a photo-voltaic cell and a meter connected in series. Inasmuch as the amount of current depends upon the area of active surface of the photo-voltaic cell exposed to light, these units usually are at least two inches in diameter. This allows the use of a less expensive meter (in the order of one milliampere). If a smaller active surface were used, it would be necessary to use a microammeter which would be more expensive.

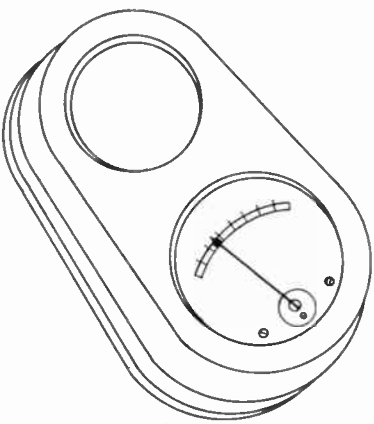


FIG. 22

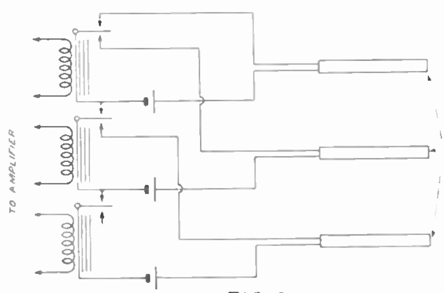


FIG 23

SORTING BY SIZE

Figure 23 illustrates a typical set-up for sorting different sized objects. Three photo-electric cells and three beams of light are used, the light being made to span a conveyor belt at three different heights, depending upon the size of the articles being sorted. Three relays are used—one for each cell, and three solenoids connected to the three relays as shown in Fig. 23. These solenoids are arranged to push the articles off the belt at the location of the photo-electric cell. The basis of operation depends upon the connections or wiring of the relay contacts. From Fig. 23 it will be seen that if all of the rays are operated as by the passage of the tallest object along the belt, only the first solenoid will be operated. The operation of the first relay opens the circuit through contacts of the second relay, the second opening the circuit through the solenoid in the contact circuit of the third relay. If the intermediate size object passes along the belt, the first relay will not be operated at all; only the second and third, but the operation of the second relay while it energizes its own solenoid, opens the circuit of the third solenoid, therefore, only the second solenoid operates. Evidently if the smallest object passes along the conveyor belt only, the third relay operates, in turn operating the third solenoid. Thus sorting by size is obtained.

COLORIMETERS

Colorimeters are used for the comparison of various materials or liquids against standard materials or liquids. In the case of liquids, the equipment is calibrated

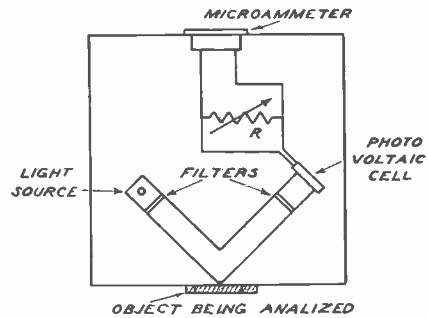


FIG. 24

using distilled water and measuring the amount of light transmitted by this liquid. The liquid to be tested is then placed in the same position in the light beam as was occupied by the distilled water. The amount of transmitted light is again measured. By comparing the reading or the percent transmission to a chart, will give the concentration of the unknown liquid. Of course, charts must be made up from tests made on liquids of known concentration.

The circuit used is always a direct coupled type. As a rule no light filters are used, although in cases of heavy liquids closer readings can be obtained by the use of a light filter.

In the case of materials the same circuit is used. However, in place of transmitted light values being measured, reflected light values are measured. In other words, the light source is placed so that it shines at an angle on the material to be tested. The photo-electric cell is placed so that it will receive the reflected beams from the material under test.

Figure 24 shows a typical installation of a color analyzer using a photo-voltaic cell.

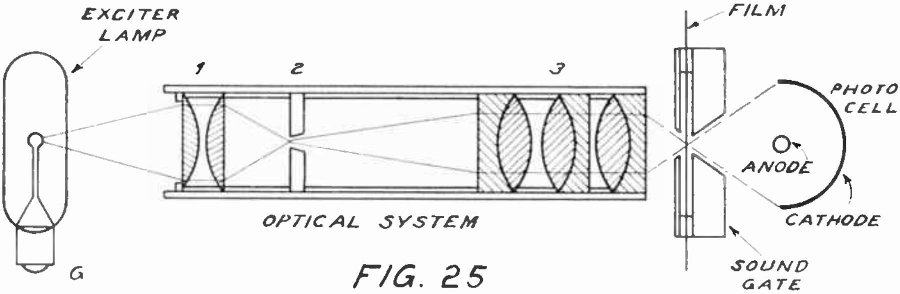


FIG. 25

SOUND MOTION PICTURES

In another lesson the details of sound motion picture amplifiers is covered. In this lesson only the photo-electric cell as used with these systems will be explained.

Figure 25 shows the light source optical system, sound gate and photo-electric cell as used in sound motion pictures. The purpose of the optical system is to concentrate the available light from the exciter lamp G to a focus on the slit at 2. The rays are then passed through the objective lens of the optical system at 3. The objective focuses the rays on the film. In fact the image of the slit at 2 is reproduced at the film. Up to this point the amount of light is constant. As the light passes through the film, the sound track actually modulates the light beam at an audible frequency. Figure 26 shows two types of sound tracks as used on film. Figure 26A shows the type known as variable density which changes the amount of light transmitted by varying the density of the film. Figure 26B shows the variable area type of recording. In this type the amount of light transmitted is varied by varying the *opaque area* of the sound track.

After being modulated by the sound track on the film, the light beam is focused on the cathode of the photo-electric cell. The output of the cell is usually amplified through a resistance coupled circuit. A typical circuit is shown in Fig. 27.

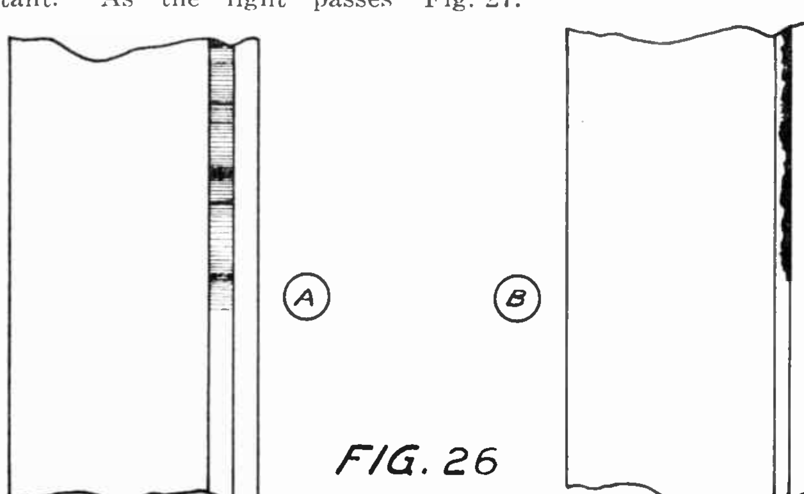


FIG. 26

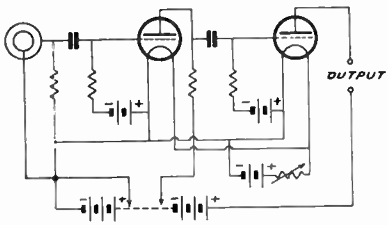


FIG. 27

TALKING PAPER

A recent invention, which, although not on the market as yet, has definite promise, is the so-called talking paper. It is similar in principle to that used for sound motion pictures in that a sound track is used. However, in place of transmitting light, reflected light is used to operate the photo-cell.

Figure 28 gives a general idea of the reproducing equipment. The *record* is made by recording the sound track on a sensitive film in exactly the same manner as sound pictures are recorded. However, the film is in sheet form, wound on a drum exactly as the paper is wound as in Fig. 28. The drum and recording head are geared together so that as the drum revolves, the recording head advances across the paper. One complete revolution of the drum advances the recording head approximately 1.33 times the width of the sound track. After recording, the film is processed and either a paper print or a printing plate is made from this negative. The printing plate is used where a great number of copies are required. These papers are then mounted on the reproducer as shown, and the equipment reproduces the sound. The amplifier used is exactly as used in sound motion pictures, except that the power required is not as great.

FACSIMILE

Facsimile, a trade name, is simply the transmission of still pictures by wire or radio. An arrangement practically the same as is shown in Fig. 28 is used at the transmitting station. A picture or typewritten sheet, the material of which is to be transmitted is placed on the drum. It is scanned by a light source and photo-electric cell exactly as shown in Fig. 28. However, the scanning unit advances only the width of the light beam. The light portions of the picture reflect more light than the darker portions, thus producing varying output of the photo-cell. The output of the photo-electric cell is amplified and then transmitted over the wires or is used to modulate an RF signal for transmission by radio. On the receiving end, the signal is detected and amplified and operates a neon light. The neon light has the property of following the high audio frequencies involved. Thus when no light is being reflected on the transmitting end, the neon lamp is not illuminated. The light from the neon lamp is focused by means of lens and apertures to the exact size of the beam of light used on the transmitting end. This beam of light is focused on a photo-sensitive paper mounted on a drum which is an exact duplicate of the drum on the transmitter. By means

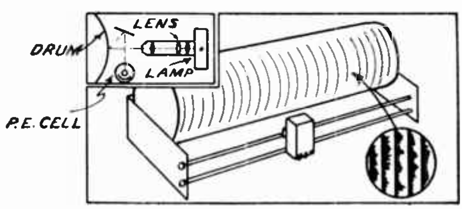


FIG. 28

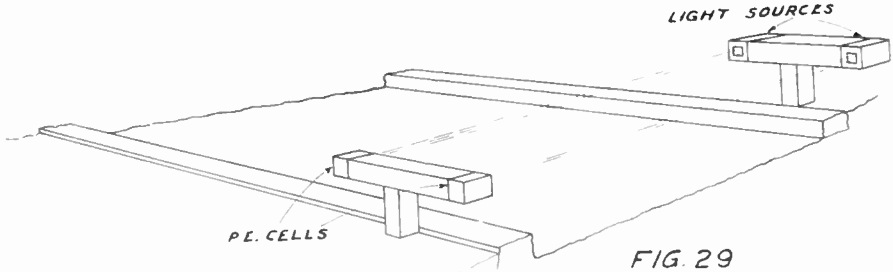


FIG. 29

of a special synchronizing signal, the transmitting unit and the receiving unit are kept in exact synchronism.

After the complete transmission the photo-sensitive paper is developed exactly as photographic films are developed.

TRAFFIC COUNTING AND CONTROL

Figure 29 shows an installation of twin photo-electric cells for the purpose of counting traffic or operating traffic signals.

You will note that the light source and the photo-electric cells are mounted on the ends of a cross-bar of a T-shaped post which is set in a concrete base. The two parallel beams of light are far enough apart so that a pedestrian will not obstruct both beams at the same time. A car, however is long enough to obstruct both beams, and operate the counter.

It is possible to count traffic passing in only one direction as well as the traffic in both directions. Figure 30 shows a circuit designed for counting objects or cars passing in one direction.

When both cells of this circuit have light falling on them, minimum current flows in both tubes, and none of the three relays are closed. As a car passes from the right to the left, the beam is interrupted and plate current in tube T2 starts flowing. This current closes relay 2 (R2). The contacts of both relays 1 and 2 are now closed, but relay 3 (R3) cannot close as the plate current is still at a minimum, and is insufficient to operate both relays, which are connected in parallel. When the car interrupts the second beam as well as the first, the current of tube T1 increases. However, as relay R3 is much lower in resistance than relay R1, it takes most of the current from

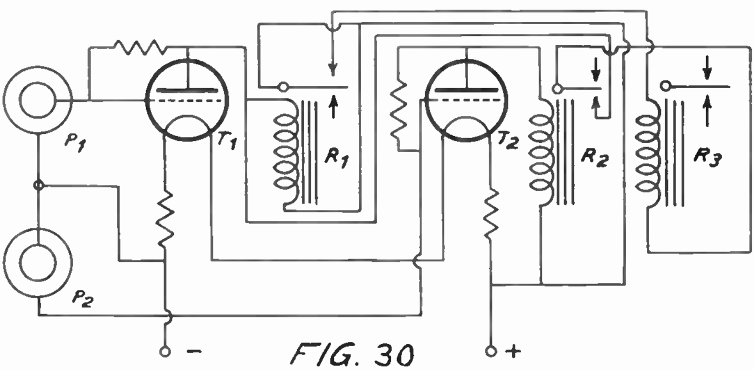


FIG. 30

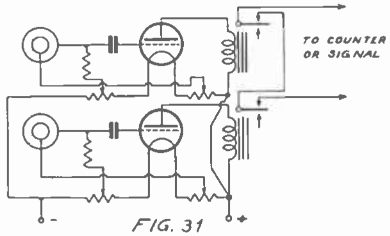


FIG. 31

relay R1. As a result, relay 1 does not carry enough current to close it and only relay R3 closes, operating the counter. As the car proceeds, the beam on photo-electric cell P2 is restored and relay R2 opens. This releases relay R3. With relay R3 open, relay R1 closes but no other action takes place.

If a car passes in the opposite direction, the beam of light on photo-electric cell P1 is interrupted first, closing relay R1. Nothing else happens until the second beam is interrupted. This closes relay R2, but relay R3 cannot operate as its circuit is opened by relay R1. When the first light beam is restored on photo-electric P1, and beam 2 is still interrupted, relay R1 opens closing the circuit to relay R3. Relay R3 will not operate as the current in tube T1 is at a minimum.

The circuit used in counting traffic in both directions or for operating traffic signals is shown in Fig. 31.

In this circuit you will note that when both beams are interrupted, both relays are closed and the counter operates. However, pedestrians will not operate the circuit as the beams are placed far enough apart so that they cannot interrupt both beams at once. In traffic control work, the closing of the two relays starts a clock mechanism which times the traffic signals.

TEMPERATURE CONTROL

In heat treatment of steel, especially automotive work, accurate control of the quenching temperature is extremely important. As speed is essential in the high speed production used today, resistance heating of the metal parts—that is, the part to be heated acts as a resistance across the secondary of a welding transformer. This heating action is so fast that within two seconds from the application of current, the metal part is brought from room temperature to 1800° F. Photo-electric control is accomplished by the color of the heated part. The radiance of the heated part is allowed to fall on a photo-electric cell. All external light is excluded by the use of an optical system. Very accurate control as to color is obtained by the use of an infra-red filter. Figure 32 shows the optical system of a typical control unit.

Light radiated by the heated object is filtered by the infra red filter and then collected by the lens and focused on the cathode of the photo-electric cell. After a great deal of experimental work, the cesium emissive type of cell was found best for this type of work due to its high response in the infra-red region. To control this unit to an accurate degree, a three-stage, resistance coupled amplifier is used with the photo-electric cell connected as in the direct-coupled

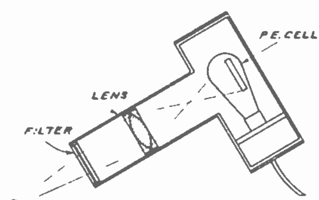


FIG. 32

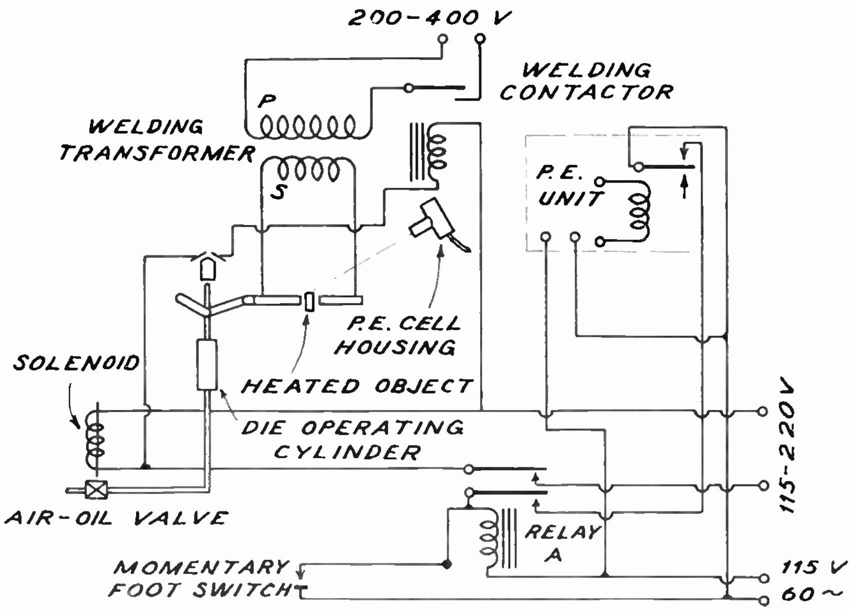
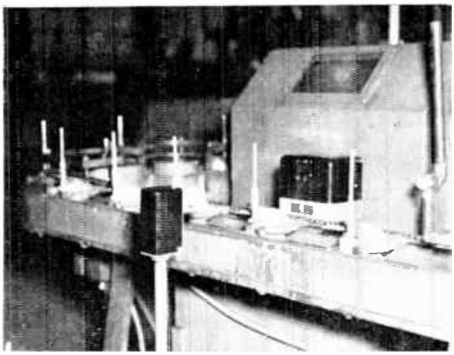


FIG. 33

type of circuit. An extremely sensitive relay which responds to .5 milliampere in the plate circuit of the last stage is used.

Figure 33 shows a typical set-up of all the equipment used. The sequence of operations is simple. The object to be heated is placed by hand between the jaws of the heater. By momentarily closing the foot switch, relay A is closed and in this way will be held closed by the circuit through the open photo-electric cell amplifier relay contacts. The contacts of this relay also operate a solenoid valve in an air or oil line which operates a plunger closing the holding jaws of the equipment. This plunger also closes a switch which operates the power relay on the welding transformer and closes the circuit of the primary. The jaws having closed on the piece being heated, the secondary circuit is closed and the piece is heated. When it reaches the correct temperature as indicated by its radiated color, the photo-electric cell amplifier closes its relay. This opens the circuit of relay A and it opens releasing the air or oil valve. The piston is released by a quick operating spring, the holding jaws open and the heated piece is dropped into a quenching bath. As soon as the heated piece passes out of range of the photo-electric cell, its relay reopens but nothing else is affected.

Another application of this same principle is the permanent recording of the temperature of sheet steel passing through rollers in a rolling mill. The same photo-electric cell, housing an amplifier is used. However in place of a relay in the output stage of the amplifier, a recording millimmeter is used. This gives a permanent record of the temperature of the sheet stock being rolled at all times. It is also an immediate indication of



Above is shown a G.E. installation of a photo-cell counting unit. In this set up, the control unit counts float valve mechanisms in a refrigerator factory as these units move along a conveyor belt.

too rapid cooling of the steel and immediate steps can be taken to rectify the trouble.

USE OF PHOTO-ELECTRIC CELLS IN SPORTS

Perhaps one of the most interesting uses of photo-electric cells in the field of sports is for the timing of races of all kinds. In automobile races, a light beam is projected across the track at a sufficient height to be intercepted by the cars. The photo-electric cell and amplifier are connected in the impulse circuit of a single stage amplifier (having sufficient sensitivity). The relay is connected to a timing device in the judges stand. As the first car crosses the light beam the timing device is started. When the race has completed several laps, the timing device is disconnected until the last lap. Just before the winning car crosses the finish line, the timer is reconnected and is stopped when the car interrupts the light beam. In some cases the timer is stopped manually by the operator when the relay operates a signal light. In the case where the time for several positions must be determined, the relay output is connected to a camera and as each car finishes a picture of the time recorder is taken. As the picture can be developed in only a couple of minutes, no real delay is encountered.

The methods of timing of horse races have been constantly improved. One of the latest devices is the multiple timer and camera. Five separate photo-electric cells mounted one above the other, and five separate light sources are used.

This arrangement provides a *wall* of light which is intercepted regardless of the position of the horse's head as he comes across the line. All five photo-electric cells are fed to the common input of an amplifier. As the first horse crosses the finish line, the photo-electric amplifier operates the relay which in turn actuates a camera located in a booth above the grandstand. This camera takes a still picture of the finish. An automatic indexing device delivers an impulse to a second camera which takes a picture of the second horse and so on until four pictures have been taken. These pictures are developed, enlarged and printed in two minutes after the horses cross the finish line. In case the camera system fails, a high speed motion picture camera also takes pictures of the finish, and these can be printed and run off slow motion to determine the winner of the race.

A new application in sport is the

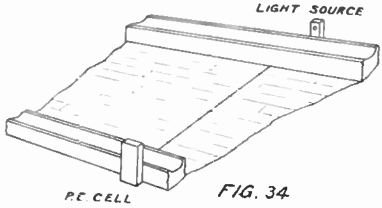


FIG. 34

use of photo-electric cells as a foul line guard in bowling alleys. Figure 34 shows an installation of such a guard.

The light source and photo-electric cell are placed on opposite sides of the alley, in such a manner that the beam of light crosses the bowling alley right at the foul line. The amplifier is connected in an impulse circuit. The relay is connected to an alarm which rings for two seconds and operates an indicator which shows the number of the alley upon which the foul occurs.

Recently a great number of so-called photo-electric rifle ranges have appeared. Basically these consist of moving targets through which a hole has been cut. Back of this hole in each target is mounted a photo-electric cell. These cells are connected to the amplifier through sliding contacts. The amplifier is always of three and sometimes four stages because of the extreme sensitivity required. The output of the amplifier is connected to a sensitive relay which in turn controls many operations. It rings an alarm which indicates a hit or a bulls-eye. It also operates a solenoid on the traveling target, which knocks it over in much the same manner as a bird falls when it is shot. Each hit is scored and recorded on an indicator sign by means of a stepping relay.

The gun used is a duplicate of a single barrel shotgun. A special light with a concentrated filament, occupies the space usually taken by the shell. A lens system in the barrel collects this light and focuses the rays in a parallel beam. The trigger of the gun is so constructed that the light is turned on only for an instant and will be connected again only when the trigger is released and again pulled. By means of another stepping relay, the number of shots is limited to ten. The extreme sensitivity of the amplifier is required due to the small amount of light available.

Another recent application of the photo-electric cell which has given quite an impetus to the sale of novelties is in the so-called *pin-ball* game. In these units a beam of light is reflected back and forth across a board. When a ball is shot, it bounces back and forth, intercepting the light beam many times. Each time the beam is intercepted, an impulse type amplifier is operated and its relay in turn operates a stepping relay. This stepping relay is connected to an indicator which registers the total number of times the light beam has been intercepted. In other words, the indicator acts as a scorekeeper. A stepping relay is shown in Fig. 35.

The action of these units is simple. A solenoid operates a plunger, which in turn engages a dog or ratchet wheel on the shaft of a rotary switch. Every time the relay coil is energized, the plunger moves

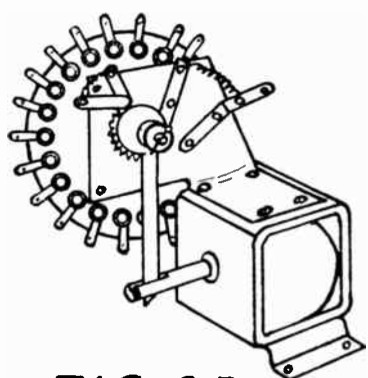


FIG. 35

out engaging the ratchet and advancing the switch one position. When the relay is opened, the switch is held in place by a locking mechanism, and the plunger is pulled back by means of a spring.

UNUSUAL APPLICATIONS OF PHOTO-ELECTRIC CELLS

There are many unusual applications of photo-electric cells. Some of these are quite interesting from the electrical point of view, while others are unique in their application.

Recently a mechanism has been developed by the British for indicating whether stamps are correctly placed on letters for cancellation. It can also be adapted to distinguish between stamps of different colors. The letters are carried, along a narrow channel on edge, by a moving band and at a chosen point a bright light is caused to fall on them. Light from two parts of the paper—that is, the stamp and the plain envelope, is allowed to fall alternately on a photocell by means of a revolving shutter. If the stamp is in position, the amount of light will differ and an alternating current will be generated in the cell circuit. This current is amplified by a special arrangement of tubes tuned to the shutter frequency and is used to operate a relay which kicks the letter into an appropriate compartment. The amplifiers are biased so as not to operate below a certain input and thus the device ignores such things as ink writing and variation of paper coloring.

Letters with advertising matter printed on them can still be passed through the machine as most of them do not have the printing in the place normally occupied by the stamp. The present machine, which is purely of an experimental nature, can deal with 1000 letters per minute.

The U. S. Post Office also makes use of photo-tubes, but for quite a different purpose. In the Government Printing Office, the perforation of large sheets of stamps is kept in register by a photo-tube relay, so that the 3/64 inch perforations are accurately centered in the 7/64 inch space between each row of stamps.

Another interesting British application of photo-tubes was recently completed in a new draw bridge at Kincardine-on-Forth, Scotland.

This bridge was built to carry road traffic over the Forth but at the same time has to be partially movable so that shipping can pass freely. The problem was solved by making the central span a double cantilever rotating on a pivot. On the operator's desk in the control cabin is a hand wheel which controls pilot motors. They in turn move the main rheostats in connection with the two fifty horse power DC motors which move the span through a rack and pinion turning gear. Among other things, the control desk has indicator lamps, a dial to show the position of the span and buttons for *inching* the bridge. When the bridge is closed two bolts and four wedges are *shot* and it was to arrange for this that photo-cells were used.

Below the level of the road and on one of the fixed abutments there is a projector cabinet containing three lamps and a similar cabinet containing three cesium cells on one end of the moving span. The operation of the cell control is as follows:

The span in closing and approaching the end of its travel, cell number one receives light from the outer lamp of the set, causing a bell to ring in the control cabin, and lighting one of the three indicator lamps on the control desk. Moving on, the same cell passes the other two lamps which in turn gives two more signals.

Immediately afterwards, cell number two, which is higher than the others, glides into the beam of a lamp placed higher than the other two. This causes the center indicator lamp to light on the control desk and shows that the bridge is correctly aligned for the bolts and wedges to be *shot* in place. Should the span overshoot a little, cell number three is brought opposite the last lamp and an indicator informs the operator. The photocells also cause the driving motors to be de-energized but *inching* buttons are brought into the circuit. These are required as the span may not come to rest in quite the correct position owing to wind pressure, etc. They are at all times kept out of operation until the cells indicate that their use is required.

You undoubtedly are familiar with cards used in business machines. These are used for record purposes by the U. S. Government as well as by insurance companies. They are coded by punching holes in certain numbered positions. At present when cards of certain codings are required, all cards of the group are placed in a contact machine which sorts out the cards desired by making contact through the holes in the cards. Now a method has been devised whereby these cards are photographed on motion picture film. When run through a projector, the holes in the photographed card allow light to pass through the film and these spots of light are focused on a bank of photo-electric cells. There being one cell for each coded position on the record card. When cards of certain coding are to be counted or sorted out, the photo-electric cell amplifiers of the impulse type are connected to the cells corresponding to that coding. The relays of these amplifiers are connected in series and then to a counter. When the cards of the coding desired are projected on the bank of cells, all the relays close and the counter operates. However, if only one cell is not illuminated the counter is not operated as that particular relay is not closed and of course the counter circuit is not closed.

Recently an advertising sign was set up in New York City which attracted a great deal of attention. From a distance it appears to be a huge motion picture screen upon which silhouettes were projected. Actually this consisted of thousands of lamp bulbs placed so close together that from a distance they appear as a solid sheet. Each lamp bulb is connected to a photo-electric cell and amplifier. The photo-electric cells being mounted on a panel in a position corresponding to the lamp bulbs to which it is connected. This means thousands of photo-electric cells mounted very close together on a large panel. Pictures are projected on the bank of photo-electric cells from a motion picture projector. In the dark portion of the picture, there is not sufficient light to operate the photo-electric cell amplifiers, and the relays do not close. Consequently the corresponding lamps do not

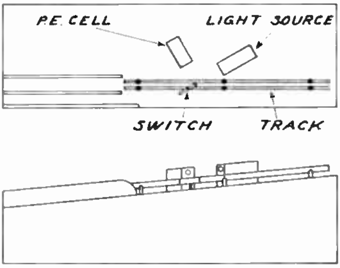


FIG. 36

light on the large sign. The opposite effect takes place on the lighted portion of the picture. Thus you can see that the picture is faithfully reproduced on the large screen.

In establishing emergency landing fields on regular plane routes, it was found unnecessary to keep a man on duty at these fields both day and night. The field or boundary lights are turned on and off by the action of the sunlight. This circuit is exactly as used for illumination control work. Another photo-electric cell and impulse type amplifier is connected through a power relay to the floodlight on the field. When a plane makes a landing at night, it flies across the field so that the landing light falls on the photo-electric cell. This actuates the relay circuits and turns on the field flood lights. The power relay is of the latch-in type, and cannot be released except by a manual operation.

ADVERTISING NOVELTIES

Perhaps too much stress cannot be made as to the possibilities of the use of photo-electric cells in advertising. Anything containing an element of mystery always attracts the curiosity of anyone. Accordingly, the use of photo-electric cells in advertising is a fast growing field of endeavor. Although many *tricks* can undoubtedly be done cheaper and easier mechanically, the use of a photo-electric cell makes this same *trick* appear mysterious and becomes a valuable advertising medium. Only a few of these novelties will be explained, however, a little ingenuity will bring many different possibilities to mind.

A unit that always attracts a great deal of attention is a ball sorter. This unit can be built up quite cheaply. Figure 36 shows the construction of this unit.

The mounting box is built of plywood and is stained and varnished. The track is made up of strip steel and one side is cut to form a switch as shown. The angle of slope is just sufficient to allow the balls to roll down the incline of their own

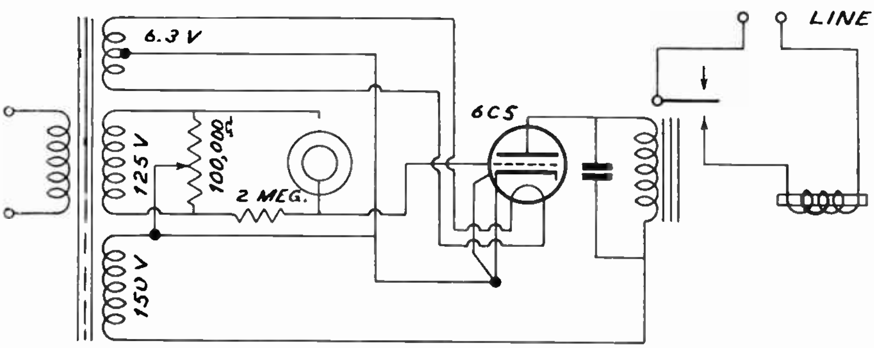


FIG. 37

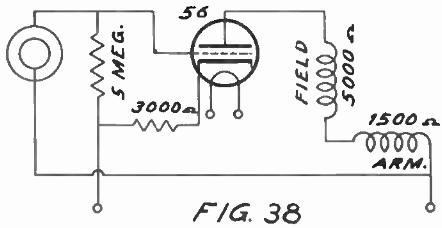


FIG. 38

accord. Ping-pong balls are used for sorting, half of which are painted black with India drawing ink. The light source and the photo-electric cell are placed so that the center line of the lens is in the same plane as the center of the ball resting on the track. Figure 37 shows the circuit used in this equipment. A metal tube is used although it is not absolutely necessary. The action of this unit is as follows: The balls are allowed to roll down the incline and through the light beam. The white balls reflect light to the photo-electric cell, closing the relay and operating the solenoid. This throws the switch and the ball rolls off the track into the outside bin. As soon as the ball is out of the beam of light, no light is reflected to the photo-electric cell, the relay opens and the solenoid releases. A spring then returns the switch to normal position.

When a black ball rolls down the track it does not reflect light. Consequently no action occurs and the black ball rolls on down the track into the inner bin. The position of the light source and the photo-electric cell with respect to this switch can only be determined by experiment.

Another unique idea which can be adapted to many different applications is the control of a small toy motor through a photo-electric cell. Figure 38 shows the circuit used. The motor is a special toy motor which can be built up from a standard toy motor by removing its winding and rewinding it with very small wire (No. 38 to No. 40) until it has a comparatively high resistance.

The action of this unit depends upon the amount of light falling

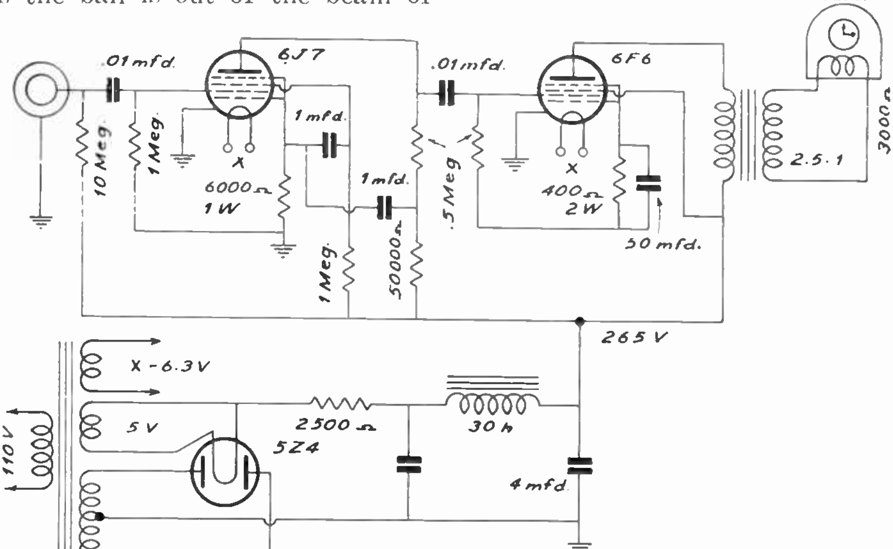


FIG. 39

on the photo-electric cell. The more light present the faster the motor will run due to the increased current in the plate circuit of the amplifier tube. By varying the light falling on the cell, the speed of the motor can be varied.

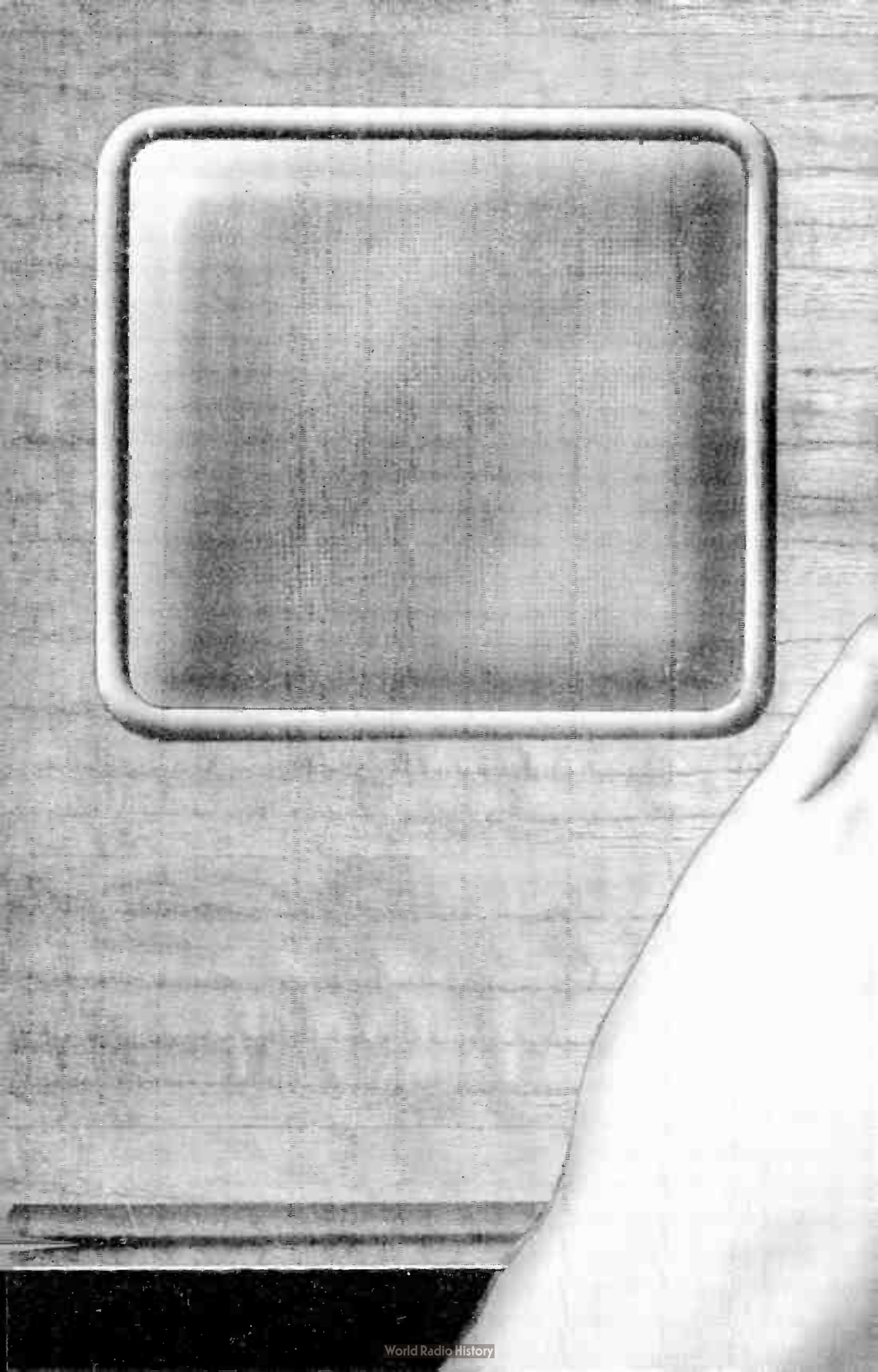
A unit that never fails to attract attention is an electric clock operated over a beam of light. Basically this unit consists of a beam of light which is interrupted by notches on the edge of a revolving disc. The beam is interrupted at the rate of 60 times per second. This interrupted beam is picked up by a photo-electric cell and amplified by an amplifier, the circuit of which is shown in Fig. 39. After amplification the impulses are strong enough to run the standard electric clock shown. The light source and rotating disc are mounted on one end of a wood base about 40 inches long, 8 inches wide and 4 inches deep. The photo-electric cell and the electric clock are mounted at the other end. The amplifier is concealed in the base. The rotating disc is driven by a low speed synchronous motor and gear system which runs at constant speed. Knowing the speed of the disc it is easy to calculate the number of notches to cut in the disc. A lens is mounted in front of the disc which focuses the interrupted light beam on the photo-electric cell.

When operating, the clock is operated, as stated, by the amplifier impulses. If the light beam is stopped from reaching the photo-electric cell by the hand or a card, the clock stops. It is interesting to watch the skeptics try and prove that it is a trick, by slowly interrupting the light, or by trying to hold the clock hands. It is usually advisable to cover all the working parts of these units with glass to prevent tampering.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. **What two general types of amplifiers are used with photo-cells?**
No. 2. **Why is a relay not necessary in testing for light intensities or intensities of colored light?**
No. 3. **What circuit is used for electronic counting when the frequency of counting impulses is too great for a mechanical counter?**
No. 4. **Is it possible for photo-cell control equipment to count objects moving in one direction and omit those going in the other direction?**
No. 5. **Once a door is automatically opened, what is done to keep it open until its passageway is cleared?**
No. 6. **How can more than one entrance be protected from entry with a single light source?**
No. 7. **What is done when the contacts of the sensitive relay cannot carry the current it is desired to control?**
No. 8. **Name two applications of the photo-voltaic cell which do not require any voltage source or amplifier?**
No. 9. **Is it possible to operate photo-electric equipment entirely from AC?**
No. 10. **How is a photo-cell adapted to make it respond to infra-red rays only?**



Substitute Testing and Practical Use of Your Multitester

LESSON R-5

SPRAYBERRY ACADEMY *of* RADIO

ESTABLISHED 19[illegible]

CHICAGO, ILLINOIS

OCB 8-54 2000

SUBSTITUTE TESTING AND PRACTICAL USE OF YOUR MULTITESTER

LESSON R-5

In the two previous lessons on the construction of your multitester you have learned how the meter circuit operates and also much about general measurement methods. This lesson will treat the resistor and condenser substitute circuits as well as practical use of the complete unit.

One of the unique features of your multitester is the resistance and capacity substitution circuits which will be added in this lesson. You will find numerous uses for resistor or capacity substitution in all your Radio-TV work. Through the internal connections, various values of resistance or capacity are made available at the output binding posts by a setting of either the resistance or capacity selector switch.

The values of burned or missing resistors or unmarked condensers may be determined quickly by inserting the test leads in the binding posts and setting the proper switch to a value that gives the best operation. If, for example, you are called upon to service a television receiver, and you find that a resistor has burned open, you would use the resistor substitution circuit. You can determine the approximate size of the resistor and in this way temporarily connect a resistor in the circuit so that it would operate while other tests are being made. This is only one use of this section of your multitester.

Wiring The Resistance Substitution Switch

The resistor substitution circuit is wired around an 11 position single deck rotary switch. This switch will be mounted on the lower left side of the tester panel and the condenser substitution switch which is identical will be mounted on the lower right side of the panel. Locate one of the 11 position single deck rotary switches and the pointer knob from your parts. Temporarily mount the pointer knob on to the shaft of the switch, tightening the set screw so that the shaft will rotate when the knob is turned. Hold the switch in your hand with the pointer knob up and turn the knob fully clockwise. You will note that the shaft will rotate to a certain point where it will stop. With the shaft turned fully clockwise, it is in the OFF position. Now slowly turn the pointer counter clockwise and it will stop in each of the other ten positions. Look at the engraved markings on the RESISTANCE-OHMS position on the lower left side of your tester panel. With the switch turned fully counter clockwise the pointer is in the *50* ohm position. Turn the pointer clockwise one click. It is now in the *100* ohm position. Continue to turn the pointer clockwise and each click indicates one position of the switch until at the full clockwise rotation it is in the *OFF* position.

Now turn the switch over so that the pointer knob is down.

On the back of the deck you can see 11 terminals, and in the center is the round contact ring. The small square contact point of the center ring should now be in the blank position. Rotate the knob all the way around and note how the square contact point makes a connection to each of the lugs in turn except the last one which is longer than the others and rides on the center ring. This is the common terminal of the switch and is always in contact with the center ring. Turn the switch knob until the square contact point of the center ring is again in the blank space. Figure 1 is a schematic diagram of the switch with the knob turned to the same position as your switch. The blank space is labeled position 1. The common terminal is position 12. When the switch is mounted, position 1 will be the *OFF* position and each of the other 10 positions of the pointer knob indicate one of the resistor values on the panel. Turn your switch back to the same position as the diagram in Fig. 1, fully clockwise and lay it on the work bench in front of you.

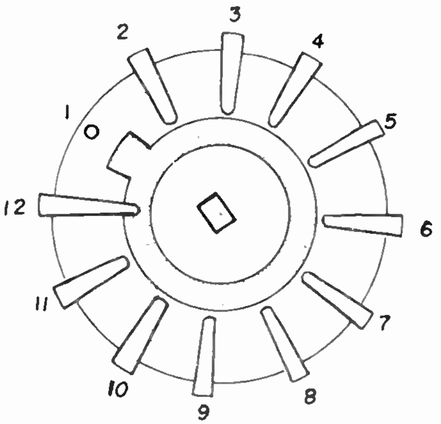


FIG 1

Now locate the 10 resistors that will be mounted on this switch. Refer to Fig. 2 for the resistor sizes. Note that the resistor sizes differ from the panel engraving because the resistors are connected in series. Check the color coding of the resistors and lay them in a row in front of you with the 56,000 ohm resistor on the far left and the two 47 ohm resistors on the right. (The resistors will be mounted on the switch before it is fastened to the panel.) Check the color codes to be sure that you have the resistors in the correct order. Refer to Fig. 3 for the proper way to mount the resistors on the terminals. Note 47 ohm resistors are actually used for the 50 and 100 ohm positions. This is done because there is no RETMA 50 ohm value manufactured. The use of 47 ohm resistors is permissible in situations of this nature and is standard practice in the Radio-TV industry.

The 56,000 ohm resistor will be mounted first. It is fastened between terminals 2 and 3. Bend the pigtail leads of the resistor as shown in Fig. 3, and slip one lead through terminal 2 and the other through terminal 3. Wind the leads once around the terminals to make a good connection and clip off the excess length. Do not solder the connections until all of the resistors are fastened to the switch terminals. Now locate the 22,000 ohm resistor and bend the leads in the same manner and fasten the leads between terminals 3 and 4. Clip off the excess length. Note how the resistors are being mounted perpendicular to the switch deck, as shown in Fig. 3. This is because the space inside of the multitester is limited. Next mount the 15,000

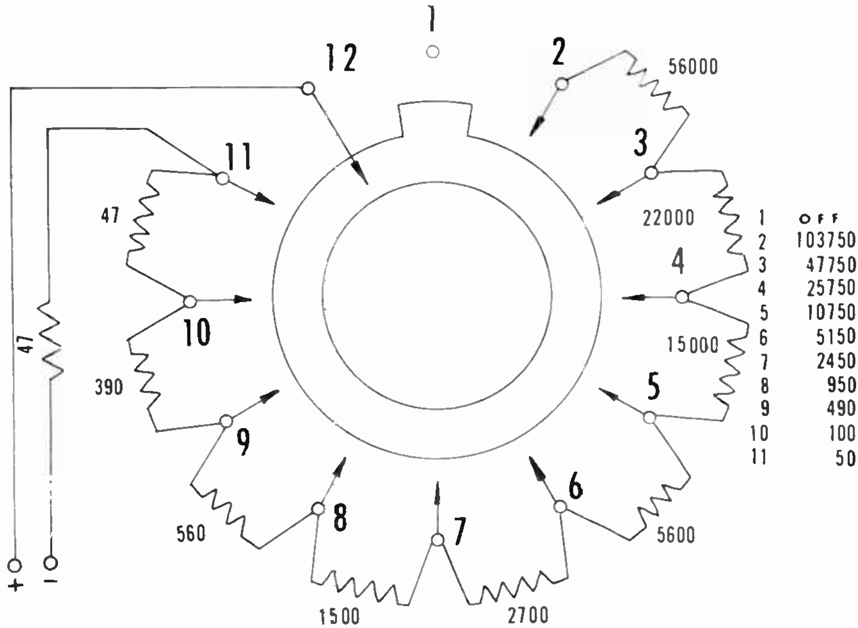


Fig. 2 Resistor Substitution Connections

ohm resistor between terminals 4 and 5 in the same manner.

Refer to Fig. 2, and continue to mount the resistors around the deck as shown. The 5,600 ohm resistor is mounted between terminals 5 and 6 in the same manner as the others, then the 2,700 ohm resistor is mounted between terminals 6 and 7. The 1,500 ohm resistor is mounted between terminals 7 and 8; the 560 ohm resistor between terminals 8 and 9; the 390 ohm resistor between terminals 9 and 10 and one of the 47 ohm resistors is mounted between terminals 10 and 11. Be sure to clip off the excess lead length on each of the resistors. If you make a good mechanical connection the resistors will all be held firmly in place before the solder is applied. Do not mount the 47 ohm resistor between the MINUS binding post and terminal 11 until the switch is mounted to the panel. Now solder the connections to all of the resistor terminals except 11 and 12. Work carefully and be sure that you do not get any cold solder joints. Flow the solder to the connections. You are now ready to mount the switch to the tester panel.

Remove the knob from the switch shaft. On the panel, under the mounting hole for the switch shaft there is a small hole for the positioning pin of the switch. Slip the switch shaft into the RESISTANCE-OHMS position from the rear of the panel and fit the positioning pin into the hole under the shaft. This will locate your switch in the proper position so that when the pointer knob is attached it will be pointing to the marking that corresponds to the proper setting of the switch. Locate the 3/8 inch hex nut and washer. Turn the nut

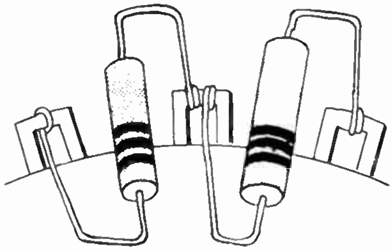


Fig. 3

on to the shaft from the front of the panel and make sure to use the washer. It is necessary to turn this hex nut down securely with a small wrench or pliers to draw the positioning pin up through the hole. When the switch is tightly mounted, add the pointer knob and tighten the set screw.

Trace the wiring on the tester panel from the *MINUS* binding post and you will find that there is a wire connecting this binding post to the *POS* tip jack, J2. So any connection to the *POS* tip jack will be connected to the *MINUS* binding post. Fasten one end of a 47 ohm resistor to the *POS* tip jack and solder this connection. Fasten the other end of the 47 ohm resistor to terminal 11 on the RESISTANCE switch. There will now be one end of both 47 ohm resistors connected to terminal 11 of the switch. Solder the connections to this terminal. Now cut a length of wire about 9 inches long and trim the insulation back on both ends. Fasten one end to terminal 12 of the switch and solder this connection. Run the wire along the rear of the panel face to the *PLUS* binding post, and solder the wire to the *PLUS* binding post.

When all of the connections have been made, turn the pointer to the OFF position. Now look at the rear of the switch. The square contact point of the center ring should be in the blank space on the bottom of the deck. Turn the switch all the way to the *50 ohm* position. The square contact point should now be under terminal 11 to which there are two 47 ohm resistors connected. Check your wiring against Fig. 2. The resistor substitution switch is now complete and ready for use.

Substitution Testing—Resistance

By setting the RESISTANCE-OHMS switch of your multitester to the desired position you have available at the *PLUS* and *MINUS* binding posts resistance values from 50 ohms up to 103,750 ohms—plus or minus 10%. In this section we have listed some of the uses of the resistor substitution switch to help you become familiar with this function of your multitester. As you progress with your studies and in your servicing work you will find many applications based on the principles described here.

Note when either the resistor or condenser substitute circuit is in use the main selector switch for the meter must be in the OFF position. Likewise when the main selector switch is in use the resistor and condenser substitute switches must be in the OFF positions.

Perhaps the most important use of this section of the multitester is for *resistor substitution*. By connecting the test leads to the *PLUS* and *MINUS* binding posts, you are able to substitute any of the ten values of resistance into a circuit. In many cases you will find a resistor in a circuit that is burned or badly charred so that the size cannot be easily determined. In a case of this type you would remove the defective part and touch the test leads to the circuit in place of the defective resistor as shown in Fig. 4. Now of course all values of resistance are not available in your multitester but you will find that the values are representative of standard resistors used in commercial circuits. With the test leads in place in the circuit, you turn on the power and vary the selector switch to give as close to normal operation as possible. Once the circuit is operating other tests can be made to determine the exact size of the replacement unit to be installed.

In your experimental work you will often find need for a quick way to *alter the operating conditions of a circuit* by changing the value of a resistor. Rather than go through a time consuming process of soldering a resistor into the circuit, testing it and unsoldering it, the substitution tester can be used. For example, suppose you desire to determine the proper value of load resistance to be used with a certain audio amplifier system. You would construct the circuit leaving the plate load resistor out. Then you would attach the test leads in place of the plate load resistor and test the circuit with different values of resistance. In this way you can determine the best values of components to be used for a particular circuit. In the same manner the operating conditions of a circuit can be changed by varying the plate or cathode load resistor with your substitution circuit.

Remember higher values of resistance may also be made available by connecting an extra resistor or resistors in series with one of

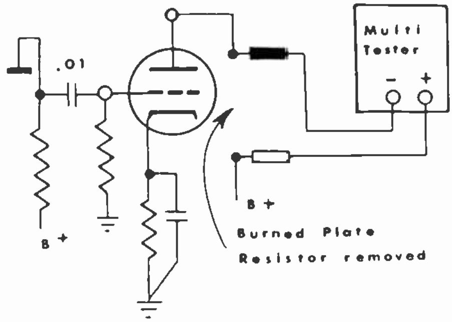


Fig. 4

the binding posts. For instance if you wanted to have 470,000 ohms available you would turn the selector switch to 103,750 ohms. Then an extra resistor or resistors would be connected to one of the binding posts to make up the approximate difference between 103,750 and 470,000 ohms. A single 350,000 ohm resistor would suffice or you might use two resistors, one rated at 150,000 and the other approximately 200,000 ohms. Once a resistor or resistors are connected to one binding post one of your test leads would connect to the free end of the resistor or resistors. In this way any combination of resistors could be arranged to provide any approximate value you might need.

In *calibrating meters*, such as a voltmeter, an ohmmeter or an ammeter, the resistor substitution switch can be used. To determine the proper value of voltage multiplier resistor to use with a voltmeter you would connect the substitution circuit test leads in series with the meter and the voltage source, then set the switch to its highest value and turn on the power. If the voltage source is regulated so that a known value of voltage is applied to the circuit, the switch is then set to the position to give as close to full scale deflection as possible. That would give the approximate value of multiplier to use with the particular voltage range.

To determine a meter shunt, connect the resistor substitution leads in parallel with the milliammeter and the current source. In this case you set the switch to its lowest value and turn it to a higher value until the meter gives full scale deflection with a known current. The setting of the switch gives the value of resistance to be used. Now suppose you wanted to use a value of resistance lower than 47 ohms which is the smallest resistor in your tester. Then you would place a 47 ohm resistor in parallel with the milliammeter being tested and also place the leads of your tester across the meter terminals. With the switch set to 50 ohms, there will be two 50 ohm resistors (approximately) in parallel across the meter to give a total of 25 ohms. When the switch is set to the 100 ohm position, the total resistance of the parallel circuit will be about 33 ohms. When the switch is set to the 490 ohm position the resistance of the combination across the milliammeter under test is about 45 ohms. In this way many smaller values of resistance are available, by using only one external resistance.

In using the resistor substitution switch connection to calibrate an ohmmeter, you can use the resistors as a standard of comparison. CAUTION: Because of the internal connections of your multitester do not attempt to measure the resistance of the substitution circuit with the meter of your tester. As mentioned when the main selector range switch is in use, both the resistor and the condenser substitution switches should be in the OFF position.

Wiring the Condenser Substitution Switch

The condenser substitution switch is mounted on the lower right side of the tester panel. The switch used is identical to the one used for resistor substitution. The connections and terminal lugs are exactly the same as shown in Fig. 1. The principal difference between these two circuits is that a separate condenser is provided for each switch position while the resistors are connected in a series arrangement. Locate the other eleven position single desk switch. This switch will be wired before it is mounted because of the limited amount of working space on the rear of the tester panel.

Figure 5 is a schematic diagram showing the condenser connections to the switch. On this switch only one condenser is mounted on each of the terminal positions. The

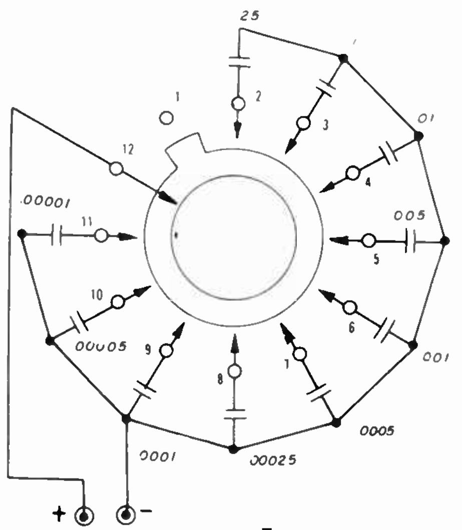


Fig. 5

numbering of the terminals is exactly the same as the other switch. Turn your condenser switch fully clockwise so that the square contact point of the center ring is pointing to the blank space. This will put the switch in the OFF position (Number 1). Now locate the 10 condensers. Some of the condensers have the size marked on them but most of the smaller ones are color coded, using the standard RETMA Color Code. Lay the switch with the pointer down on the work bench and line up the ten condensers in the correct order with the .25 mfd. condenser on the left and the .00001 mfd. (10 mmfd.) condenser on the right.

Start with the .25 condenser. This is a rather large paper condenser, with the size printed on the side. Cut one lead of the condenser to about 3/4 of an inch. Bend a small hook on the end of this lead and fasten the .25 condenser to terminal 2 of the switch as shown in Fig. 6. This is the only connection that will be made to this terminal so fasten it securely and then solder it. Bend the top lead toward the center of the switch as shown in Fig. 6. This lead will serve as a tie point for all of the other condensers so it should not be clipped.

Now cut one lead of the .1 mfd. condenser to about 1 inch and bend a hook on this short end. Fasten the hook to terminal 3 and solder. This will bring the top of the two condensers fastened to the switch just about together as shown in Fig. 6. Now bend the top lead of the .1 mfd. condenser over to the lead of the .25 mfd. condenser and wrap it around the .25 mfd. condenser lead once as shown in Fig.

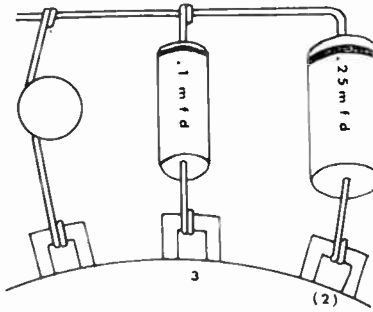


Fig.6

6, then clip off the excess length.

Next obtain the .01 mfd. condenser and measure the lead length so that when this condenser is fastened to terminal 4, the top of the condenser will be about even with the top of the other two condensers. Although the condensers being used are all of different sizes, you can do a neat job of connecting them to the switch if you try to cut the bottom lead so that the tops of all of the tubular paper condensers are about even. The top leads of all of the condensers are wound once around the top lead of the .25 mfd. condenser and soldered. Not all of the condensers used are tubular paper. Some are small ceramics. In this case the tops of the condensers need not be even but measure the leads carefully before you cut any excess length off. In every case, one side of the condenser is fastened to the proper switch terminal and the other end is wound around the top lead of the .25 mfd. condenser.

Bend a hook in one lead of the .005 mfd. condenser so that it can be fastened to terminal 5. Cut off the excess length of this lead and solder the connection. Wrap the other end of the .005 mfd. condenser once around the lead of the .25

mfd. condenser at the top and clip the excess length. Next add the .001 mfd condenser to terminal 6 in the same manner. The connections around the switch are now beginning to look like an inverted cone with the switch at the base. Add the .0005 mfd. (500 mmfd.-Silver - Green - Black - Brown - Black) condenser to terminal 7 and wrap the top lead one turn around the lead of the .25 condenser. Then add the .00025 mfd. (250 mmfd.-Silver - Red - Green - Brown - Black) condenser to terminal 8; the .0001 mfd. (100 mmfd.-Silver-Brown-Black-Brown-Black) condenser to terminal 9; the .00005 mfd. (50 mmfd.-Silver - Green - Black - Black - Black) condenser to terminal 10 and the .00001 mfd. (10 mmfd.-Silver - Brown - Black - Black - Black) condenser to terminal 11 in the same manner. Solder all of these connections, and the top connections to the lead of the .25 mfd. condenser. Cut a length of wire about 4 inches long and trim the insulation back from both ends. Wrap one end of this wire around the lead of the .25 mfd. condenser at the top of the cone of condensers and solder. Cut another length of wire about 4 inches long and trim the insulation back from both ends. Fasten one end of this wire to terminal 12 and solder it. The switch is now ready to be mounted.

Mount the condenser substitution switch in the proper hole on the lower right side of the panel from the rear. Fit the positioning pin into the hole under the shaft and add the washer and hex nut. Tighten the hex nut securely, drawing the positioning pin up through the hole. The switch should be firmly mounted in the correct position. Slip the pointer knob over the shaft and tighten the set screw. Turn the pointer knob fully clockwise and it should point to the OFF position.

Now fasten the other end of the wire connected to terminal 12 to the PLUS binding post and solder this connection. Fasten the other end of the wire connected to the top of the condensers to the MINUS binding post and solder this lead in place. The condenser substitution switch is now complete and ready for use.

You should now have your multimeter completely wired and ready for full use. Thus at this time the panel should be fitted in place, being careful not to short any parts on the reverse side of the panel. With a good fit obtained the panel may now be fastened to its cabinet using the sheet metal screws provided for this purpose.

Substitution Testing—Capacity

The capacity substitution section of your multitester contains ten condensers ranging in size from .25 mfd. to 10 mmfd. These condensers can be connected one at a time by means of the CAPACITY-MFD selector switch on the lower right side of the tester. By connecting the test leads to the PLUS and MINUS binding posts, you are able to select any of the values of capacity to be used for substitution purposes.

In using the capacity selector switch be sure the resistor selector switch and the main meter selector switch are turned to the OFF positions.

Because of the physical construction of a condenser, it is often impossible to tell from a visual examination its condition. Most condensers have some type of coating on the outside so that any evidence of a defect cannot be seen. Very often a defect such as an open or a short will occur in a condenser. especially one which is under a constant voltage stress. If a direct short occurs in a condenser, the defect can usually be located with a voltmeter test or an ohmmeter. However. a high resistance short which is very common may not give an indication on an ohmmeter. *Condenser substitution* is one of the best methods for testing the condition of a capacitor.

Suppose that the .01 mfd. coupling condenser in Fig. 4 has opened. The effect on the receiver would be a loss of output since no signal is being passed. The voltages of the circuit would all be normal and so would the resistances so the defect could not be located in this manner. Since the .01 mfd. coupling condenser would be suspected, you would put the test leads on the PLUS and MINUS binding posts and turn the capacity selector switch to the .01 mfd. position. The test leads would then be placed between the plate of the first tube and the grid of the second tube. Now when the power is turned on, the set would operate normally. The defective part would then be replaced.

Suppose that a high resistance short occurred in the same condenser. Then placing the test leads in the same position with a substitute condenser across the defective part would not locate the trouble. In this case it would be necessary to unsolder one side of the defective coupling condenser before using the substitution tester. If the size of the defective coupling condenser were not known then you would set the selector switch to some value within the range of commonly used condensers such as .1 mfd. By changing the value of the substitute condenser you would be able to select the proper value to give the best output.

The substitution tester is particularly useful in servicing television receivers because of the very small values of capacities which are used. Because of the high frequencies present in a TV set. a small change in capacity will give a large change in the output. Use of condensers in the range of 10 to 100 mmfd. in a TV circuit is not uncommon. For example if you were to substitute a .001 mfd. (1000 mmfd.) condenser in a video circuit that should have a 100 mmfd. condenser, the loss of part of the frequency range would be very noticeable in the picture. So the wide range of the capacity substitution tester is very useful in both Radio and TV work.

Another use of this section of your multitester is in *determining the size of unknown capacities.* Figure 7 shows a simple capacity bridge which is used to determine the size of an unknown condenser. The input is from a signal generator, usually a 400 cycle frequency

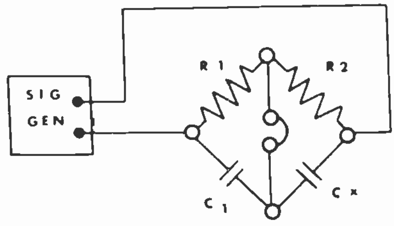


Fig. 7

is used. R-1 and R-2 are equal and the headphones are used as the indicating device. The unknown condenser C_x is placed in the circuit and the capacity substitution tester is used as C_1. With the circuit set up as shown, the selector switch is rotated through its range until one position is found that gives a null point (little or no sound) in the headphones. This is the value of C_1 that closely corresponds with the value of C_x.

As with the resistance substitution circuit, you are not limited to values of capacity contained in the tester. By placing the leads of the tester in parallel with another condenser, you can obtain a greater value of capacity. For example, suppose you have a .1 mfd. condenser in the cathode circuit of an amplifier circuit and you wish to determine if a larger value of capacity will give better operation. Without unsoldering any parts, all you would have to do is set the capacity switch to the desired value, say .25 mfd., and place the test leads across the .1 mfd. condenser in the cathode circuit. The total capacity of the two condensers in parallel is determined by adding the values (just like resistors in series). In this case it would be .1 plus .25 or .35 mfd. If the switch were turned to the .1 mfd. position, the total capacity would be .1 + .1 or .2 mfd.

How To Use Your Complete Tester

Measurement of voltage, current and resistance in a radio or a television circuit is usually the best way in which circuit malfunctions or a defective part can be located and isolated. It is very important therefore that the technician have a thorough knowledge and understanding of the use of the multitester. Lessons R-3 and R-4 describe the construction and operation of the various positions of the range selector switch and the multimeter portion of the tester. The pertinent facts of measurement are given in this lesson. Of course all of the uses of every range position can not be given in one lesson but once you understand the principles of operation of each range you can then use it for all applications.

Along with your Training Unit No. 5 you receive Lessons IR-1, TV-2 and TV-3. These are important lessons on practical circuit testing. They will give you the details of how to make circuit tests of all kinds. You are urged to study the principles of circuit continuity testing in Lessons IR-1, TV-2 and TV-3. The ohmmeter section of your multitester is also a continuity tester and each of its ranges may be used for circuit continuity testing including tests for defects (shorts and opens) in condensers, resistors, etc. Lessons TV-2 and TV-3 also cover in detail the measurement of voltages, both AC and DC. So these two lessons should be studied with reference to your complete multitester. Most of the measurements described in Lessons TV-2 and TV-3 may be applied by you using your multitester. So keep this in mind when you study these two lessons.

The basic meter design in greatest use in the radio and television industry is the O-1 milliampere direct current meter of the type used in your multitester. Meters of much greater sensitivity are used in shops and laboratories where greater accuracy and sensitivity are required, however such meters are usually more delicate and will not withstand the handling required in servicing work. The O-1 milliammeter represents a compromise between sensitivity and ruggedness. Sufficient sensitivity is provided for measuring all but the most critical circuits and rugged enough to withstand ordinary use and handling without changing calibration. However, the impression must not be gained that this type of meter can be overloaded, mishandled or abused in any way without serious injury resulting. Its range, O-1 milliamperes, direct current means exactly what it stands for. That is, one one-thousandth of one ampere of direct current will cause full scale deflection of the indicator needle and any current in excess of this value will result in an overload which may overheat and burn out the meter winding, bend the pointer needle or cause other damage. Also you can realize how delicate the meter movement must be in order that the full scale deflection of its needle will result with an applied power of .001 watt. This requires that jewel bearings be used and that the meter movement be exactly counterbalanced. Therefore, mechanical damage can result by dropping or other mishandling which should be avoided. This milliammeter will withstand ordinary handling and even a small electrical overload for a short period of time without excessive damage. Therefore it is only necessary to exercise due caution together with common sense in using your multitester.

The construction of the tester is such that most of the tip jacks and binding posts have more than one use. Therefore you should always be sure of the range and the switch settings that you are going to use before you apply the test leads to a circuit. When the range switch is being used, the test leads should be inserted in the correct tip jacks, the range switch should be set to the correct range and the resistance and capacity substitution switches should be turned to the OFF position. When using either the resistance or the capacity substitution switch the main meter selector switch and the unused substitution switch must be in the OFF position.

These facts are pointed out so that you will realize the sensitivity and fragility of your multitester and will use and handle it accordingly.

How To Read The Meter Scales

Examine the voltage scales of the dial shown in Fig. 8. The AC ranges are marked in red and the DC ranges are marked in black. See Fig. 8. The divisions are linear across the dial and all of the voltage readings are made from left to right. The setting of the range switch will determine which set of numbers you will use to indicate the reading. When connecting the voltmeter into a circuit remember that the power must be on *and the*

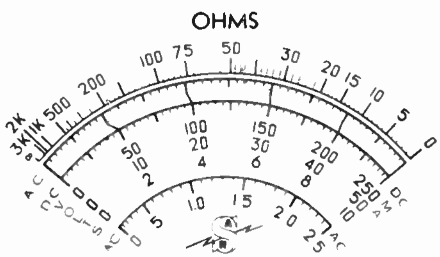


FIG 8

voltmeter is always connected across the circuit to be measured.

With the switch set to the 250 volt DC range, you would read the voltage on the black scale using the top set of numbers. For this range the dial is calibrated in divisions of 50 volts, with ten spaces between divisions. For example, between 0 and 50 there are 10 spaces. Half way between each number on this range is a large division which equals 25 volts. Then each of the small divisions will be equal to 5 volts. Suppose that your pointer is resting on the second small division to the right of the 150. (Locate this position on the meter dial.) The voltage reading would be 150 plus 10 (2 small divisions of 5 volts each) or 160 volts DC.

With the switch set to the 50 volt DC range, the middle set of numbers is used. See Fig. 8. For this range each small division indicates 1 volt and each large division equals 5 volts. On the 10 volt scale, the value of the large and small divisions are again different. Each large division on the 10 volt DC range is equal to 1 volt and the small divisions indicate .2 volts. For example, if the range switch were set to the 10 volt DC position and the pointer were resting directly over the large division between the 4 and 6 (almost in the center of the scale) the reading would be 5 volts DC. If the pointer were resting on the large black division half way between the 0 and 2 what would the voltage be? Since this point is half way between 0 and 2 the reading would be 1 volt DC.

With the range switch set to the 2.5 volt DC position the readings are taken using the top set of black numbers. Suppose you are measuring a voltage of 1.75 volts DC. The needle will rest on the large division between the 150 and the 200 (on the 250 scale). There are ten spaces between 150 and 200 and so each space equals 5 but since you are using the 2.5 volt range each small space equals .05 volts. So if the pointer rests on the large division between the 150 (1.50) and the 200 (2.00) the reading would be 1.75 volts DC.

1. *All voltage measurements are made ACROSS or in parallel with the component to be measured.* For example, if you were measuring the voltage drop across a 330 K ohm resistor in a plate circuit the black test lead would be placed on the end of the resistor connected to the plate of the tube and the red test lead on the end of the resistor connected to B+.

2. *Always observe polarity when placing the tester across a component to measure DC voltage.* The positive or red test lead is connected to the most positive point in the circuit. If the meter is not connected with the proper polarity, the needle will swing to the left rather than to the right and will strike the needle restraining pin and may bend it.

3. *Always set the meter to the highest range when measuring an unknown voltage.* In this way you will be sure not to overload the meter by having the range switch set to the wrong scale. If the needle moves only a slight amount on the high range turn the switch to a lower setting. Always try to read the meter with the needle as close to the center of the scale as possible.

4. If you do not know whether a voltage at a particular point is AC or DC *always use the highest DC range first*. If AC is applied to the meter when the switch is set to a DC range the needle will vibrate but there is less chance of damaging the meter than if you were to apply DC to the tester when it was set to an AC range.

The AC Voltmeter Ranges

In order to use the DC milliammeter movement for AC readings it is necesary to convert the alternating current to direct current in some manner before it is applied to the milliammeter. This is done as was explained in lesson R-4, by means of a small rectifier. Because of the fact that the action of the rectifier is not exactly the same for all voltage ranges, there is a slight variation in the AC readings. This is compensated for on the meter dial as shown in Fig. 8.

If you will note the AC scales on the dial are marked in red. Both the AC and the DC ranges use the same numbers but the red AC scales are displaced slightly from the black DC scales. On the 2.5 volt AC range, a separate scale has been provided at the bottom of the dial.

Suppose that the range switch is set to the 10 volt AC position and the needle pointer rested directly over the large red division between the 4 and the 6. The reading would be 5 volts AC. Note that this point on the red scale is slightly to the left of the 5 volt point on the black DC scale. On the 2.5 volt AC position of the range switch, the readings on the dial are taken on the small red scale at the bottom. The AC voltage is read directly from this scale. On this scale there are 5 spaces between each number so each space is equal to a deflection of .1 volts AC.

The AC ranges of the meter are used in the same manner as the DC voltage ranges except that few circuits use a common or ground point for the AC voltage. One place where this is common is in the filament circuit of a radio or television receiver. The circuit shown in Fig. 10 uses a filament circuit with a common return for the AC. When using the AC voltage ranges it does not make any difference which test lead is placed on the ground point since the voltage is not converted to DC until after it enters the switching circuit. With this exception, the same precautions given for the DC voltage ranges should be observed for the AC voltage ranges.

To measure the AC line voltage of a circuit like that shown in Fig. 10 you would set your multitester range switch to the 250 volts AC position and measure from one side of the line cord to the other.

The Ohmmeter Ranges

There are five positions of the range switch for the ohmmeter portion of the multitester. For all of the ohmmeter ranges a known source of voltage is provided and a resistance of unknown size is placed across the meter input test leads. In the R times 1 (R×1) position, as explained in lesson R-4, the 6 volt battery supplies the known voltage and the resistance to be measured is placed across the test leads which are inserted into the *NEG* and *POS* tip jacks. When there is no resistance connected across the test leads there will be no reading on the meter because the resistance between the input leads is infinite. In calibrating the ohmmeter, the test leads are first shorted together. This means that there will be zero resistance across the input tip jacks. (Actually the resistance of the test leads is present but it is such a small fraction of an ohm that it is considered to be zero.)

Current flow from the 6 volt battery through the switching circuit is such that the meter should read full scale deflection with the test leads shorted together. The OHMMETER ADJUST potentiometer is set so that exactly one milliampere of current flows through the milliammeter when the test leads are shorted. The OHMS scale on the dial across the top is calibrated so that zero ohms equals 1 milliampere. When some value of resistance is placed across the test leads, the reading will be less than one milliampere of current. Suppose that 500 ohms of resistance were placed across the test leads. Some of the current from the battery would now flow through the 500 ohm resistor which is actually in parallel with the meter circuit. Because of the resistance of the internal circuit with the range switch in the R×1 position, about .08 milliamperes of current would flow through the meter and so the needle would point to the 500 mark on the OHMS scale. Refer to Fig. 8 which shows the dial of your multitester meter. In the same manner if 50 ohms were placed across the test leads, then about .5 milliamperes would flow through the meter and the needle would read 50 ohms.

From the parts sent to you in previous lessons (R-1—R-2) locate the 220 and 22,000 ohm resistors. These two resistors will be used to demonstrate the ohmmeter. On the meter dial, notice how the OHMS scale is calibrated. This scale is across the top of the dial and is used on all of the OHMS positions of the selector switch.

Note that *the ohms scale reads from right to left* and that *it is not linear*. From zero to about the center of the scale, there is a reading of 50 ohms. From the center to the left edge of the scale, it goes from 50 to 3K to infinity. For this reason, as the value of resistance to be measured increases, the switch should be turned to a higher ohms range.

Set the meter range switch to the *R×1* position. Insert the tip end of the black test lead into the *NEG* jack and the tip end of the red test lead into the *POS* jack. Touch the other ends of the two test leads together and note that the meter pointer swings over to the right side of the dial. When the short is broken (test leads not touching) the pointer moves back to the left side of the dial. With the test leads disconnected, the pointer should be resting directly over the zero on the voltage scale on the left side of the meter. If the pointer is not located in this position, carefully turn the zero adjust screw of the meter needle until the pointer is in the proper position. This screw is located at about the center of the meter frame just below the dial. Once adjusted for zero reading it rarely needs readjustment and since it is somewhat fragile it should not be tampered with unless absolutely necessary.

Once again short the ends of the test leads together. The needle will swing over to the right side of the dial. If the pointer does not come to rest directly over the zero mark on the Ohms scale, turn the *OHMMETER ADJUST* potentiometer and note how the position of the pointer will change. Set the *OHMMETER ADJUST* control so that the pointer comes to rest right over the zero mark on the right end of the ohms scale with the meter test leads shorted together. Separate the test leads once again. The meter is now set to read on the R×1 scale (read the scale exactly as it is printed).

Touch the test leads to the two pigtail leads of the 220 ohm resistor as shown in Fig. 9 and observe the pointer of the meter. The pointer will come to rest just to the left of the 200 mark on the Ohms scale. In reading resistance with the meter, remember that the rating of commercial resistors is such that the actual reading on the meter can be slightly more or less than the value given by the color code of the resistor. The amount of variation will depend upon the tolerance rating of the particular resistor being tested. This may be 5 to 20% plus or minus the rated value. Remove the test leads from the 220 ohm resistor and place them across the 22,000 ohm resistor. With the test leads across the 22,000 ohm resistor and the selector switch set to the *R×1* range, the pointer will barely move. In fact, the movement may be so small that it cannot be seen. Turn the selector switch to the *R×10* (read as R times 10) position. The pointer will now move to the 2K mark on the ohm scale. Remove the 22,000 ohm resistor from across the leads and place the 220 ohm resistor across the test leads. The

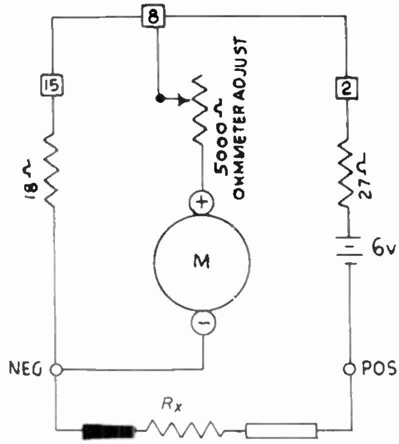


FIG 9

pointer will now move to the small line to the left of the 20 on the Ohms scale. Remember that this scale is to be read from right to left. Suppose your pointer comes to rest on the first small mark to the left of the 20 on the Ohms scale. Since there are 5 spaces between the 20 and the 30, each mark is equal to 1/5 of the value, or 1/5 of 10 which is 2. So each mark equals 2 ohms (times the setting of the selector switch). Now if the pointer is resting on the first mark to the left of the 20, that means that the meter is reading 20 plus 2 times 10 which is 220 ohms. The reading may vary slightly from the value indicated by the color code but it should be within the tolerance rating.

Turn the selector switch to the *R×100* (read as R times 100) position and once again place the meter leads across the 220 ohm resistor. The pointer will now move over to the first mark just to the left of the 0 on the ohms scale. It may be just above the first mark to the left of the 0. Note that between the 0 and the 5 there are 5 spaces and four small marks. That means that the marks all are equal to one division with the first mark being equal to one, the second mark two, the third mark three and so on.

Remove the 220 ohm resistor and place the 22,000 ohm resistor across the test leads. The pointer will swing over so that it now points to just above the 200 on the ohms scale. Switch the selector to the *R×1000* (read as R times 1000) ohms scale. The meter will now point to the first mark to the left of the 20. Note that between the 20 and the 30 on the ohms scale there are 5 spaces. Therefore, each mark equals 2. So the first mark indicates 22, the second 24, etc. The meter is now reading 22 times 1000 or 22,000 ohms. On the *R×1000* scale the 45 volt battery is in the circuit.

Now set the meter selector switch to the *R×10,000* ohms scale. There will be no reading of the meter because on this switch position, it is necessary to use an external voltage source.

Obtaining High Voltage For Ohmmeter

As mentioned in Lesson R-4, high voltage for operation of the high range of the ohmmeter may be obtained from several sources. Any receiver or amplifier you might have on your work bench can be used temporarily to provide a high DC voltage since the value is not critical. All that is necessary is two wire connections from the power supply of any receiver or amplifier you might have handy. Connect the minus binding post of the tester to the negative on the receiver or amplifier. Then connect another wire from the highest B+ available in the receiver or amplifier to the plus binding post of the tester. In this connection usually the highest B+ connection in the receiver or amplifier may be found at the rectifier filter output. In most receivers and amplifiers this would be at the output of the filter choke in the power supply.

The high range ohmmeter circuit is then used just as for the low ranges making use of the 5,000 ohm zero adjust to get the usual zero reading of the ohmmeter.

If you want a permanent circuit to operate the high range of the ohmmeter, one can be easily arranged with few parts. Figure 11 shows the circuit. Practically any power transformer with a center tap high voltage winding and rectifier tube may be used. Such a transformer may be taken from an old receiver or amplifier or you may use any of the common types available from some of the surplus radio and television parts outlets. The transformer we used had a 5 volt filament winding which permitted the use of an 80 or similar type rectifier tube. The high voltage winding was rated at 350 volts AC each side of the center tap. If the transformer you use has extra secondary windings, they may be disregarded since only two windings are necessary, one for the high voltage and one for the rectifier filament.

The rest of the circuit is very simple making use of two 8 mfd. condensers rated at 450 volts or higher. Incidentally, if you have electrolytic condensers rated more than 8 mfd., they may be used with equal satisfaction.

The resistor R-1 is used in this instance as a filter resistor instead of the usual choke coil. However, if

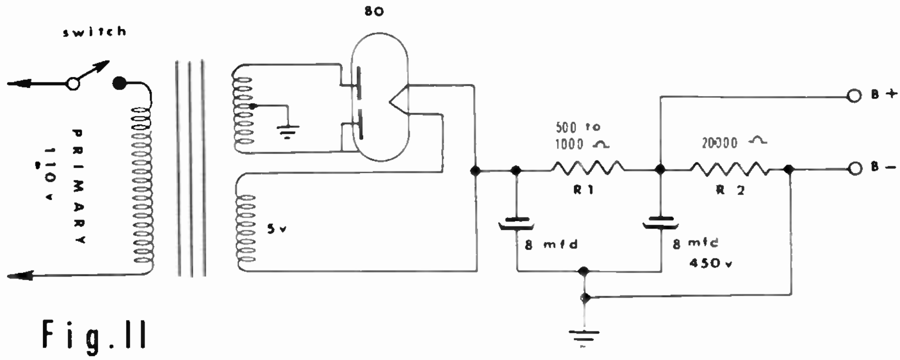


Fig. 11

you have a choke coil, it is permissible to use it in place of the resistor.

The 20,000 ohm resistor should be rated at about 5 to 10 watts. It is merely a load resistor to stabilize the circuit and its value is not critical.

To operate the circuit, the B+ and B− connections shown in Fig. 11 are connected to corresponding points on the tester, namely, the plus and minus binding posts. The circuit is then operated in the usual way.

If you should have any questions about how to arrange your particular high voltage circuit, we will be glad to help you if you will write and present your questions fully.

The higher ranges of the ohmmeter section of the multitester are used when testing circuits containing large values of resistance.

The R×1000 range is used when testing all types of condensers for shorts. Very often a condenser will have some internal leakage that will appear as a high resistance short and can not be indicated with the lower ohm ranges.

The setting of the range switch when measuring resistance will depend upon the circuit which is being tested. Since for the ohm scales, the meter provides its own voltage and reads down from full scale deflection, there is not as much danger to the meter movement if you start with the wrong ohms scale. If the deflection of the needle is too small then the range switch has to be reset to a lower position. If the deflection is too great to the left side of the scale then a higher ohms position must be used.

Practical Use of the Low or R×1 Ohmmeter Scale

Figure 10 shows a schematic diagram of the Arvin receiver, Model 460-T, employing Chassis RE-284. The circuit employed is typical of the average small six tube receiver. It will be used as a reference to show several functions of your multimeter, including use of the ohmmeter and the AC and DC voltage ranges.

First, consider use of the R×1 range. Reference to Fig. 10 will show several applications where it would be practical to use the low range ohmmeter. These include testing the antenna loop L1, the RF coil L2, the oscillator coil L3, the IF coils L4 and L5, any low value resistance, the wiring of the several circuits, the tube filaments, the pilot light, switch contacts, etc.,

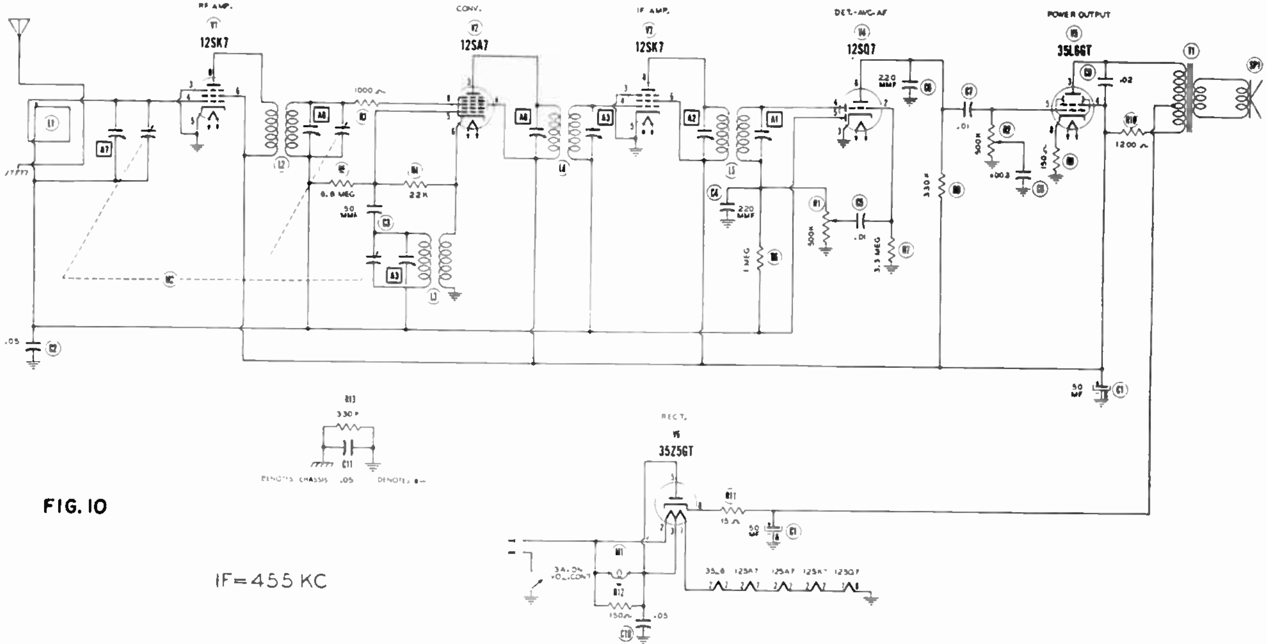


FIG. 10

IF=455 KC

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
V1	12SK7GT	0V	50VAC	0V	95VDC	0V	80VDC	27VAC	80VDC
V2	12SA7GT	0V	37VAC	80VDC	80VDC	-1 0.2VDC	0V	24VAC	-.5VDC
V3	12SK7GT	0V	24VAC	0V	8VDC	0V	80VDC	12VAC	80VDC
V4	12SQ7GT	0V	-.5VDC	0V	5VDC	-.8VDC	45VDC	12VAC	0V
V5	35L6GT	0V	85VAC	110VDC	80VDC	0V	0V	50VAC	5VAC
V6	35Z5GT	0V	117VAC	110VAC	0V	110VAC	115VDC	85VAC	115VDC

* TAKEN WITH VACUUM TUBE VOLTMETER

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
V1	12SK7GT	330KΩ	56Ω	0Ω	1.5 Meg	0Ω	†1.3KΩ	82Ω	†1.3KΩ
V2	12SA7GT	330KΩ	47Ω	†1.3KΩ	†1.3KΩ	22KΩ	7Ω	30Ω	1.5 Meg
V3	12SK7GT	330KΩ	30Ω	0Ω	1.5 Meg	0Ω	†1.3KΩ	10Ω	†1.3KΩ
V4	12SQ7GT	330KΩ	3.3 Meg	0Ω	500KΩ	1.5 Meg	†330KΩ	10Ω	0Ω
V5	35L6GT	Inf	80Ω	1120Ω	†1.3KΩ	500KΩ	Inf	94Ω	180Ω
V6	35Z5GT	Inf	120Ω	100Ω	Inf	100Ω	115Ω	80Ω	500KΩ

† MEASURED FROM PIN 8 OF V6.

THE COOPERATION OF THE MANUFACTURER OF THIS RECEIVER MAKES IT POSSIBLE TO BRING YOU THIS SERVICE

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107-3

such as you will find in any receiver. Testing these units in general is known as continuity tests and they are employed more or less on every type of receiver. Some of the parts may require their disconnection before they can be tested and others can be tested for continuity and resistance value without disturbing their connections. However, if there is a unit or part in parallel with another, which you are testing, there is always the possibility that the other unit may itself have a defect and thus your meter reading may be misleading. So, in general it is recommended procedure to at least disconnect one terminal of a unit you are testing and in that way you don't have to worry about other parallel connections having an effect on the unit you are testing.

So, in the following descriptions it will be assumed that you have at least one terminal of the unit in question disconnected. You must first, of course, prepare your multimeter circuit to make tests on the low ohmmeter range. We have previously given directions for doing this and it will be assumed that your low range ohmmeter is ready for operation. So, in Fig. 10, to test the continuity of L1, connect your test leads across the terminals of the loop. The resistance value is not usually given, but if you get a reading on the meter it indicates the winding of L1 is not open. Two good points from which to test the continuity of the loop would be to connect one of your test leads to terminal 4 of tube V1. Where to connect the other test lead will depend on the circuit arrangement, but generally you should connect it to the one remaining free loop terminal—normally a point which you would probably have disconnected from the rest of the circuit before a test is made on the loop for continuity.

Going to the coil L2, two convenient points to connect your test leads are to terminals 6 and 8 of tube V1. In this case it would not be necessary to disconnect one of the coil terminals for there is nothing in parallel with the primary winding unless it should happen that the tube in socket V1 has an internal short. The latter is not likely to be the case and you can safely determine the condition of the coil winding by connecting to terminals 6 and 8.

Going to the secondary coil of L2, one test lead could connect to terminal 8 of tube V2. The other test lead could connect to the remaining coil terminal if you had it disconnected from the circuit, or, you could pick another point in the circuit which was common to the remaining terminal of the secondary coil. Thus, if in this case you connected one test lead to terminal 8 of V2, and the other to terminal 4 of V3, you would be testing for continuity not only of the secondary coil L2, but also the secondary coil L4. Thus your meter reading should normally be in excess of a thousand ohms, or you could short the 1,000 ohm resistor R3 and then you would be testing only for continuity of the secondaries of L2 and L4. This latter test is an example of a short cut in continuity testing where you test one or more units with one meter. Of course, when making this test and you obtain no reading, you would test each secondary winding separately to find out which one of them was open. These are little tricks of testing which you will learn as you get more knowledge and experience.

Referring now to coil L3, the primary winding could be tested by connecting one test lead to one terminal of the coil, the other test lead to the other terminal of the coil. Normally a very low reading would be obtained, but if it should happen that one of the condensers across this winding were shorted, you would get a zero resistance reading. Normally, unless all of your tests indicate that the defect you were looking for localized itself to the oscillator stage, you would not be justified in taking the time to disconnect one terminal of the primary coil L3. However, if you wanted to be sure that the condensers across this coil or a similarly connected coil were not shorted, then the only thing to do would be to disconnect at least one of the coil terminals.

Going next to the secondary of L3, one test lead could be connected to terminal 6 of tube V2, and the other one connected to any point in the circuit corresponding to negative. A reading of the meter would indicate the coil had continuity and no reading would indicate that it was open.

For the primary winding of L4 you would simply connect your test leads to terminals 3 and 4 of tube V2. Here again there is a condenser across the winding and if the meter reading indicated zero resistance it might possibly mean that the condenser across the winding was shorted. Thus, to be sure the condenser should be disconnected and another test made on the coil. Of course, with experience you would also test the condenser once you had it disconnected, and directions for doing this will be given later.

The windings of L5 would be tested in general just as we have described for L4. For the primary connection place your test leads across terminals 6 and 8 of tube V3—keeping in mind that there is a condenser also connected across the primary winding of L5. The secondary winding of L5 may be tested by connecting one test lead to 4 of tube V4 and the other test lead should be connected to the remaining secondary terminal or to one terminal of resistance R1 which is common to the secondary terminal of coil L5.

Both windings of output transformer T1 could be tested by simply connecting across the terminals of the transformer for both the primary and secondary sides. Should you get abnormal or suspicious readings, it may be necessary to disconnect at least one terminal of each transformer winding to be sure of its condition. As you get experience in this method of testing you will gradually learn when to disconnect a part terminal and when you can rely on your test without having to disconnect terminals.

The receiver of Figure 10, as you will note, employs a series filament circuit and if only one tube filament burns out or becomes open, none of the tubes in the receiver will function. So, it is desirable at times to make a continuity test on each of the tubes, especially in a circuit which employs a series string of filaments. With experience you will soon learn to connect one of your low ohmmeter test leads to the ungrounded side of the power plug and the other test lead to B negative. In this way you could test all of the tube filaments at one time for continuity. However, at the beginning you might want to test each tube separately for continuity. In this case remove the tube or tubes from their sockets and connect your test leads across the tube filaments—referring to a tube manual for proper tube filament terminals, if you cannot easily identify them. Thus for the 35Z5 tube, you would connect across terminals 2 and 7, and this would also be proper connections for all of the other tubes in this receiver with the exception of the 12SQ7, and in this case you would connect across terminals 7 and 8. In every case of this kind the actual reading on the low range ohmmeter is not important. The important thing is if there is no reading it means the tube filament is burned out and should be replaced. Usually only one tube in a series of filaments is open or burned out, and when it is replaced normal operation will be restored.

Rectifier Tube Tests for AC-DC Receivers

Usually in testing circuits for continuity where considerable resistance is involved, it is desirable to use a higher ohmmeter range. With respect to the average AC-DC rectifier tube circuit, it has resistances generally less than 1,000 ohms. This condition is true for Fig. 10 as you will see by examining the rectifier circuit. So, to quickly establish continuity for this portion of the circuit, first connect one ohmmeter test lead to the power line plug corresponding to the ungrounded side of the circuit.

Then with the other test lead touch terminal 7 of the rectifier tube. A reading establishes that the filament is intact or not open. In this connection, note in this type of tube a tapped filament is employed and often the section between 2 and 3 burns out. A test between 2 and 3 on rectifier tubes of this type will quickly confirm whether or not this section of the tube filament is open. If it is open, generally the pilot light will burn out and so will the usual resistor connected across it, such as R12 in Fig. 10—a 150 ohm resistor.

The reason the pilot light, resistor, or both units, will often burn out in this type of circuit is because with the filament section between pins 2 and 3 open, all current carried by the rectifier tube is forced to flow through the pilot light and resistor. Often it is enough to burn out one or both of these units. The remedy is to replace the rectifier tube and to correct the condition or conditions which cause the overload on the rectifier tube filament in the first place.

Such a defect to cause this open filament condition would likely be a defective electrolytic condenser leading from the cathode of the rectifier tube, or a B+ circuit which in some way was grounded.

Referring now to further testing of the rectifier tube, letting one test lead remain on the ungrounded side of the AC line, move the other test lead to terminal 5 of this, or a similarly connected rectifier tube. This will establish whether or not the pilot light and resistor are in good condition. However, this test can be misleading because the pilot light and R12 are in parallel. One of these units could be open and you would still get a reading on the ohmmeter because a conductive path would still be established through the other unit, assumed to be in good condition.

Leaving one test lead connected to terminal 5, move the other one from the ungrounded side of the AC line and touch it to B negative or to a common point in the circuit corresponding to it. This tests the condition of C10 or the .05 mfd. condenser. A reading on the meter proves the condenser to have leakage and no reading proves it to be in good condition.

R11 in Fig. 10, or one like it in a similar AC-DC circuit, is easily tested. Place one test lead on terminal 8 of the tube socket and the other one on the plus terminal of condenser C1. This tests the 15 ohm filter resistor R11 for continuity. No reading means that it is open.

These tests are general which you can apply to most rectifier tube circuits using either a low or high ohmmeter range, but the low range especially for low resistance circuits is preferred.

Similar tests may easily be made on other types of rectifier circuits even though they might employ a power transformer with several secondary windings. In general, in this type of circuit it is preferred to remove the rectifier tube from its socket and then test for continuity of secondary windings by connecting to proper pin terminals on the rectifier tube socket. These tests would hold for the high voltage secondary and the filament winding that supplies power for the filament of the rectifier tube. In such circuits the filter R11 as in Fig. 10 would probably not be included, but instead a filter choke would be used. It, however, would have a low resistance value and to test it for continuity it would be necessary to connect the test leads across its two terminals. Other low voltage secondary windings would probably be on a power transformer. The safest procedure in testing these to avoid effects of tube filaments connected to these secondary windings would be to either remove the proper tubes from the sockets or disconnect one filament winding from the circuit so as to free the secondary from any possible parallel effects, such as tube filaments or a possible short across a filament circuit at some point. Where everything indicates trouble in such a filament circuit, the best procedure is to disconnect one filament terminal of the winding, test it for continuity, and then proceed to test the rest of the filament circuit for shorts or opens.

Practical Use of the Higher Ohmmeter Ranges

The higher ranges of the ohmmeter are to be used every time where high resistances are involved. In many cases the high resistance ranges can also be used in testing for continuity of simple wire circuits or even where very low resistances are involved. This is especially true where you are not interested in exact resistance values, but are more interested in establishing that continuity of circuits exists.

Use of the higher ohmmeter ranges is very desirable when testing all types of condensers especially paper, mica, and ceramic types, because with these you are concerned primarily in whether they have internal leakage and often where such leakage is present, it is of a high resistance nature and will show up only by use of the high ohmmeter range.

As you get experience in testing condensers, you will soon learn how to test them without disturbing connections to them. In this connection you will be guided by the way the condenser to be tested is connected. If it does not have a parallel circuit across it, you can quickly establish its condition by connecting your test leads across the condenser—this test to be applied only to paper, mica, and ceramic condensers—it will not hold true for electrolytics.

An example of where you might test a condenser without disconnecting it is the coupling condenser .01 mfd., C7 in Fig. 10. A quick way to test it is to simply connect your test leads from terminal 6 of tube V4 to terminal 5 of tube V5. A reading would indicate condenser C7 to be shorted or to have internal leakage. Such a test for condenser C9 in Fig. 10 is not to be trusted as described for C7. This is because of the way the condenser is connected, meaning that if C9 had an internal short it would not be clearly established because of the path provided through the secondary winding of T1 and R10.

If the test leads are simply placed across C9 a reading would be obtained, assuming C1 and R10 not to be open. So, the proper thing to do here is to disconnect one terminal of C9 and then apply test leads which would firmly establish the condition of this condenser.

For a condenser connected like C8 of Fig. 10, it, too, should have one terminal disconnected. You can then be sure of your test, although an additional factor here is that if the condenser C8 should have an internal short, the reading on the meter would vary as R2 was varied, assuming the test leads to be connected to the two condenser terminals.

So, you have to be very much aware of how a condenser is connected. Generally, and especially for beginning servicemen, it is suggested that one condenser terminal always be disconnected for a test. As you gain experience, you will learn when it is proper not to disturb the condenser connections for test purposes.

The same general conditions must be observed when testing resistors of high value, that is for parallel effects of other resistors and circuits. Here again the beginning serviceman should disconnect one resistor terminal before making a test. Later you will develop techniques of your own which will enable you to test many resistors without the necessity of disconnecting one terminal. However, many resistors are so connected that it is impossible to be sure about the condition of the resistor without disconnecting at least one lead of it. The possibility of other resistors or circuits being in parallel with a given resistor is an important question always to be decided before establishing the true condition of the resistor under test. So, always be sure to analyze your circuits and in case of doubt, be safe. Disconnect one resistor lead.

The high ohmmeter range establishes two things for you at the same time. First, you must observe that any resistor under test must be within 10% to 20% of its rated value. A greater variation than

20% calls for a replacement of the resistor. Secondly, the high ohmmeter range establishes whether or not the resistor has continuity. No reading means the resistor is open and needs replacing.

A reading establishes that the resistor has continuity, but the reading must be interpreted in terms of the resistance value within the 20% tolerance as mentioned. Resistors do not often change in value, but occasionaly their values do change due to overloading, age, moisture, and other conditions. So, not only must you establish that the resistor is not open, but you must also, at the same time, establish that its value is correct.

In some circuits resistance values are very high. This is especially true in television and in AVC networks and in other tube circuits used for control purposes. There will even be cases where the average ohmmeter will not read the value because the actual value exceeds the range of the ohmmeter. In such cases a more sensitive ohmmeter must be used or a substitute resistor may always be tried in place of the one whose value it is difficult to establish. In case of very high resistance values, the vacuum tube voltmeter is usually used or a meter with a sensitivity equal to 20,000 ohms or more per volt. However, the use of such extremely sensitive meters is not often required, and you will find that a meter such as provided here with a sensitivity of 1,000 ohms per volt will satisfy the conditions of most radio and TV circuits in 90-95% of the applications and tests to be made.

Without expanding this lesson to equal in length the several lessons in our Service Course, it is not possible to go into all functions of the multimeter you have just built. However, enough general instructions have been given to enable you to make frequent use of the instrument until you get more knowledge and experience.

Other lessons of your course will treat in detail tests that you can make with this meter, and with other similar meters. You will be getting these lessons dealing with electrolytic condensers, output meter measurements, transformer, and choke coil tests, as well as voltage, current, and ohmmeter tests.

So, it is at this point that we bring to a conclusion the general tests that you may make with the ohmmeter described in this lesson. Your other lessons are going to supply much more information, but if you should have specific questions on further uses of this instrument, write and we will try to give you as much additional help as is needed.

Voltage Measurements

In establishing that a defect exists in a receiver, two general methods of measurement are followed. The defect may be so self-evident that there will be no necessity to apply power to the receiver in order to measure voltage. Thus, continuity tests would be made immediately to determine the condition of a part or parts. Such tests are usually called static tests, making use of the ohmmeter with no power applied to the receiver.

The other test method is known as dynamic testing, wherein measurements are made with electrical power applied to the receiver. In general, this type of test is usually made first, in the process of which it is established that one or more circuit parts are at fault. Power is then disconnected from the receiver and continuity or resistance tests are made to determine which parts actually are at fault.

The following tests, therefore, are those which you would usually make first. These involve voltage measurements and as mentioned, are commonly called dynamic testing as distinguished from static tests made when no operating power is applied to the receiver.

To acquaint you with this general method of testing, reference will again be made to Fig. 10 using the circuit of it as an example of how you would make voltage tests on this or any other type of receiver.

First, the power line cord would be plugged into a power outlet and the receiver switch turned on. A quick careful observation would then be made to see if any parts are overheating, smoking, etc., which would immediately indicate to you that a short circuit or overload is occurring, in which case the power line cord should be immediately removed from the power outlet. Static tests would then be made to find out what was causing the overload. This condition would be corrected and then the power line cord would be connected to a power outlet again. If everything now appears normal, you would proceed to make voltage measurements.

Usually you will be confronted with a situation somewhat like the following. After the receiver switch is turned on there will be no response, after allowing time for the tubes to heat. Your next step would then be to make voltage measurements at the several tube sockets, the results of which would indicate to you where the defect or defects exist. You would immediately be suspicious where abnormal voltage was noticed or where there was no voltage at a point in the circuit where you would normally expect it. You would then investigate the condition of abnormal or no voltage, which in general will lead you direct to the cause of the defect.

In making voltage measurements on a given receiver, it is a good practice at the start, especially in an AC-DC receiver, to establish B negative or circuits which are common to it. The black test lead is then permanently connected to a convenient B negative point, the red test lead then being moved to successive points in the circuit where you are interested in establishing that voltage exists. Note in Fig. 10, as is true with many AC-DC circuits, a ground symbol indicates B negative with a different ground symbol indicating the metal chassis of the receiver. B negative in this case, will be represented by a circuit of common wiring, and it is to be noted that the metal chassis of the receiver is not B negative or not the point to which your black test lead would be connected. So, locate an easily accessible B negative point to which you may connect your black test lead. In Fig. 10 a convenient point would be the on-off switch terminal shown connected to the ground symbol. Thus, you could clip your black test lead to this point, and then quickly move the red test lead from point to point, interpreting the reading as you make individal measurements.

Assuming the black test lead connected as mentioned, and using the AC 250-volt range of your meter, touch the red test lead to 5 of tube V6, or the rectifier. You should normally get a measurement at this point equal to the line voltage. If no voltage is indicated, it would mean in Fig. 10 that the pilot light is open or that the resistor R12 was open. If the voltage value is considerably less than the line voltage, then you would suspect the .05 mfd. condenser designated as C10 in Fig. 10. This condenser could be shorted or have high internal leakage, thus reducing the voltage at terminal 5 of tube V6. This condenser, if suspicioned, should be temporarily disconnected and voltage measured again at terminal 5 of tube V6. A proper voltage measurement this time would definitely indicate C10 to be at fault.

The only other AC voltage measurements that you would normally make for a receiver similar to the one represented by Fig. 10, would be across the tube filaments. In this case you would simply connect your voltmeter leads directly across the tube filaments of each tube, using of course, a suitable voltage range. Thus, for the 35Z5 tube the voltmeter leads would connect across terminals 2 and 7.

The same connections with respect to terminal numbers would apply for the 35L6, 12SK7, and 12SA7 tubes in Fig. 10. The 12SQ7 tube has different filament terminals, namely 7 and 8, and so the voltmeter leads should connect across these for filament voltage measurement of this tube.

The remainder of the measurements for this circuit would be DC with the black test lead connected to a common B negative circuit. The red lead should first be connected to terminal 8 of tube V6. Reference to the voltage table shows that the voltage measured here should be about 115 volts, and it should, of course, be DC, your meter being adjusted to make this type of measurement. No voltage at this point would indicate a defective rectifier tube or an abnormal condition preceding the rectifier tube, and the cause for this would have to be investigated. An abnormal measurement at this point generally indicates the same thing, a defective tube or an abnormal condition preceding the rectifier tube. However, an abnormal condition along the B+ circuit could also cause abnormal voltage at terminal 8 of tube V6. It could be in the nature of a defective electrolytic condenser such as C1. Note in the circuit of Fig. 10 that two condensers are designated as C1, they both being 50 mfd. of the electrolytic type, and designated as A and the other as B. If condenser A or B should develop excessive internal leakage, it would represent an overload, making resistor R11 excessively hot and reducing voltage at terminal 8 of tube V6. A full short of condenser A would place a heavy load on resistor R11, and probably burn it out immediately. If electrolytic condenser B should be the one with heavy leakage, or a full short, the overload would occur on resistor R10 as well as R11.

A full short of this condenser B would surely burn out either resistor R10 or R11. So, if you found one or both of these resistors open, in this or any other similar AC-DC circuit, you would immediately suspect the electrolytic condensers. An individual test on them would immediately establish if they were at fault.

Assuming that the two electrolytic condensers are not defective, your red test lead would be placed successively at the following tube terminals representing the plates of each tube involved. Terminal 3 for tube V5, terminal 6 for tube V4, terminal 8 for tube V3, terminal 3 for tube V2, and terminal 8 for tube V1. If you are beginning such work as this, you would make reference to the voltage table included with the diagram. However, after you service a few AC-DC receivers, you would know the approximate voltage value to expect at the plates of the tubes, and by experience you could quickly tell whether or not there was anything wrong with the circuit of the tube involved. For instance, at terminal 3 of tube V5 no voltage here would mean that the primary of the output transformer was open or that condenser C9 was shorted or had excessive leakage. A continuity test on each of these units would quickly establish whether or not they were at fault.

Should abnormal voltage measurement be made at terminal 6 of tube V4, you could logically suspect resistor R10, the electrolytic condenser C1B, resistor R8, or condenser C6. However, the probability is in testing and determining the condition of the rectifier tube that you would have already established that resistor R10 and condenser C1B were not at fault. Thus, this leaves resistor R8 and condenser C6 as possible sources of defects. A quick continuity test on these would determine their condition. In connection with the plate circuit of tube V4, condenser C7 is employed as a coupling condenser. It conceivably could be shorted or have high internal leakage, and should this be the case, little or no voltage would reach the plate of tube V4, for C7, if defective, would drain current through resistor R2 to ground or B negative. Thus, if low voltage persisted to be evident, at terminal 6 of tube V4, and you established that C6 and R8 were in good condition, you would then proceed to investigate the condition of condenser C7, although it or a similarly connected condenser does not often develop a defect. All of this assumes that for tubes V4 and V5 the tubes are in good condition and that the cathode circuits are complete back to B negative.

In connection with tube V5, an additional factor is to be considered, with respect to plate voltage. Should there be no plate voltage, the defect could be due to the resistor R9, which is the cathode resistor that develops grid voltage for tube V5. If this resistor were open, it would interrupt the flow of plate current, but plate voltage could still be measured because your voltmeter leads would still be between B+ and B negative. So, the fact that you measure plate voltage at terminal 3 of tube V5 does not guarantee that resistor R9 is in good condition. There is one evident point, however, to be observed here for this condition. If R9 should be open, the voltage you will measure between plate and B negative of this tube will be higher in value with R9 open than it will when R9 is normal. The reason for this is that with R9 open, tube V5 cannot draw plate current and since it represents a considerable load on the rectifier and with it not drawing current, the voltage will be considerably increased due to the regulation action of the rectifier tube. With R9 normal for tube V5, the tube draws normal current and voltage then at its plate should be normal—not above normal.

So, in testing for plate voltage, especially for an output tube, when the plate voltage is higher than the rated value, you should immediately suspect the cathode resistor, for in all likelihood it will be found to be open.

The foregoing described condition would not hold true for tubes V4, V3, and V1 in Fig. 10. The reason for this is the cathodes of each of these tubes are connected direct to B negative and no cathode resistor is involved. Practically the same thing holds true for tube V2 in Fig. 10, for the cathode of this tube is connected to B negative through one winding of coil L3. The latter has very low DC resistance, so from a voltage viewpoint the cathode of tube V2 will be considered just as for the cathodes of V1, V3, and V4.

Returning to plate voltage measurements, the red test lead should in turn connect to terminal 8 of tube V3, terminal 3 of tube V2, and terminal 8 of tube V1. No voltage or abnormal voltage at the plates of any one of these three tubes should be sufficient cause for you to trace the circuits for possible defects. The only part involved is a coil winding in the plate circuit, and connecting your ohmmeter test leads across the two proper terminals should enable you to immediately establish the condition of these coils. This, in general, is how you would go through a receiver testing for plate voltage and establishing the condition of parts and circuits as you make progress with your testing. This same treatment can be applied to any type of receiver in general, as far as principles of voltage testing are concerned. Of course, individual circuit variations would have to be considered, but that you could easily do by making reference to the diagram of the receiver involved.

There are other B+ circuits in Fig. 10 from which voltage measurements could conceivably be made. These in general would be the screen grid circuits such as terminal 4 of tube V5, terminal 6 of tube V3, terminal 4 of tube V2, and terminal 6 of tube V1. Generally, screen grid circuits have no loads such as you will find in plate and sometimes in cathode circuits. Usually, then, if you make an abnormal voltage measurement in a screen grid circuit it will mean that one or more resistors feeding voltage to the circuit or circuits are possible sources for defects, as well as any bypass or filter condensers that might be connected across the screen grid circuits to ground or B negative. Any such resistors should be tested for continuity and any condensers connected across screen grid circuits should be tested for a short or high internal leakage, making use of the ohmmeter.

Other voltage measurements that you might make in a circuit like Fig. 10, are those which exist in the cathode and control grid circuits. For a control grid measurement, remember that the negative or black test lead is to be connected to the grid. Such voltage values are usually rather low and often high values of series resistances are involved, which prevent accurate measurements with a voltmeter of low sensitivity. In such circuits, rather than rely on voltage measurements, it is better to make resistance tests of the elements involved in the circuit, seeing that continuity exists and that resistances are within tolerance limits. If this is done, you can assume that voltage values will be correct and that it will not be necessary to establish their exact value. This is especially true where you have established that plate and screen grid voltages of the tube or tubes involved are normal.

The Milliampere Ranges

The last four positions of the main selector switch provide for measurement of current. You will note that although the milliammeter is made to read from 0 to 1 milliampere, this range is not used in the multitester. The reason for this is that in very few circuits is it necessary to measure this small an amount of current.

The milliammeter ranges are widely used for calibration and alignment of various circuits in a manner similar to the output meter use. The milliammeter measures current flow through a circuit. Therefore it is necessary that the meter be placed in series with the circuit in order to measure current. In this way the total current in the circuit will flow through the milliammeter. The total current in the circuit flows through the meter movement (and the shunt resistors) causing the needle pointer to move. Because of this, care must be taken not to place your tester in a circuit where the current is greater than the capacity of the highest range selector switch setting. If you have any doubts, measure the voltage of the circuit, then turn off the power and measure the resistance. Then calculate the current using Ohm's law. In this way you will avoid overloading and possible damaging of the milliammeter.

The DC milliampere scales are read on the same lines and using the same set of numbers as the DC voltage scales. See Fig. 8. Use the black, linear scale divisions just above the numbers. On these ranges the milliammeter is also read from left to right. You will note that the first three milliampere ranges correspond to the numbers marked on the dial so they can be read directly. The 2.5 MA range is read on the 250 scale by dividing any value on this scale by 100. Thus a reading of 180 on the 250 scale is equal to 1.8 for the 2.5 MA range.

One caution that should be observed in using the milliampere ranges is to never connect the meter across any source of power. The reason for this is that the meter resistance is very small even with the shunt resistors in the circuit, and when connected across a source of power, excessive current can easily flow through the meter movement. In connecting the milliammeter in series with a circuit never connect both test leads into the circuit. This will avoid placing the meter across a current too high in value. Instead, touch one lead of the meter to one side of the circuit, then touch the other lead. If when the second lead is connected the needle swings over to full scale, the circuit can be quickly broken to prevent damage to the meter.

For example suppose you were

measuring the cathode current of the 12SK7 IF tube in Fig. 10. You would have to unsolder the cathode from ground so that the meter could be placed physically in series between cathode and ground. Then turn on the power and set the meter range switch to the 250 MA position. Touch the black test lead to ground and then touch the red test lead to the cathode pin (5) of the tube. The current through the tube must now flow through the meter and so the needle would be deflected. If the reading were less than 50 milliamperes then you could turn the range switch down to the 50 MA position and from there to a lower range. This would be continued until a satisfactory range were selected giving a reading somewhere near the center of the scale. Always remember to use extreme care in using the milliammeter ranges to prevent meter damage.

The 1000 Volt Range

To use the 1000 volt range of the multitester, it is necessary to move the red test lead from the *POS* to the *1000* volt tip jack. The circuit for this tip jack for both AC and DC ranges is given in lesson R-4. When this range is used, the internal switching circuit adds resistance in series with the meter. The red test lead is moved from the *POS* tip jack to the *1000* volt tip jack and the black test lead is left in the *NEG* tip jack. The voltage, either AC or DC is read using the 0 to 10 scale divisions. The reading obtained is multiplied by 100.

For example, suppose you wish to read a voltage of between 250 and 1000 volts DC. Set the range switch to the 250 volt DC position. Move the red test lead to the 1000 volt tip jack. The black lead is placed on ground and the red test lead is touched to the high voltage point. Suppose the needle comes to rest on the third small division between the 6 and the 8. The reading would be 6.6 times 100 or 660 volts DC. For an AC reading, set the range selector switch to the 250 volts AC range position and connect the test leads across the component to be measured. The reading is taken from the red AC scale near the top of the dial using the 0 to 10 numbers and multiplying the reading by 100 in the same manner.

Output Measurement

In adjusting the tuned circuits of radio and television receivers it is desirable to have some form of indicating device that will show the relative condition of the tuned circuits. This is provided for by the *OUTPUT* tip jack of your multitester. By moving the red test lead to the *OUTPUT* tip jack and taking the meter input from between the *NEG* and the *OUTPUT* jacks your multitester can be used as an output meter.

In measuring the output of a tuned circuit, the general procedure as you will learn in other lessons is to feed a signal of known frequency to the input of the circuit. As a stage of amplification is brought more nearly into resonance it will pass more of the resonant frequency which will result in a greater signal output. This greater signal output is measured by means of the output meter. In this way as a given trimmer condenser or tuning coil core is adjusted bringing the circuit in or out of resonance the reading on the meter will increase or decrease accordingly. There are several lessons (the TV series of lessons) in your course which treat this in detail. We shall not attempt here to try and include in one lesson the same information that is given in several other lessons. However, enough instructions will be given at this time to enable you to use the multitester should you find it desirable to make use of it to indicate the condition of a tuned circuit.

If you will examine the schematic diagram of your multitester given in lesson R-4, you will note that the *OUTPUT* tip jack is connected to the *POS* tip jack by means of a .1 mfd. condenser. If you take the input to the tester through the *OUTPUT* jack then this .1 mfd. condenser will serve to block the DC. In this way only the AC present in the circuit will be applied across the milliammeter and the switching circuit. The range switch is set to the 250 volt AC position. After the power is applied to the circuit, the range switch can be reset to give a reading as close to the center of the scale as possible. In this way you will avoid overloading the milliammeter.

As stated the reason for the .1 mfd. condenser is to block the DC that is present in the stage and allow only the AC to reach the milliammeter circuit. The test leads of the output meter are normally placed in between the plate of an amplifier stage and ground. At this point in a vacuum tube circuit there is usually both AC and DC present. For example, suppose that the plate of the 12SQ7 amplifier shown in Fig. 10 has 150 volts DC applied from the B+ source. When the circuit is conducting the plate voltage will vary above and below this 150 volt level at an AC rate. Suppose that the plate voltage was varying from 140 to 160 volts DC. The AC swing of the plate voltage is only 20 volts peak to peak (160-140) yet if an AC meter were connected from plate to ground, it would give a reading of about 156 volts instead of the true AC reading of about 7 volts. So if it is known that both AC and DC are present in a circuit then the output connections should be used.

The general procedure as you will learn in other lessons is to feed a signal to the input of the receiver. The signal source may be from a regular broadcast station in the frequency band from 550 to 1700 Kilocycles. However the preferred method is to use a signal generator and thereby feed a controlled signal of constant amplitude into the receiver. There are other variations of feeding an input signal to a receiver which will be covered in detail in other lessons. In aligning a superheterodyne radio the output meter is connected to the circuit and an input signal is applied. Tuning adjustments are made on the IF and RF stages which will cause the reading on the meter to increase to a maximum and remain at a constant value with a constant input signal. Thus one meter connection will serve while adjustments are made on the RF, oscillator and IF stages. The output meter will indicate the condition of tuning.

The meter may be connected in several different ways depending upon the adjustments to be made. If you wanted to measure the signal output of the 35L6GT stage of the circuit shown in Fig. 10, you would use the red test lead in the

-PUT tip jack of the multitest- and connect this lead to the plate of the tube. The black test lead in the NEG tip jack is connected to ground. Thus only the AC component of the signal present on the plate would register on the milliammeter and your reading would be an accurate measure of the output. As the tuning of the stages preceding the power output circuit is varied, the output reading on the meter will vary. In this way the tuning adjustments of the various stages can be set for maximum output.

The meter could also be connected to the grid of the 35L6 tube, however this is not commonly done. Another connection of the output meter that is commonly used is directly across the speaker voice coil. This connection will serve in cases where you do not have an output meter as no DC is present. Usually there are two solder terminals somewhere on the speaker frame to which the output meter leads can be easily connected.

It is important to use the proper meter range according to the way the output meter is connected into the circuit. In other words do not choose an output meter range which will not allow you to follow changes in the meter reading. If you should use a range that is too low, the meter will read off scale. If too high a range is used, small changes in meter reading will not be noticeable. It is best to use a high range first and then turn the switch down to a range that will allow the meter needle to read close to the center of the scale. The reading on the meter can be controlled to a great extent by the setting of the output control on the signal generator or by the setting of the volume control on the receiver under test. On your multitester, all of the AC ranges can be used when using the OUTPUT tip jack.

CONCLUSION

As you continue your work in the radio and television field, you will find that your multitester will become one of your most useful tools. This series of lessons was designed to aid you not only in constructing the tester but also in learning how it operates and how to use it. The Sprayberry multitester was designed to include certain functions as a result of much research and experience into the type of tester most needed by servicemen. Learn how to use each section well and you will be able to get the most good out of this instrument.

Part of learning how to use an instrument is learning how to take care of it. When using any electrical meter certain fundamental precautions are necessary. Current flow through the milliameter winding must at all times be 1 milliampere or less. Any condition that will permit more current than 1 milliampere to flow through the winding will either burn out the winding or severely damage the meter moving mechanism.

One common mistake made by many persons is to apply the test leads to a higher voltage than the range selector switch is set for.

For instance if the range switch is set for 10 volts and the test leads were applied to 100 volts or more, it will cause excess current to flow through the winding of the meter and would therefore damage it. To prevent this from happening to you, make it a rule to always use the highest possible range (1000 volts) when measuring an unknown voltage. Then turn the range switch to a position that will give as close to a center reading as possible.

Review the instructions for the various ranges and switch settings carefully so that you fully understand each function of the tester. In this way you will be able to get the most good and the greatest service from your test instrument.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. To what position should the resistor and condenser substitution switches be set when the main range selector switch is in use?

No. 2. List three uses of the resistor substitution section of the tester.

No. 3. Is it always possible to determine the condition of a condenser by visual examination?

No. 4. Are voltage measurements made in series or in parallel with the component being measured?

No. 5. What is the purpose of shorting the test leads together before taking a reading when using the Ohms scales?

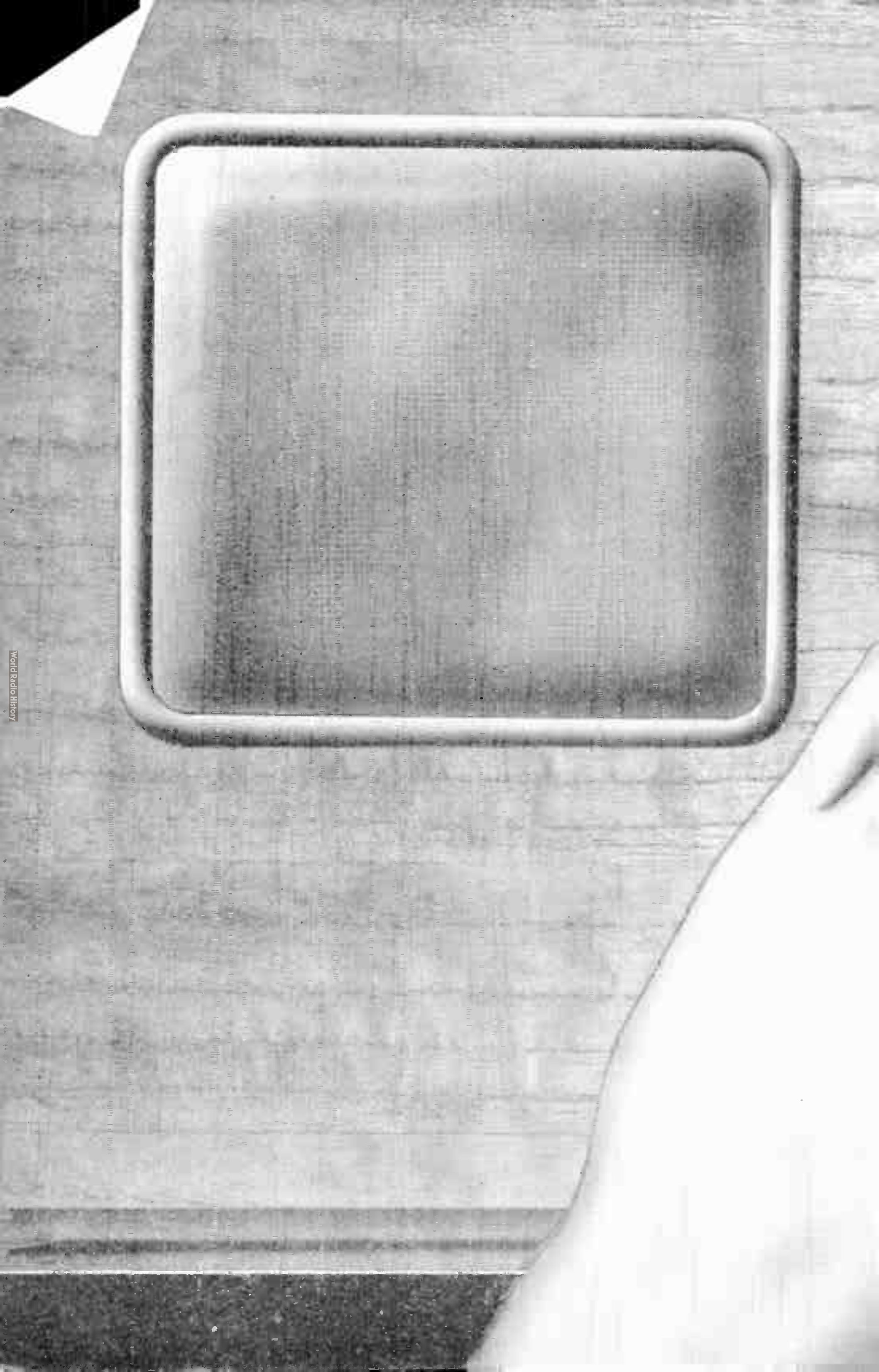
No. 6. When testing a unit for continuity, why is it best to disconnect one terminal?

No. 7. What is the difference between a static and a dynamic circuit test?

No. 8. Explain how you would test the filament of a tube for continuity.

No. 9. What is the purpose of the .1 mfd. condenser between the POS and the OUTPUT tip jacks?

No. 10. What precautions must be observed when using the milliammeter ranges?



DC CIRCUIT TESTING
RECTIFICATION—FILTERING

LESSON R-6

SPRAYBERRY
ACADEMY
of RADIO

ESTABLISHED 1932

CHICAGO, ILLINOIS

ACHIEVEMENT

There are many men whose names have gone down in history because of achievement. Some of these men were driven to their famous efforts by such things as desire for power, thirst for knowledge and search for riches. Many of them, however, reached fame through achievement for its own sake.

There is a certain satisfaction, which cannot be denied by anyone, in doing a job well. The more difficult the task, the greater the pleasure which can be derived from its successful completion. Such professions as music composition, painting and other artistic avocations, are noted for their famous members who had only one goal in sight as they worked all their lives at a few projects—this goal was achievement. They had a strong desire to paint, or to write and were willing to go to any extreme of hardship and effort in order to complete their work. Through heart-aches, illness and other misfortune, they drove onward, toward their goal.

So it must be with anyone who has a desire to make a mark in his community or in his country. Keep in mind always the adage "If a task is worth doing, it is worth doing well." You must begin at once to get yourself into the habit of achievement. Apply yourself diligently to your studies and know for yourself the wonderful feeling that comes from doing a job well.

O'B 9-55 2M

DC CIRCUIT TESTING
RECTIFICATION—FILTERING

LESSON R-6

You have learned in previous lessons how alternating current reacts on resistors and condensers; how to determine the approximate values of resistors and condensers with an incandescent lamp and a neon bulb; how to test low and high resistance circuits for continuity and the important, basic principles you used in circuit testing. Also, you have learned how to test speakers, gang condensers, trimmer and padder condensers, household appliances and other radio and electrical units using alternating current. Many practical uses for the neon bulb were demonstrated, including its use as a high voltage indicator, leakage indicator, tachometer, etc.

Alternating current has its limitations in circuit continuity testing of radio and electronic circuits which contain capacity, as the capacitive reactance will, *in effect*, pass AC. In tracing plate and grid circuits which contain condensers, for example, it is difficult to determine the values of high resistance units and voltage leakages unless you disconnect all condensers in these circuits. This requires considerable time and effort and will not ordinarily be necessary if you use direct current (DC) instead of alternating current. Also, in series circuits containing high values of inductive reactance, such as filter, speaker, and transformer circuits, your resultant indications using AC will be considerably lower than when using DC. These differences in indications between AC and DC in circuits containing inductive reactance have their definite advantages, however. If you test such a circuit first with DC, which will indicate its DC resistance, and then with AC, which will indicate its AC impedance, then the difference between these two indications will give you an approximation of the inductive reactance in the circuit. You can find shorted turns in filter choke coils by this method. Shorted turns will result in an increase in hum heard in the speaker. Also, distortion and low output in audio transformers can be caused by shorted turns in either the primary or secondary windings and low speaker output can result from shorted turns in the speaker field coil winding. Shorted turns in power transformers usually cause overheating of these units and are readily found.

You can see from this that testing with AC and DC has definite advantages for each method. When you combine the two methods, you can obtain further information concerning components in a circuit, especially capacitive and inductive reactances. Usually when you obtain indications in a circuit which are abnormal, you must disconnect each unit and test it separately in order to locate the defective unit.

Your Kit 6 contains the necessary parts which, when added to those you have already received,

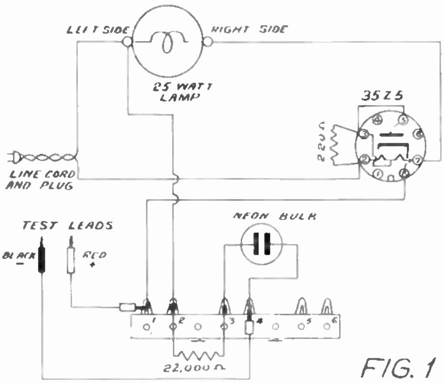


FIG. 1

will make it possible for you to construct an AC-DC resistance type half-wave rectifier, which will change the alternating current to direct current. With this demonstration kit you will be able to make circuit continuity tests on receivers, amplifiers, power units and other electronic devices; construct a relaxation oscillator; test paper and electrolytic condensers; show polarity; demonstrate electrolysis; locate and repair rectifier defects; test for breakdowns and leakages; test resistors, volume controls, etc.

This is good practice and prepares you well to make best use of your multimeter tester which you constructed in connection with your training units 3, 4 and 5. By making these tests first with lamps and a neon bulb you will learn testing techniques and thus will learn to properly use and protect your more expensive meter type tester. Remember, also, to carefully *observe* the results of your tests and demonstrations and to mentally compare the results with others you have observed.

DEMONSTRATION NO. 1

Assembling and Wiring the Rectifier

Your metal chassis was wired for low and high resistance continuity circuit testing, using AC, in your previous demonstrations of Lesson R-2. To convert it to an AC-DC rectifier, it should be wired according to Fig. 1. Remove the two test leads from terminals 1 and 2 on the terminal strip, by unsoldering the terminal contact tips. Lay the test leads aside for future use and so they will be out of the way while you are assembling and wiring the rectifier. Mount the octal tube socket in the hole provided in the top of the chassis which is between the incandescent lamp socket and the neon tube socket, toward the rear of the chassis. The other octal socket hole you will use for an amplifier tube in training unit 8.

Use the two 1/4 inch, 6-32 machine screws, 1/4 inch nuts and lock washers and mount the octal socket with its key toward the rear of the chassis. See Fig. 2 for the top and bottom views of the completed rectifier unit.

Remove the neon bulb from the circuit by unsoldering and removing the two wires which connect it to one terminal of the incandescent lamp socket (leave the line cord connected to this terminal) and to terminal 3 on the terminal strip. Next remove the 470,000 ohm resistors from between terminals 2 and 3 on the terminal strip and set them aside. Unsolder the wire from terminal 2 on the terminal strip, pull it through the hole in the top of the chassis, cut off about three inches on the end and discard this short piece. Solder the end of this wire to terminal 7 on the octal socket.

This wire now connects terminal 7 with the right hand terminal of the incandescent lamp socket. Next unsolder the end of the line cord from terminal 1 of the terminal strip, pull it through its hole on top of the chassis and connect it to terminal 2 on the octal socket. You now have only four soldered connections: to terminals 2 and 7 on the octal socket and to the two solder lug terminals on the incandescent lamp socket. The filament circuit is now complete and to test it, insert your 35Z5 tube in the octal socket by locating the pin in the base so it coincides with the keyway in the socket and press firmly into place. Then screw a *25 watt* lamp in the incandescent lamp socket and plug the end of the line cord into the AC outlet. The 25 watt lamp will light brightly and then dim down to about two-thirds brilliancy as the filament of the 35Z5 tube becomes hot. You will notice the tube filament will reach full operating temperature (a cherry-red color) in from 20 to 30 seconds. The 25 watt lamp permits just enough current to pass in the circuit so that the voltage drop across the tube filament will be approximately 35 volts. *Do not use any other size lamp except 25 watts.* A lamp with less power rating would not heat the filament of the tube sufficiently, while a larger lamp would permit too much AC current to pass through the filament in the tube and it would burn out.

Now that you have tested the filament circuit and found it to be correct, disconnect the line cord plug from the AC outlet and proceed with the remainder of the wiring. Solder your 220 ohm resistor, which you received in Kit 2, across terminals 2 and 3 on the octal socket. This helps to protect the filament of the tube and to equalize the current. Solder a short piece of wire between terminals 3 and 5 on the octal socket. This connects the plate of the tube to the filament tap and hence to one side of the AC line. Next solder a piece of hookup wire to terminal 8 of the tube socket, place it through the small hole in the top of the metal chassis which is directly under terminal 1 on the terminal strip (the left-hand terminal) and solder it to this terminal. Next solder a piece of hook-up wire to the left hand terminal of the incandescent lamp socket (to which you already have one end of the line cord soldered), pass it through the hole in the top of the chassis which is directly un-

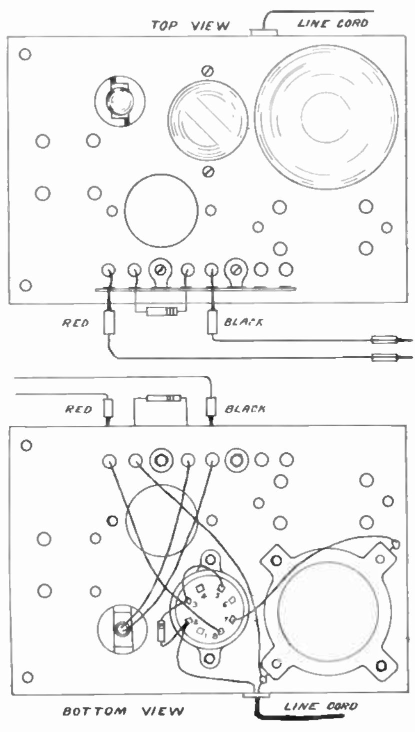


FIG. 2

der terminal 2 on the terminal strip and solder its end to this terminal. In making these soldered connections, it will be satisfactory to use temporary hook or lap joints, as you will be changing the wiring many times. Then solder your 22,000 ohm resistance between terminals 2 and 3 on the terminal strip; solder one lead from the neon bulb socket to terminal 3 on the terminal strip, (wiring through the holes in top of the chassis); connect the other lead which is attached to the neon bulb socket to terminal 4 on the terminal strip and, finally, solder the tips of your test leads to terminals 1 and 4 on the terminal strip. With your neon bulb, incandescent lamp and rectifier tube in place, your rectifier circuit is complete, with the exception of the filter. The 25 watt lamp protects the filament of the tube and the 22,000 ohm resistor protects the neon bulb from conducting too much current.

DEMONSTRATION NO. 2

Stroboscopic Effect with Pulsating Direct Current

Plug the line cord plug into the AC outlet and short your test leads together. In approximately 15 to 20 seconds the neon bulb will start to glow. This occurs when the filament of the rectifier tube has heated the cathode of the tube sufficiently so that it emits electrons. The electrons are attracted to the plate during the time it is positive (during the positive cycle of the alternation) and a current will flow through the tube, test leads, resistor and neon bulb. This results in raw, unfiltered, pulsating direct current in this circuit. Therefore, as there are sixty positive impulses per second in the 60 cycle alternating current, the neon bulb will flash off and on 60 times per second. As you have learned in Lesson R-2, this pulsating or intermittent glow from the neon bulb appears to be a continuous glow, due to the optical effect of the persistency of vision. In order that you may see these pulsations, you can do as in Lesson R-2, and take the tester in a darkened room and watch the reflections from the neon bulb on a moving object, such as a light colored pencil. Connect your rectifier to the AC outlet; short the test leads together so that the neon bulb will light; place a cardboard box or some other object over the 25 watt lamp, in order to further darken the room and to prevent its light from interfering with the test; then move a light colored pencil near the neon bulb, so you can see the reflection of the neon glow on the pencil. As you move the pencil back and forth, at varying speeds, you will see what appears to be several pencils, the number and distance apart of which will vary with the speed you are moving the pencil. This is the same stroboscopic effect you have observed when you conducted this demonstration with alternating current *except, you will note that the images of the pencil are twice as far apart* with the same speed of the moving pencil. In this way you can see the difference between 120 pulses per second, when you were testing with 60 cycle AC (60 positive and 60 negative alternations per second), and 60 pulses per second, when you are testing only when the plate of the rectifier tube is positive. In the next demonstration you will install a filter and these pulsations will be smoothed out, resulting in an even flow of direct current in the circuit, which will be without noticeable pulsations.

Another difference you will note between the AC and the DC effects on the neon bulb will be that, on AC both elements of the bulb will glow while on DC only one element (that connected to the plate, or *negative* side of the circuit) will glow. *Thus, your neon bulb can be used to indicate polarity* (to show which terminals in a circuit are positive and which are negative) and also to *indicate the difference between alternating and direct current.*

DEMONSTRATION NO. 3

Adding a Filter to the Rectifier

You have learned in your ND lessons that there are several types of rectifier filters; brute-force filters, which contain sufficient capacity and inductive reactance to smooth out the DC pulsations so an even flow of DC results; tuned filters, where an exact balance of capacity and inductive reactance result in a circuit which resonates to the DC pulsations, and resistance filters, which use condensers and a resistor. Variations of these filter types include condenser input filters, reactance input filters, etc. Each type has certain advantages, and disadvantages including efficiency, cost, voltage regulation characteristics, production and servicing aspects, etc. In a later demonstration you will construct a capacitive and inductive reactance filter, but for the present a resistance filter will demonstrate the principles of filters and will be the easiest to construct. Although the voltage regulation characteristics (lowering of output voltage with load) of a resistance filter leave much to be desired, this feature is unimportant when there is very little current drain on the filter circuit, such as when making circuit continuity tests with DC, operating a relaxation oscillator, etc.

Having disconnected your rectifier from the AC power source, you are ready to add a resistance filter to your rectifier. Mount the 20-20 mfd. electrolytic condenser on the front, inside panel of the chassis, by means of its bracket and one 1/4 inch machine screw, nut and lockwasher. Use the 1/8 inch hole you will find in the front panel of the chassis. The positive leads are connected to the *positive* plates of the condenser, inside its case, and the negative lead is connected to the 2 *negative* plates. *Always carefully observe polarity when connecting electrolytic condensers in a circuit.* A reversal of polarity will usually ruin the condenser and overload the tube and filter circuit, with resultant damage. You know that the negative electrons are attracted to the plate of the tube, therefore the plate circuit is negative in so far as the direct current pulsation flow is concerned (although the plate must be positive in order to attract the electrons). Therefore, solder the negative lead of your electrolytic condenser to the left hand terminal of the incandescent lamp socket. You already have two other wires soldered to this same terminal; one end of the line cord and the wire which connects to terminal 2 on the terminal strip. Solder one positive condenser lead to terminal 8 of the octal socket (the cathode). This adds 20 microfarads of capacity across the filter input. This condenser will increase the *no load voltage output* of your filter from approximately 90 volts (pulsating DC current) to somewhat less than 162 volts of partially filtered DC (115 volts RMS line voltage times 1.41 = peak-volts). You will note an increased brightness of your neon bulb when you short your test leads together, due to this increase of voltage. It is now necessary to rewire your chassis slightly, in order to complete the resistance filter. Unsolder and remove the test leads. Remove the 22,000 ohm neon bulb protective resistor from the terminal strip and set aside. Remove one neon bulb lead from terminal 4 and solder it to terminal 5 on the terminal strip. (Leave the other neon bulb lead soldered to terminal 3). Passing the remaining red condenser lead up through the hole in the chassis top, which is directly below terminal 3, solder it to this terminal. Now take the 2,200 ohm resistor which you received in Kit 2, and solder its leads on terminals 1 and 3. Then solder your 22,000 ohm resistor to terminals 2 and 4. Solder the tip of your test lead, which is fastened to the negative lead, to terminal 4 and solder the other test lead tip, which is fastened to the positive lead to terminal 5, see Fig. 3. The 22,000 ohm protective resistor is now in series with your neon bulb; you have the correct polarity on the test leads; the filter resistor and the other 20 mfd. condenser are wired in the circuit and the filter is complete. If you now perform demonstration 2 in a darkened room, you will note that the mov-

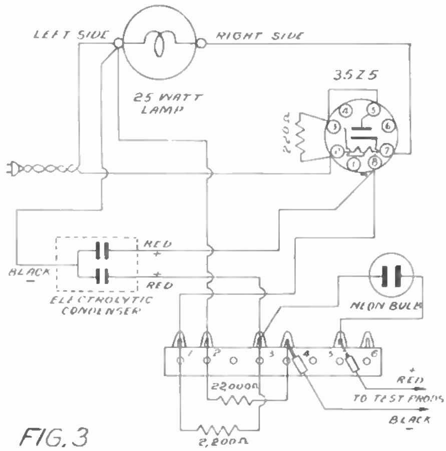


FIG. 3

ing pencil shows no variations in light intensity and the reflections on the pencil from the neon bulb form a solid band of light, which proves that the neon bulb is glowing steadily, without pulsations.

DEMONSTRATION NO. 4

Continuity Testing for Open Plate Circuits

You have learned in previous lessons that Radio-TV receiver circuit continuity testing, using alternating current, has definite limitations, due to condensers and inductances in the various circuits, which influence the alternating current and which may give misleading indications. This is particularly true where there are condensers in a circuit, as their capacitive reactance will, *in effect*, pass AC and the test results will indicate that a current is flowing in the circuit. This condition makes it difficult to test high value resistors, high resistance circuits, leakage in condensers, leakage in other parts and to give a true indication of circuit condition. These difficulties do not occur when you use direct current for continuity testing. Demonstrations 4, 5, 6, 7, 8, 9 and 10 offer practical suggestions for testing various circuits, using the direct current of Fig. 3 to operate the neon bulb. Note the circuits to be tested are not turned on or connected to the power line —only the test circuit of Fig. 3 has power applied to it. Using any available radio receiver chassis, test the tube plate circuits for open circuits as follows. Every plate circuit is subject to opens and many of them do open during the lifetime of a receiver. The open usually occurs in the plate circuit load, although it may occur in a voltage reducing resistor which feeds the plate circuit. Plate circuit loads consist of resistors, AF choke coils, RF and IF coils, IF coil windings and AF transformer windings. When they open, no voltage is applied to the plate of the tube, which means the signal circuit is interrupted and, therefore, no sound is reproduced. The open condition is to be suspected when you find there is no voltage applied at the tube socket plate terminal. This may be confirmed by use of the neon bulb circuit of Fig. 3 when one test lead is touched to ground and the other test lead is touched to the tube socket plate terminal and then to the high voltage source of supply, which may be the cathode of the rectifier tube, the positive lead of the electrolytic filter condenser or the filter choke coil terminals. If the neon bulb shows no indication, you have an open some place in this plate circuit. By progressively testing each of the units in the circuit, the open will be found. It may be a poor connection, an open winding in a RF, IF, detector or audio amplifier coil, an open resistor or, in fact, an open in any unit of the complete plate circuit.

You can simulate open plate circuit conditions in any receiver by disconnecting the wires at the plate terminals of the tube sockets. Note that this interrupts the circuit completely. Do this and make a test to prove that the continuity of the circuit has been disrupted.

DEMONSTRATION NO. 5

Testing for Shorted Plate Circuits

Plate circuit shorts are, in a majority of the cases you will find, a condition wherein the plate circuit becomes grounded—that is, some part or wire has come into direct or indirect contact with the receiver chassis or a metal object at ground potential, or else a part has its insulation or dielectric broken down or punctured, which allows the current to flow to ground and creates a short circuit. A plate circuit exposed lead can be shorted or grounded (probably due to accident) to another part of the circuit, and then give the effect of a direct short. The most common cause for this defect is a by-pass or filter condenser puncturing (a short circuit through its dielectric, from one plate element to the other plate element) and thus result in a short circuit between the B+ voltage and ground or to the metal chassis. If the puncture of the dielectric is complete from plate to plate of the condenser, which will form a circuit of little or no appreciable resistance, the plate circuit becomes fully shorted or shunted away from the plate terminal at the tube socket. If the puncture of the dielectric is partial, it will form a parallel path of considerable resistance and the voltage at the plate of the tube will be reduced in proportion to the amount of resistance formed by the partial short circuit. Regardless of whether the condenser is completely or only partially shorted, it must be identified as such and then replaced with a suitable new condenser.

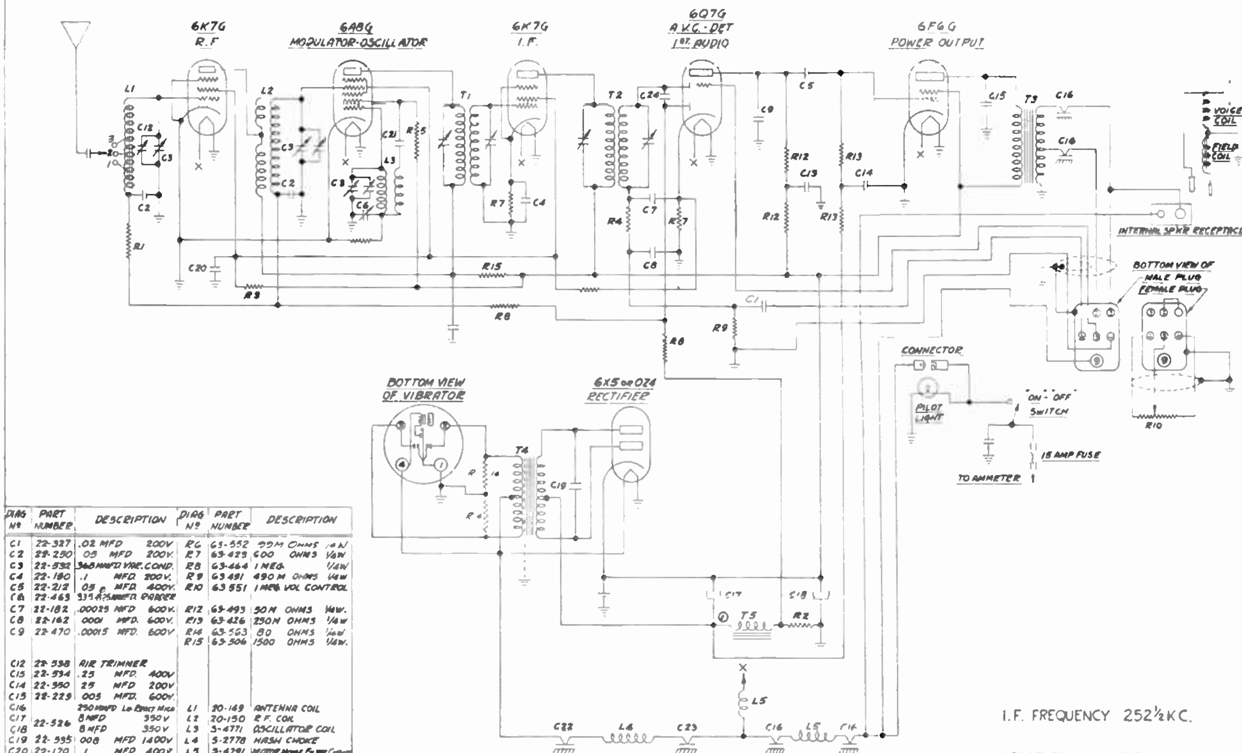
A quick test at the plate terminal of each tube socket will show up a direct or partial short circuit. In almost all receivers there is a single lead, or connection, which supplies the B+ circuit from the output of rectifier filter. *With no power applied to the receiver being tested,* disconnect the plate circuit at the high voltage source and then test with your neon bulb and test leads, from ground to each part of the plate circuit. Check each bypass blocking or filter condenser, disconnecting from the rest of the circuit, if necessary. Usually it will be necessary to disconnect only one of the condenser leads in making this test. In testing the electrolytic condensers in the filter circuit, be certain that you are placing your positive (red) test lead on the positive electrode terminal of the condenser and the negative (black) test lead on the negative terminal. (See Demonstration 16 for further information on testing electrolytic condensers). A shorted paper, mica or plastic dielectric type condenser will cause your neon bulb to glow brightly; an open condenser will show no effect; a partially shorted condenser will cause the neon bulb to glow with a degree of brilliancy which will be proportional to the degree of the short circuit or leakage, and a condenser which is correct will cause the neon bulb to flash when you first touch your test leads to its terminals (when the condenser is first charged) and then show no further effects, no matter how long you hold the test leads on its terminals. An open resistor will cause no indication of the neon bulb, while a resistor which is of the correct value will cause the neon bulb to glow in proportion to its resistance.

Remember that during these tests, there is no power applied to the receiver. It can be seen from these test principles that shorts in plate circuits can be located by means of your neon bulb by checking the circuit as a whole and then testing each individual part until the defective unit is located. You should observe the neon bulb circuit is merely acting as a type of ohmmeter. You may of course make these same type tests with your ohmmeter. For more information on similar neon bulb tests see your lessons R-2 and 1-R1.

DEMONSTRATION NO. 6

Testing for Open Grid Circuits

When reference is made to a grid circuit, the signal or control grid is usually referred to. It is the grid on which a negative bias voltage is usually applied. This grid circuit extends from the usual control grid connection at the tube socket, through the grid load (usually a coil or a resistor), back to B negative or ground. In RF and IF stages, this usually includes AVC filter resistors, such as R1 and R8 of Fig. 4. Before it gets back to ground or B negative, it may go through one or more bias resistors, such as R2 of Fig. 4. In other cases, the grid circuit connects to ground after it leaves the load. The grid return of the 6A8G and the 6K7G (IF) in Fig. 4 are examples of this type of circuit. The 6F6G grid return in Fig. 4 is an example of a more complex circuit. Here, the path of the circuit is through T5, R13 and R2 before ground is



DIAG Nº	PART NUMBER	DESCRIPTION	DIAG Nº	PART NUMBER	DESCRIPTION
C1	22-327	.02 MFD 200V	R6	63-552	99M OHMS 1/4W
C2	22-250	.05 MFD 200V.	R7	63-423	600 OHMS 1/4W
C3	22-532	360 MMFD VAR. COND.	R8	63-464	1 MEG. 1/4W
C4	22-180	.1 MFD 200V.	R9	63 491	490 M OHMS 1/4W
C5	22-212	.05 MFD 400V.	R10	63 551	1 MEG VOL CONTROL
C6	22-463	339.4 MMFD PADDER			
C7	22-182	.00025 MFD 600V.	R12	63-493	50 M OHMS 1/4W.
C8	22-162	.0001 MFD. 600V.	R13	63-426	250 M OHMS 1/4W
C9	22-470	.00015 MFD. 600V	R14	63-563	80 OHMS 1/4W
			R15	63-506	1500 OHMS 1/4W.
C12	22-538	AIR TRIMMER			
C15	22-534	.25 MFD. 400V			
C14	22-550	.25 MFD 200V			
C15	22-229	.005 MFD. 600V.			
C16		250 MMFD Lo Effect Mica	L1	20-149	ANTENNA COIL
C17	22-526	8 MFD 350V	L2	20-150	R.F. COIL
C18	22-526	8 MFD 350V	L3	S-4771	OSCILLATOR COIL
C19	22-535	.008 MFD 1400V	L4	S-2778	HASH CHOKE
C20	22-170	1 MFD 400V	L5	S-4791	MOTOR Noise Filter Choke
C21	22-82	.001 MFD 600V			
C22	22-539	.5 MFD 200V			
C23	22-468	.5 MFD 200V			
C24	22-289	.00005 MFD 600V			
			T1	95-392	1ST I.F. TRANSFORMER
			T2	95-393	2ND I.F. TRANSFORMER
			T3	95-397	OUTPUT TRANSFORMER
			T4	95-390	POWER TRANSFORMER
R1	63-550	240 M OHMS 1/4W	T5	95-396	POWER CHOKE
R2	63-557	60 OHMS 1/4W			
R3	63-494	13 M OHMS 2W		190-9	VIBRATOR
R4	63-490	48 M OHMS 1/4W		49-170	DYNAMIC SPEAKER
R5	63-512	18 M OHMS 1W			

FIG. 4

CHANGES ON 6M 92

Item	Description	Date
A	[illegible] .00025 [illegible] 22 4 [illegible]	[illegible]
B	Taps Raised	[illegible]
C	Resistor Added (R2)	[illegible]
D	Resistor Added R6	[illegible]
E	Connection Shown	[illegible]
F	2nd 22-468 [illegible]	1-8-37

I.F. FREQUENCY 252½ KC.

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reached. Regardless of the circuitous route that a grid circuit may take, it is subject to opens, and a test of its entire length must be made to establish continuity.

Since the voltage of most grid circuits is low and the resistors are of high values, it is best to test the continuity of the circuit rather than attempting a voltage test. To make this test, use your direct current neon bulb continuity tester in the usual way; with the tester plugged into the 115 volt house current and the 22,000 ohm resistor, neon bulb and test leads in series. Then using Fig. 4 as an example, place one test lead on the control grid of the 6K7G RF tube and the other one to ground. If the neon bulb lights, it proves that you have circuit continuity through L1, R1, R8 and R2. A test from the control grid of the 6A8G tube to ground would give a test over the same circuit but would omit L1 and R1 and include the secondary winding of L2. A test from the 6K7G IF tube control grid to ground would check the continuity of the secondary of T1. The 6Q7G tube includes the diode plates. A test from one plate to ground would test the continuity of the secondary of T2, R4 and R9, while a test from the other diode plate would check R8 and R2. For the control grid of the 6Q7G tube, a test from it to ground would indicate the continuity of R10. The remaining control grid circuit of Fig. 4 is for the 6F6G tube. A test from it to ground would indicate the continuity of the two R13 resistors, T5 and R2. The continuity of all other control grid circuits for other radio receivers would be tested in a like manner. Merely test from the control grid to ground and then examine the diagram of the receiver or trace the actual wiring to see just what units are included in the tests.

Now consider cases where *no continuity* is indicated. No matter what kind of control grid or diode plate circuit is involved, the procedure is the same in every case. No light of the neon bulb means that at least one of the units in the control grid circuit is open. To determine which one is open, merely place your test leads across each unit in the control grid circuit. For example, consider the control grid circuit of the 6K7G RF tube in Fig. 4. To find out which one of these units is open, first test across L1, then R1, next the two R8 resistors and finally test across R2. Testing across a unit merely means placing one test lead on one terminal or lead of the unit and placing the other test lead on the remaining terminal or lead of the unit. If an open were previously indicated for the entire circuit, then a detailed test, unit for unit, in the circuit, as outlined, will indicate which unit is open. A light of the neon bulb means the unit has continuity, no light means it is open.

There is one other precaution you must observe when testing the continuity of control grid circuits to ground. That is, you must not let a shorted condenser deceive you. For instance, consider condensers like C2, C7 and C8 of Fig. 4. If they become shorted (which can happen, but rarely does) then the remaining part of the circuit is also shorted. Thus, you may get an indication of continuity, which will be true, *yet it will be through the shorted* condenser. This automatically omits a test of the remaining part of the circuit, which is shorted out due to the condition of the condenser.

Since these and similarly connected condensers are in reality in shunt (parallel) to the control grid circuit, the neon bulb is going to light to a certain degree because of the shunt path. *Make it a rule, therefore, to disconnect all condensers which shunt a circuit before you test it for continuity.* Note you can make these same tests with your multimeter by using its ohmmeter ranges in place of the neon bulb.

DEMONSTRATION NO. 7
Testing for Open Coupling Condensers

A coupling condenser is one connected between the plate of one tube and the grid of the following tube. Its purpose is to transfer the signal from one stage to another. There are two such condensers in Fig. 4—which are C1 and C5. C1 couples the signal from the diode load circuit to the triode grid of the 6Q7G tube. C5 couples the signal from the plate of the 6Q7G to the control grid of the 6F6G power output tube. Condensers of this type are very critical in operation and very little leakage can be allowed. If excessive leakage develops, distortion is certain to be present, and the grid voltage of the tube following the coupling condenser will be affected. These condensers may also develop *opens*, resulting in no signal, or there may be an intermittent type of defect, with the signal starting and stopping for no apparent reason. In this case, the DC voltage throughout the receiver is not likely to be affected. This type of defect can be very elusive because no outward clues are usually present. So, when you observe the general symptoms as outlined, be sure to test the coupling condensers.

To determine the condition of coupling condensers with your neon bulb continuity tester, proceed as you would when testing any paper dielectric condenser—a small initial flash of the neon bulb when you first touch your test leads to its terminals indicates that the condenser is not open and that it is taking a charge; any continuing glow of the neon bulb indicates that the condenser is either shorted or is leaking, and it should be discarded. By carefully observing the neon bulb, therefore, in making this test, you can determine if the condenser is open, shorted, or has an internal resistance or leakage. In cases where the condenser is of small value (of low capacity) and the initial charging current is so small that the neon bulb flash is difficult to observe, you can first touch the condenser leads with your test leads, then reverse the test leads and touch the condenser leads again. This will increase the brilliancy of the neon flash so it will be easier to see.

You should observe that if an ohmmeter is used instead of a neon bulb—a reading means a short—no initial charging current usually means an open condenser.

DEMONSTRATION NO. 8
Testing for Grounded Circuits

The distinction between a grounded circuit and a short circuit is not very clear. Many times both terms are used to denote the same thing. For instance, if the screen grid by-pass condenser C20 in Fig. 4 punctures through from one set of plates to the other, these plates become shorted and the screen grid circuit becomes grounded through the shorted condenser. Thus, there is both a short circuit and a ground. Either term, therefore, would describe the same condition.

What you will be most interested in here is a direct ground not involving a short circuit, such as that of a condenser. A direct ground can be caused where a tube socket terminal touches the metal chassis; where a coil terminal, gang condenser terminal or other parts touch or come in contact either with the chassis or some other metal part. Such grounds are usually accidentally caused by moving the wiring or are brought about by expansion caused by heat. Then, again, a small piece of solder or short length of wire or metal can work itself under a terminal, due to vibration or movement of the chassis, and so short the terminal to the chassis.

Where you have reason to believe such a ground exists (where, for instance, there is no plate or screen grid voltage on a tube, and you have proven that there are no opens or shorts), then make a check for grounds. To do this, disconnect the terminal under suspicion from its normal connection or connections, and then make a continuity test between the terminal and the ground. A light of the neon bulb indicates that the terminal under test is grounded. Be careful in making this test to see that a parallel path to ground does not exist, and in that way indicate a grounded circuit where none really exists. Sometimes you can make a visual test of a terminal under suspicion and determine if it is grounded. This would be particularly true for a tube socket, solder lug, coil or switch terminal.

DEMONSTRATION NO. 9

Testing for AVC Circuit Defects

The automatic volume control circuit in all radio receivers is a delicately balanced system. It consists principally of a network of resistors and condensers, usually starting at the diode load and ending at the grid returns of one or more tubes. The AVC action is based upon the time constant of a combination of resistors and condensers (an RC circuit). These units are subject to opens and shorts, and should have values reasonably near those called for by the diagram. The condensers, particularly, should be in excellent condition and have very little leakage. An AVC circuit with incorrect values usually causes oscillation and reproduction in general is distorted. When this circuit is seriously interrupted, due, for instance, to an open resistor or shorted condenser, there will be no AVC action. Fading will be more noticeable and there will be blasts or increases in volume from the speaker.

Whenever AVC defects are suspected, a detailed check should be made on every part of the AVC system, including the tube which develops the DC voltage which operates the system (usually a diode or the diode section of a multi-element tube). In a circuit similar to that shown in Fig. 4, where the diode plates are involved, the AVC circuit consists of the filter resistors R8 and R1, and their filter condenser C2 in one branch, and the other R8 resistor and C2 condenser in another. In other AVC systems, the diode load resistor and its associated condensers will probably be a part of the AVC system. Regardless of the arrangement, all condensers and all resistors should be carefully tested. Use your neon bulb circuit continuity tester to check these circuits, just as you would test other resistors and condensers.

DEMONSTRATION NO. 10

Testing Tube Filament Circuits For Continuity

A common defect found in AC-DC receivers is burned out or open filaments of vacuum tubes. Since pilot lights, line resistor cords and voltage regulators (ballast resistors) are often in series with filament circuits, these also may be considered to be a part of the filament circuit. Thus, when tubes fail to light in an AC-DC radio receiver, one of the first things you want to check is the possibility of an open. This test may be easily made with your neon bulb tester and the defect traced to its exact position in the series circuit. To make this test, disconnect the receiver to be tested from the power line. Then turn on its switch and test across the terminals of the line cord plug. If the neon bulb lights, there is no open (assuming there are no parallel circuits in the receiver), but if it does not light, you may be certain that there is an open somewhere in the circuit. To find it, test one element of the circuit at a time, including the switch and ballast or line cord resistor. First test the line cord, then the ballast, next the switch, then the pilot light and pilot light circuit and, finally the tubes and the tube sockets (for poor contact). To test the pilot light and ballast resistor, all you have to do is to touch the ends of your test leads across their terminals—no light of the neon bulb means you have found an open.

To test the tube filaments for continuity, remove them from their sockets and apply your test leads across their filament pins (the exact number on the pins will depend on the tube type). No light of the neon bulb means that the filament is burned out and the tube should be replaced with a new one. In making this check, be sure your test is made across the proper terminals, because their pin numbers and locations on the tube base vary for different types of tubes. You need not be concerned about the high voltage (115 volts) used to test the tube. The resistor (22,000 ohms) and the resistance of the neon bulb will limit the current flow, so no damage will be done to the filament.

Occasionally you will find a tube filament which will be intermittently open. The filament will be burned out and have an open circuit but the burned ends will be touching and making contact when the tube is cold. When the receiver is turned on, the filament will heat and expand, causing the burned ends to separate, due to the thermal expansion of the filament. This causes an open circuit—the filaments cool, contract and again the broken ends touch and the cycle is repeated. To find this kind of defect, convert your neon bulb continuity tester to measure voltage.

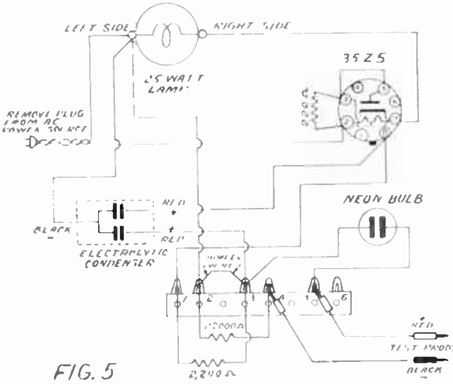


FIG. 5

as you did when performing demonstration 6 in Lesson R-2. The easiest way to do this is to take your neon tester, just as you now have it wired and connected as a rectifier, disconnect it from the AC power outlet (by pulling the line cord plug from the receptacle) and solder a short jumper wire between terminals 2 and 3 on the terminal strip. Your neon bulb will now glow when the test leads are connected to a scource of voltage (over 90 volts, either AC or DC). See Fig. 5.

To find an intermittent filament in a receiver, operate the receiver in the regular way and place your test leads across the filament terminals of each tube socket, in succession. If the filament is constantly continuous, your neon bulb will not light but if it becomes intermittently open, your neon bulb will light each time the filament opens, as the full 115 volt AC current will flow through your test circuit. After making this test, *remove the wire jumper from between terminals 2 and 3* and your tester will be as it was before, supplying DC for testing.

DEMONSTRATION NO. 11

Constructing a Neon Bulb Relaxation Oscillator

A neon relaxation oscillator is very easily made and has many practical uses. Figure 6 shows the schematic diagram of one type of relaxation oscillator. Its theory is simple: the direct current from the rectifier tube and filter charge the condenser C1 through resistors R and R1. When the voltage across C1 rises high enough so that the gas in the neon bulb is ionized, the condenser discharges through the neon bulb, which glows momentarily as the condenser discharges down to the critical voltage point of the neon bulb. After the neon bulb ceases to conduct the current, resistors R and R1 start to charge condenser C1 again and the cycle of charge and discharge is repeated. This results in a continuous flashing on and off of the neon bulb, the rate of which is dependent upon the supply voltage, the values of the resistor and condenser in the circuit and the resistance and flash (ignition) characteristics of the neon bulb used. A wide range of frequencies can be obtained from this method. One of many practical uses for this type of oscillator is to supply saw-tooth wave patterns for cathode ray oscilloscopes.

To construct a simple neon relaxation oscillator proceed as follows: Unsolder your test lead tip from terminal 4 on the terminal strip and solder it to terminal 3. Then solder the 15 megohm resistor, which you received in Kit 2, between terminals 4 and 5. Your completed circuit will be similar to Fig. 6. After the filament of the rectifier tube has heated the cath-

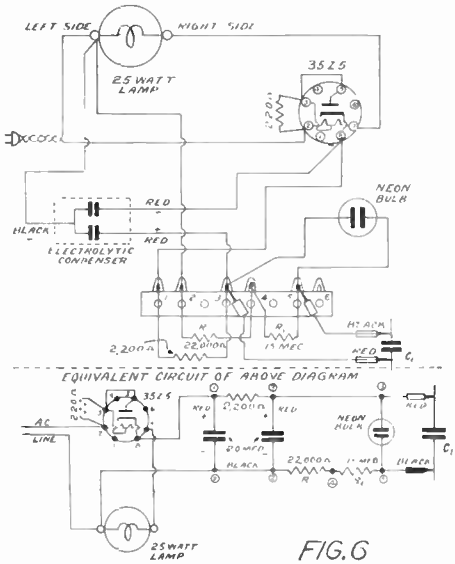


FIG. 6

ode sufficiently (in about 20 to 30 seconds) rectification of the AC begins and the DC voltage rises to its full value. You will notice one element of the neon bulb glows faintly. This is due to a small amount of current passing through the 22,000 ohm protective resistor and the 15 megohm resistor which you have just added to the circuit. Now touch your test leads across the leads of various size condensers. With a .25 mfd. condenser the neon bulb will flash approximately once every second; a .1 mfd. condenser will discharge a little faster than twice per second; a .05 mfd. condenser will cause the neon bulb to flash off and on about four times per second; a .02 mfd. condenser eight times per second; etc. A .0036 mfd. condenser will cause flashes in such rapid succession that each individual flash is barely discernable, while smaller capacities will cause the neon bulb flashes to appear as a continuous glow. If you connected headphones in series with this circuit you could hear audible frequencies. By replacing the 15 megohm resistor with a resistor of lower value, you will obtain the same results but, due to the fact that more current will flow through a lower value resistor in a given time, the condensers will charge and discharge faster and the neon bulb will flash on and off faster. Now solder a 2.2 megohm resistor and a 3.3 megohm resistor in series across terminals 4 and 5. This will give you a total resistance across these terminals of 5.5 megohms. Try various sizes of condensers with this value of resistance and note the frequency your neon bulb flashes.

Several important conclusions can be made from the results of these experiments. One is that *you can determine the approximate capacity of any condenser from a large value to .0035 mfd. capacity by noting the frequency of the neon bulb flashes.* Another important conclusion is that you can determine *open condensers* and *leaking condensers.* Neither an *open* condenser or one with *high or low internal* resistance will cause the neon bulb to flash. Therefore, this test is an effective check of the overall condition of condensers.

Another circuit arrangement of a neon relaxation oscillator is to connect (solder) your test lead tips to terminals 4 and 5, on the terminal strip (as you had them connected in Demonstrations 3 to 10 inclusive) and leave the 15 megohm resistor across these same terminals. Your wiring will then be as shown in Fig. 7. In this circuit, the neon bulb which charges the condenser you are testing across

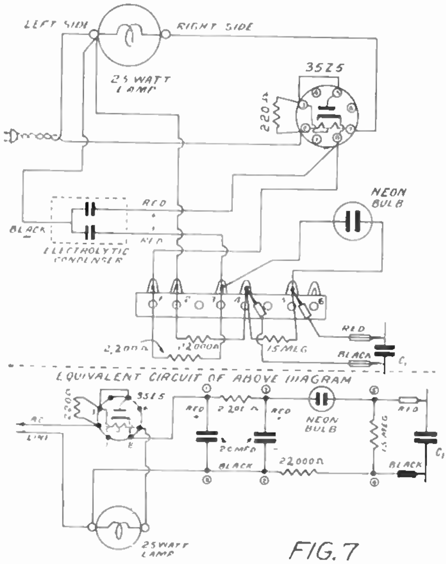


FIG. 7

your test lead terminals by the current flowing through it, will flash each time the condenser discharges through the resistor and lowers the voltage sufficiently so the condenser can be charged again. In other words, the condenser receives an initial charge of current through the neon bulb; this charge gradually leaks through the 15 megohm resistor until the voltage across the condenser is reduced to such a value that it will take another charge from the current passing through the neon bulb, which will cause the neon bulb to again flash. This method of testing condensers is not as satisfactory as the one described in the first part of this demonstration, as a leaky condenser (one with internal resistance between its plates) will cause the neon bulb to do one of two things, depending upon the degree of internal short. The neon bulb will either glow continuously or will flash off and on at a greater rate than it should with a given value of capacity and, therefore, indicate erroneously. However, this circuit has its uses, as you will see in later demonstrations.

By working with and experimenting with condensers, resistors, wiring, etc., you are becoming familiar with simple, basic circuits, which will be of great assistance when you are tracing and analyzing more complex and involved circuit diagrams.

DEMONSTRATION NO. 12

Neon Code-Practice Oscillator

Many radio technicians wish to study the International Morse Code, in order to pass the Government Examination for amateur or commercial radio operator's license. As this is code made up of dots and dashes from a continuous tone, your neon relaxation oscillator can furnish the tone signal required. To obtain a tone of approximately 400 cycles, use the circuit arrangement you used in the last part of Demonstration 11, and connect your rectifier and circuit tester as in Fig. 7. Replace the 15 megohm resistor with a 2.2 and 3.3 megohm resistor connected in series, across terminals 4 and 5. Then connect a .002 mfd. condenser in

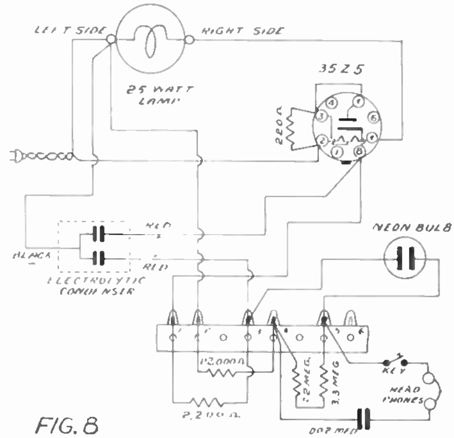


FIG. 8

series with your practice key and headphones. See Fig. 8 for the wiring diagram. Every time the key is depressed, you will hear the 400 cycle tone in the headphones. Two keys and two headphones may be connected in series with this circuit so two persons can practice together. The addition of the other set of headphones will lower the tone of the oscillator very lightly, due to addition of inductance and resistance in the circuit. This can be compensated for by either using a smaller value condenser or a somewhat lower value of resistor (not less than 3.3 megohms) in place of the 5.5 megohm resistance. As the circuit is closed, the appearance of the neon glow will be changed and this can be watched as the code is practiced and thus coordinate visual as well as audible practice, as explained in Lesson R-2. To amplify this signal practice tone, you can connect this circuit to the audio amplifier section of your home receiver. In a later lesson you will construct an audio amplifier, complete with permanent magnet speaker, and this can be used in conjunction with your oscillator code practice circuit.

DEMONSTRATION NO. 13

Testing Resistors on Direct Current

You have tested resistors using alternating current, in a previous demonstration, and have determined their approximate values, within limits, by comparing the degrees of brilliancy of the neon bulb and incandescent lamp when the resistors were connected in series with the lamps.

The same effects can be obtained by testing on DC. Wire your circuit as in Fig. 7, except that you remove the 15 megohm resistor from between terminals 4 and 5. See Fig. 3. Place the terminal leads of the resistors across your test leads and observe the degree of brightness of the neon bulb glow. The 22,000 ohm protective resistor, as well as the 2,200 ohm filter resistor are in series in the circuit, so shorting the test leads together will produce the maximum degree of neon bulb brilliancy possible with these resistors in the circuit. The bulb will glow somewhat brighter with a given resistor when making this check on DC than it did on AC, as you are using a higher voltage. Using the resistors supplied with your kits, you will note the following results as shown in the table on page 18.

It can be seen from this data that the value of a resistance can be estimated, within limits. A more accurate method would be to compare the appearance and degree of brightness of the neon bulb when testing a known value of resistance with a resistor of unknown value. For example, if you have a resistor and you wish to find its resistance, connect your test leads across its terminals and observe the neon bulb. Then, using various sizes of resistors of known value, select one which will give the same degree of neon bulb glow and appearance. Then this resistor will be approximately the same resistance as the unknown resistor. Of course, this method is not nearly as accurate as the use of a high grade ohmmeter, but it will be of value to you in case an ohmmeter is not available.

Resistance	*Appearance of Neon Bulb*
15 megohm	Very faint gas glow—covering one end of one element.
5.5 megohm (3.3 megohm and 2.2 megohm in series)	Same as above—except approximately twice as bright.
3.3 megohm	Glow brighter—covering one-third of one element.
2.2 megohm	Glow covering one-half of one element.
940,000 ohms (two 470,00 ohm resistors in series)	Glow covering two-thirds of one element.
470,000 ohms	Glow covering one element—about twice as bright as for 2.2 megohm.
235,000 ohms (two 470,000 ohm resistors in parallel)	Glow entirely covering one element. One-third of full brightness.
40,000 ohms	Two-thirds of full brilliancy.

DEMONSTRATION NO. 14

Testing Condensers on Direct Current

In previous demonstrations, you have tested condensers by two methods, with AC and with DC with your neon bulb relaxation oscillator. A third useful method, which determines capacity and the resistance leakages of paper and mica dielectric condensers will prove to be of value to you. This method is based on the fact that a certain capacity of condenser will store up and hold a certain amount of electricity at a fixed value of voltage and this stored electricity will take a definite time to flow through a known resistor. By taking advantage of this fact, you can determine the capacity of a condenser by charging it, then discharging it through a resistor and noting the time of discharge. The time of discharge will be proportional to the capacity, other conditions being equal.

To test condensers by means of this charge-discharge method, change the wiring of your neon bulb tester as follows: unsolder and set aside the 22,000 ohm protective resistor. Unsolder the tip of the test lead from terminal 4 on the terminal strip and solder it to terminal 6. Then disconnect the lead, which runs to one terminal of the neon bulb socket, from terminal 3 and solder it to terminal 4. Lastly, solder a 15 megohm resistor between terminals 4 and 6. See Fig. 9. To charge a condenser, place its terminal leads on terminal lugs 2 and 3. To discharge it, remove it from the terminal lugs and hold your test leads on its two leads. The neon bulb will glow faintly and continue tc do so until the condenser voltage charge has dropped below the ignition point of the neon bulb. By timing the length of time this glow is visible, you can determine its capacity.

Taking the condensers you have received in your kits, test them for

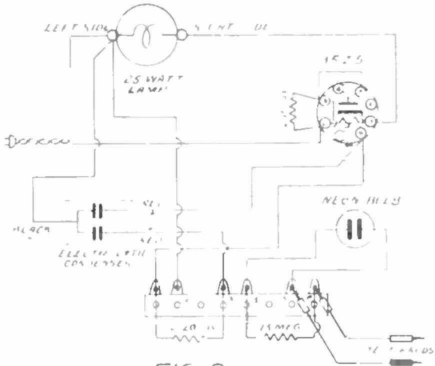


FIG. 9

capacity and compare the results with the following data:

Capacity	*Approximate Time of discharge*
.25 mfd.	15 seconds
.1 mfd.	7 seconds
.05 mfd.	4 seconds
.02 mfd.	2 seconds
.004 mfd.	1 second
.002 mfd.	¾ second
.0005 mfd.	brief flash
.00025 mfd.	very brief flash

It can be seen from this data that the time of discharge is proportional to the capacity. This is a very important fact and one to be remembered when you are dealing with resonance and time constants in inductive and capacitive circuits which also contain resistance. The condensers are not completely discharged, only from a full charge of approximately 160 volts, down to approximately 65 volts. This degree of discharge with time gives a close indication of capacity. Other values of resistors may be used instead of the 15 megohm resistor—the time of discharge of the condensers under test being directly proportional to the resistance used. Try a 3.3 megohm, a 2.2 megohm and a 470,000 ohm resistor in place of the 15 megohm resistor and note the variations in times of discharge.

DEMONSTRATION NO. 15

Experiments with Electrolysis and Polarity

You have demonstrated how your neon bulb indicates polarity due to the fact that only the *negative* element will show a gaseous glow when the lamp is connected to a direct current. Several improvised and extemporaneous methods may also be used to indicate polarity in case you do not have a direct current voltmeter available. One crude, but effective method, is to connect your direct current source to two copper wires. Place the bare ends of these wires in a cup or dish of water. Pure water is an insulator but, as it is very difficult to obtain absolutely pure water, due to dissolved gases, salts and other substances, some conduction of current will take place between the ends of the two copper wires. Due to the electrolysis effects, the water, which consists of two hydrogen atoms and one oxygen atom per molecule, becomes ionized and the positive hydrogen ions are attracted to the negative wire and the negative oxygen ions are attracted toward the positive wire (unlike charges attract each other). Therefore, you will observe small bubbles of gas coming off of both wire ends. *Twice* as much gas (hydrogen) comes off of the negative wire as does gas (oxygen) from the positive wire. Therefore, you can determine which wire is positive and which is negative by observing the amount of gas created. To increase the amount of gas in this experiment, and thus make identi-

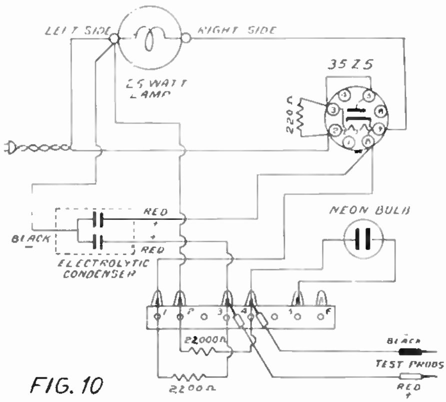


FIG. 10

fication of the positive and negative wires more certain, a small amount of common table salt may be dissolved in the water you are testing with. This decreases the resistance of the water considerably, by the formation of sodium and chlorine ions, and more current will flow through the solution, which will result in the formation of more gas bubbles.

To make this electrolysis polarity test, it is necessary to revise the wiring of your rectifier tester slightly. Wire your tester in accordance with the diagram shown in Fig. 10. Remove the 15, 3.3 or 2.2 megohm resistors you used in demonstration 14, from terminals 4 and 6 on the terminal strip; replace the 22,000 ohm protective resistor by soldering its leads to terminal lugs 2 and 4 and lastly, solder the *positive* test lead tip to terminal 3 and the *negative* test lead tip to terminal 4. The neon bulb is out of the test circuit completely, as you will not use it in this demonstration. You now have the full DC voltage from the rectifier available at the test leads and you can make the electrolysis polarity test. The 22,000 ohm protective resistor is in series with the test leads, so a direct short of these leads will not damage the rectifier. *If the test lead ends are shorted together even for a short time, this resistor will overheat and be damaged.*

Another simple test for polarity is to insert the ends of your test leads in a piece of freshly cut potato—the test leads to be about one-half to one inch apart in the potato. After a short time the potato next to the *positive* lead will be discolored a greenish color, due to chemical changes from the current.

DEMONSTRATION NO. 16

Testing Electrolytic Condensers With a Neon Bulb

Your neon tester provides a very accurate method for testing the condition of electrolytic condensers. Change the wiring of your tester from the way you had it in the last demonstration to the way it was in Demonstrations 3 to 10, inclusive, as in Fig. 3. The positive (red) test lead tip should be soldered to terminal 5 and your negative (black) test lead soldered to terminal 4 on the terminal strip.

To test any electrolytic condenser, connect its *positive* lead to the *positive* test lead and its negative lead to the *negative* test lead. *Always observe polarity when installing or testing electrolytic condensers.* The positive voltage *always* is connected to the red or + terminal of the condenser, and the negative voltage connected to the black or − terminal. Reversal of polarity will result in the condenser being damaged and a heavy load being placed on the rectifier and filter circuits to which it is connected. When electrolytic condensers are manufactured, the plates are *formed* by applying an electric current to them, in the proper chemical solution. This results in chemical changes taking place on the plates (analogous to the process used in forming storage battery plates) and the positive and negative plates take on definite characteristics. The dielectric in electrolytic condensers is a microscopically thin coating of gas on the negative plate. The large capacity with relatively small size found in this type of condenser is explained by the fact that the capacity of a condenser increases as the spacing between its plates is reduced. Therefore, the capacity is high, due to the extremely thin gas dielectric.

When electrolytic condensers are freshly manufactured the chemical solution between their plates is very active and when they are connected to a source of voltage (such as a DC rectifier) the gas forms rapidly on the negative plate, the capacity immediately reaches its correct value and current leakage is reduced to a minimum amount.

After an electrolytic condenser has been used for a considerable time, however, or it has stood, either on dealer's shelves or installed in a radio receiver or other unit without being used, it may dry out (the liquid or semi liquid paste becoming evaporated) and the gas dielectric film is formed with difficulty or not at all. Also, corrosion may take place on the plates or the elements (of the liquid type) become loosened, either condition causing a short circuit and loss of all capacity.

To test for these conditions, connect the electrolytic condenser leads to your neon bulb tester test leads, *observing correct polarity.* You will note that the neon bulb lights brightly when the condenser is first connected and then gradually dims and ceases to glow after a short time. That is, provided the condenser is satisfactory and in correct operating condition. As the DC current is applied, the gas is formed on the negative plate, leakage is reduced and the condenser reaches its correct value, as explained. When this condition is reached, the condenser is charged, current ceases to flow and the neon bulb ceases to glow. As there is always some leakage in this type of condenser, the charge will gradually leak off (between the plates) the voltage across the terminals will gradually be reduced and. when the critical voltage value across the neon bulb is reached, the bulb will again light and the condenser will again start to increase its charge. This action is similar to that found in a neon tube relaxation oscillator, except that in this case, the resistance causing the condenser discharge is in the condenser itself.

By observing the action of the neon bulb, the overall condition and efficiency (Q) of the condenser can be readily determined. No flash indicates an open condenser; a continuous dim light indicates either a partially corroded, dried out or high leakage condenser; a full glow indicates a shorted or badly corroded unit, while a very slow oscillation (flashing off and on of the neon bulb) indicates that the condenser is satisfactory for use. The rate of oscillation will depend on several factors; the applied voltage and current (limited by the neon bulb)—the degree of leakage within the condenser, and its capacity. If the neon bulb ceases to glow after approximately one minute, the condenser can be considered to be satisfactory. However, condensers which have not been used for a considerable length of time may require more time than this to reform their plates. If the neon bulb flashes off and on at a slow rate (approximately one cycle per minute) the condenser is satisfactory.

DEMONSTRATION NO. 17
Testing Volume Controls

The volume control used in receivers is subject to all of the defects found in other components —shorts, leakage, opens and grounds. In addition its resistance may change, mainly due to wear, and various mechanical troubles may develop, such as worn shafts, bearings and sliding contacts. Also, contact spring washers may wear and lose their tension and cause poor contact, as well as insufficient lubrication which results in shaft binding and sticking. Many of these defects can be found by a close visual inspection of the volume control and its various parts. However, an electrical check will find many defects which will be discovered by no other means. When you have cause to suspect a volume control, on account of poor tone, hum, distortion, loss of volume, noise, intermittent operation or any other effects which a defective or worn volume control can cause in a receiver, disconnect the connecting leads from the unit (carefully marking them and noting how they are connected to the control, in order that you may reconnect them correctly) and remove the control from the chassis. Usually it is held in place with one mounting nut, with a small metal tab holding it in position and preventing it from turning after being mounted—the tab fitting into a small hole in the plate on which the control is mounted. A large proportion of volume controls used in receivers are of the carbon or graphite type of high resistance (100,000 ohms to 3 megohms), which control the amount of audio signal admitted to the demodulator or the first audio frequency amplifier circuit. There are many methods of controling volume and each requires a certain value of variable resistance; from a very few ohms up to several megohms, depending upon its action in the circuit. High resistance controls are usually constructed so a sliding contact rubs on a carbon or graphite impregnated surface, while low resistance units have their moving contact connected with successive turns of resistance wire which is wound on a semi circular form. Volume controls may be wired as rheostats or potentiometers, depending upon their resistance and to the circuit to which they are connected. Usually, rheostats are used in low resistance circuits and potentiometers are used with high resistance components.

To test high resistance volume controls (those having an overall resistance of 50,000 ohms or more), connect your neon bulb continuity tester as it was in the last demonstration as in Fig. 3. If you wish you may substitute your ohmmeter for the neon bulb tester.

A—Testing for grounds and leakage. You will find some controls have their center terminals connected directly to their control shafts (and, therefore, the moving contact). To test for shorts and grounds in these types, hold one test lead on the center terminal and the other test lead first on one of the end (outside) terminals and then on the other terminal. As you test in both of these positions, rotate the shaft with your fingers, in a clockwise and counter clockwise direction, and note the appearance of your neon bulb. If the control has neither of its outside contacts shorted to ground, the neon bulb will brighten and dim as you rotate the control shaft—it will brighten as the moving contact nears the outside terminal on which you have placed your test lead and dim as the contact moves away from this terminal. The difference in brightness noted will depend on the total resistance of the control—a low resistance will cause less difference than a high resistance. This test determines if either end terminal is shorted to ground. Other types of controls have the center terminal (which is connected internally to the moving contact) insulated from the control mounting or housing. Grounds and leakage in these types can be found by placing one test lead on the housing or mounting and the other test lead on each of the contact terminals. Any indication from the neon bulb would indicate a ground or leakage within the control.

B—Testing for a shorted volume control. Make the same test as you did in the foregoing, by placing one test lead on the center control terminal and the other test lead on, first, one outside terminal and then on the other meanwhile turning the shaft back and forth. No variation in neon light intensity means that the outside terminal you have your test lead connected to is shorted to the center terminal.

C—Testing for an open volume control. Make the same test as in the foregoing. As you turn the volume control shaft slowly, an open place in the volume control resistor will cause the neon bulb to cease to glow. Turning the shaft further will result in the neon bulb again glowing. Open carbon type volume controls are found frequently in servicing receivers. This condition is usually caused by a shorted condenser, which allows a high current to pass through the control, which overheats and burns out a small segment of the resistance element.

D—Testing for a noisy volume control. Worn out and defective volume controls cause, by far, the most trouble in receivers. Poor tone and a scratchy sound in the speaker, resulting when the control shaft is turned, is the usual indication. To test for this condition, make the same test as you did in the foregoing and watch the neon bulb closely. Any flicker or change in light intensity of the neon bulb, as you rotate the control shaft slowly, indicates a noisy control and it should be repaired or replaced. Practically always, a defective control should be replaced with a new one, as most control repairs are impractical.

E—Testing resistance of volume controls. Due to the wide variations in high resistance volume control types, such as right hand taper, left hand taper, etc., it is usually difficult to determine if the

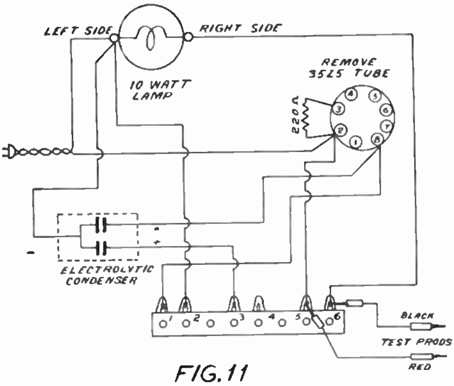


FIG. 11

resistance of a control has changed materially (usually due to excessive wear) unless a sensitive and dependable ohmmeter is used. However, in case the receiver under test exhibits symptoms of a high resistance control (considerably higher than the control was originally or for which the receiver was designed) which usually are distortion, hum, flutter, motor boating, loss in volume, loss in control, etc., your neon bulb tester will usually indicate that the control has changed in resistance sufficiently to cause these conditions and therefore requires replacement. Test across the two outside terminals of the control and note the degree of brightness of the neon bulb. Compare this with the degree of brilliancy of a resistor which has the same resistance as the control had originally. To find this amount of resistance, look on the outside housing of the control, where it is usually marked or stamped. If you cannot find this information, then you can refer to the manufacturer's schematic wiring diagram. Usually the resistance value of a volume control will change 30% or 50% from normal before it seriously impairs a receiver's reproductive qualities.

To test low resistance volume controls (those having an overall resistance of from 2 ohms to 10,000 ohms), a low resistance type of circuit continuity tester is required. You have studied how to use both high resistance and low resistance testers in previous demonstration lessons. As a volume control has negligible inductance or capacity, you can test a low resistance control on alternating current, using the proper safeguards, which, in testing with the 115 volt AC current, consists of being very careful when making the tests and using a current limiting device (a low-power lamp) in series with the volume control circuit and the 115 volt AC current. To connect your continuity tester in order to make these tests, a few changes are necessary as shown in Fig. 11. Unsolder the wire from filament terminal 7 on the octal tube socket, pass it up through the small hole in the top of the chassis which is directly below terminal 6 on the terminal strip and solder it to this terminal. This wire now connects this terminal 6 to the right hand terminal on the incandescent lamp socket. Next unsolder the wire from terminal 5 on the terminal strip (the wire that runs to one terminal on the neon bulb bayonet socket), pull it through the small hole in the top of the chassis, remove and set aside the neon bulb socket. Then solder a short length of wire to terminal 2 on the 35Z5 tube socket (leaving the line cord and 220 ohm resistor connected to this same terminal), pass it up through the small hole directly below terminal 5 on the terminal strip and solder its end to this terminal. Remove the test lead from terminal 4 on the terminal strip and solder its tip end to terminal 6. You already have the red test lead tip soldered to terminal 5. It is best to remove the 35Z5 rectifier tube from its socket, as it will not be required further in this demonstration lesson. **Remove the 25 watt incandescent lamp and replace it with a 15 watt lamp.** You may remove the 2,200 and 22,000 ohm resistors from the terminal strip. Your continuity tester is now wired as it was for simple AC continuity testing in Lesson R-2. To test low resistance volume controls, **proceed just as you would with high resistance volume control testing**, with the exception that high resistance leaks cannot be found with this low resistance testing method. However, high resistance leaks are usually of little consideration in low resistance volume control circuits. One precaution is very important—your 15 watt lamp will permit .128 amperes to pass through your test circuit.

This current may be excessive when testing volume controls with medium high resistance (over 5,000 ohms). Therefore, when testing controls of medium high resistance, leave your test leads connected to the control for very brief periods of time, to prevent overheating of the control. Also, care should be taken to avoid electrical shocks from the alternating current. Wire wound volume controls of almost any resistance value may be tested by this method without damage to the control **but the carbon type is very easily damaged by excessive current and extreme care must be taken.**

These test procedures have been more or less elementary in nature. The neon bulb and incandescent lamp methods have been purposely introduced at this time. Their purpose has been protective in that they make you acquainted with test methods and give you practice. Thus, you learn HOW to test using inexpensive units and do not have to take a chance on ruining your more expensive multimeter. From now on you should be well qualified to use your multimeter for testing all values of voltage, current and resistance.

SUMMARY

The experience gained by performing the demonstrations in this lesson will prove to be invaluable to you in actual receiver servicing and maintenance. You have constructed a rectifier and experimented with circuit changes. By doing the work yourself, you have gained confidence so that you will recognize and be familiar with this type of circuit. You have learned practical, concrete methods of circuit continuity testing which you can begin to use immediately in Radio-TV servicing and repairing.

PREVIEW OF LESSON R-7

In your next lesson in this series you will experiment with inductance, reactance and resonance; learn about transformer action, turns-ratio and permeability; construct an iron core reactor and demonstrate choke and condenser input filters; and perform many interesting experiments and demonstrations which will give you a firm understanding of basic electronic principles, actions and reactions. You are well on your way now to realize your ambition to become a success in your chosen profession—electronics—the science of limitless possibilities.

QUESTIONS

No. 1. Why is a rectifier used in a radio receiver?

No. 2. What is the difference between AC and DC?

No. 3. What is meant by pulsating DC?

No. 4. What is a filter circuit?

No. 5. Why is a condenser used in a filter?

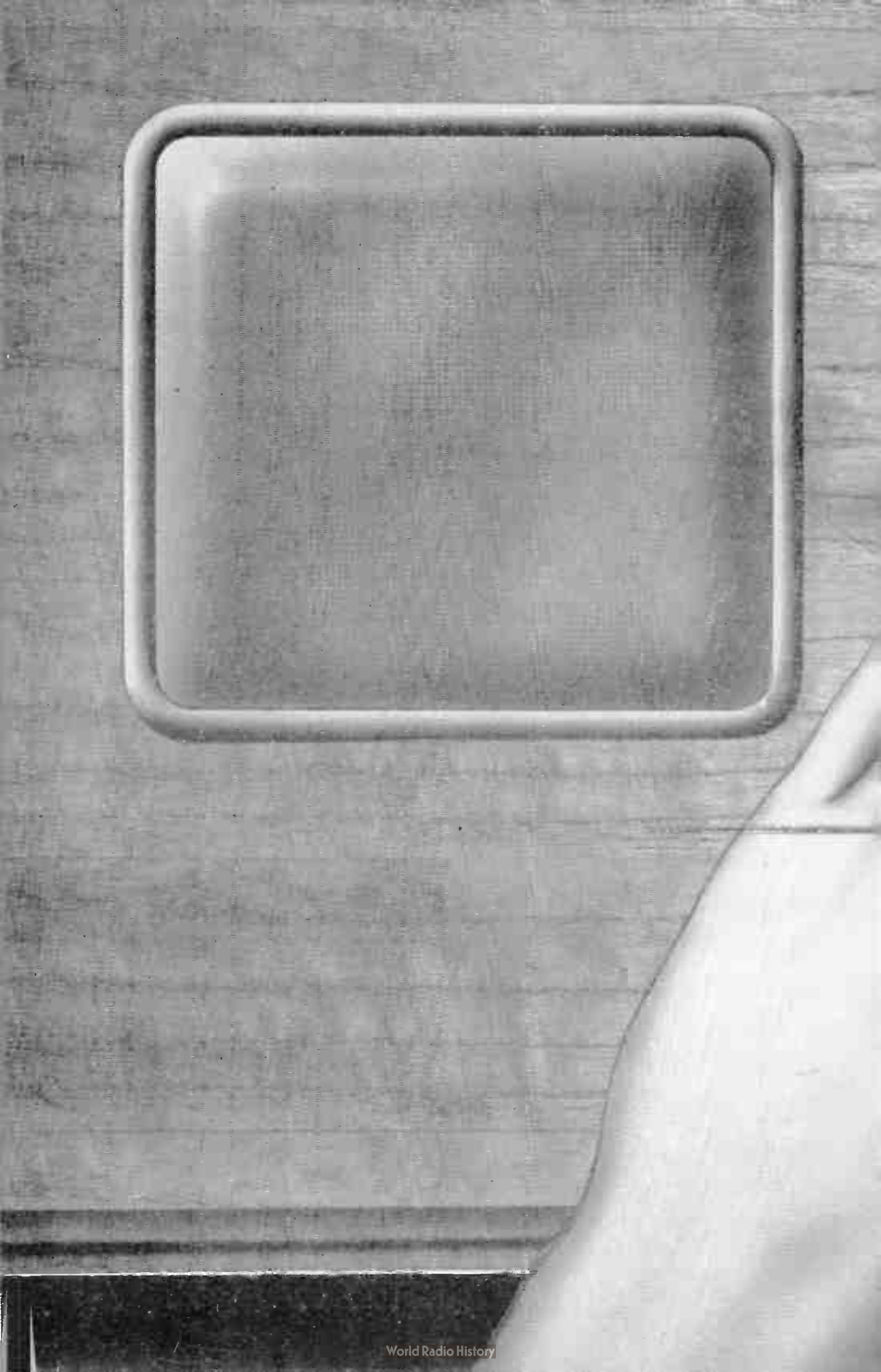
No. 6. What is meant by polarity?

No. 7. How would you test for polarity?

No. 8. How would you find a shorted condenser in an AVC circuit?

No. 9. How would you find an open in a grid circuit?

No. 10. What methods have you learned to determine the value of a resistor? The capacity of a condenser?



EXPERIMENTS WITH INDUCTANCE

LESSON R-7

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

CHICAGO, ILLINOIS

NEVER HESITATE TO REVIEW

How well do you remember the basic principles in the last lesson? How about the one you studied two weeks ago, and how about the lesson on Ohm's Law? Whatever your answers truthfully are, they are entirely dependent upon how well, how thoroughly you gave your attention to the lessons.

Whether or not you feel that you know the fundamental facts contained in your lessons, you can help yourself greatly by reviewing them from time to time. Never overlook the value of review. A little thinking on a given subject will recall to your mind some of the things you are doubtful about. As a test for yourself, go over an entire lesson on which you got a good grade. In all probability you'll find that you learn new things, or get a better understanding than you had before.

Tracing diagrams is real fun to the radio-television technician. Test yourself by tracing through a large schematic diagram. Follow the circuits and see if you can figure out why a given part is used and why it has certain value. This is very interesting, and is a good test of your basic understanding of fundamentals.

You are urged to reveiw your lessons often simply because it has been proven by experience that it is profitable and helps you progress with new lessons which you have not yet studied. Such effort is always well-rewarded and always increases your ability.

We realize, even with conscientious review, that you may still not have the understanding of a given subject that you would like to have. When you come to this conclusion, let us help you. Our staff is skilled in helping students over rough spots, and we want you to feel entirely free to ask for assistance whenever you feel the need of it.

It is in this way that we can work hand-in-hand, fulfilling the relationship between teacher and pupil. This is the ideal relationship to have at all times and we want it to be in continual existence as long as you are a student. So never let anything come up to mar our mutual interests. Try your best to do your own part and we will do all we can to be teacher and friend.

So, continue your good work and review your previous studies as often as you can work it into your schedule.

O'B 7-54 2000

Corrections

Page 5 In the second line from the bottom of the right column, change "40,000" to 39,000 ohms.

Fig. 11 The condenser value is .1 mfd.

Page 19 In the 12th line from the bottom of the left column, change "one-third" to three times and change ".000212" to .00194.

Page 20 In the 14th line from the top of the right column, change "5" to 6.

Page 25 There are several incorrect values given.
In the 12th line from the top of the left column, change "35" to 350.
In the 16th line from the top of the left column, change "parallel" to series.
In the 14th line from the bottom of the left column, change "13,198" to 131,800.
In the 12th line from the bottom of the left column, change "5,307" to 53,070.
In the 1st line of the right column, change "26,539" to 265,366.
In the 15th line from the bottom of the right column, change "13,280" to 132,500.

Demonstration No. 9

The primary and secondary inductance of the transformer being used with lesson R-7 will vary somewhat from the values given in the lesson. This will not affect the results which you will obtain in any of the demonstrations except Demonstration No. 9 on the resonant circuit. Your transformer will have the same colored leads as that shown in Fig. 17-1 on this sheet. Use these instructions in place of those given on page 25 of lesson R-7. Also, use Fig. 17-1 in place of Fig. 17 in the lesson.

The primary leads of the transformer are red and blue. They are not to be used in this demonstration. Bend them out of the way so that they will not touch. Solder the green lead of the secondary to terminal 4, which is one side of the AC input. To terminal 5 connect one end of the .01 mfd. condenser. Also fasten the black lead of the secondary winding to terminal 6 and solder. To terminal 6 connect the other lead of the .01 mfd. condenser, and the other AC lead as shown in Fig. 17-1. Solder this connection.

The secondary winding of the transformer which you are using has an inductance value of about 150 henries. It is wired in series with .01 mfd. of capacity. The input frequency is 60 cycles. If you calculate the inductive reactance ($X_L = 2\pi f L$) and compare it with the capacitive reactance ($X_C = \frac{1}{2\pi f C}$) you will find that X_L is much smaller than Xc. Therefore you would expect a larger voltage drop across the capacitor.

Apply power to the circuit. Set your SAR multitester to the 250 volt AC scale and measure the voltage drop across the coil between terminals 4 and 6. Record the voltage and then measure the drop across the capacitor, between terminals 5 and 6. As you expected, the drop across the condenser is greater.

Remove the plug from the wall socket to disconnect the power. Solder a .05 mfd. capacitor in parallel with the .01 mfd. capacitor between terminals 5 and 6. This gives a total capacity of .06 mfd. (When condensers are in parallel, their capacities add.) The value of X_L remains the same. If you calculate the value of Xc where C = .06 mfd. and f = 60 cycles you will find that Xc is now less than X_L. Therefore, you would expect the voltage drop across the coil to be greater.

Apply power to the circuit, and with your SAR multitester set to the 250 volt AC scale, measure the voltage. Across the coil, between terminals 4 and 6 the voltage has increased. Across the capacitor, between terminals 5 and 6 it has decreased. As you expected, the drop across the coil is greater because its reactance is greater. Remove the power from the circuit.

When $X_L = X_C$ the circuit will be resonant. In this case, the voltage across the coil should be equal to the voltage across the capacity. Without a variable condenser it is difficult to get an exact resonant condition. However, it is possible to have a circuit that is almost resonant.

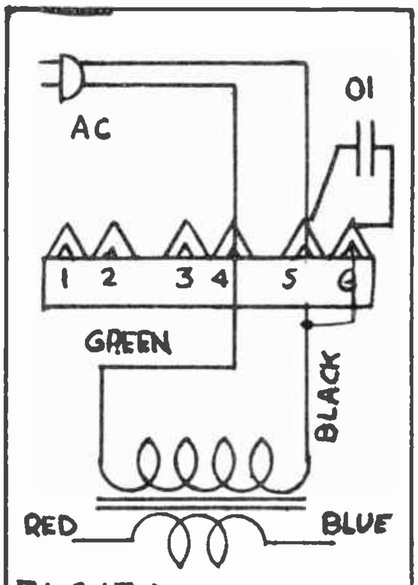


FIG 17-1

Remove the .01 mfd. capacitor from across terminals 5 and 6. Leave only the .05 mfd. capacitor across these terminals. The circuit will now be as shown in Fig. 17-1 except that a .05 mfd. capacitor is being used. Apply power and again measure the voltage drops using the 250 volt AC scale. The voltage across the coil between terminals 4 and 6 will be almost equal to the voltage across the capacitor between terminals 5 and 6. The voltage across the coil will be slightly higher. Remove the power from the circuit.

The inductive reactance remains constant. The capacitive reactance of the .05 mfd. condenser at 60 cycles is almost equal to X_L. If X_C were exactly equal to X_L then the voltage drop across each component would be equal and opposite.

For the second part of Demonstration No. 9 on page 26 of the lesson, the circuit of Fig. 18 would be used with these changes. (1) The .05 mfd. capacitor must be substituted for the .02 mfd. capacitor. (2) Only the secondary winding is used. Solder the green lead to terminal 4. Touch the black lead to terminal 5 and note the brilliance of the bulb. For the remainder of the lesson follow the procedure given in the lesson.

EXPERIMENTS WITH INDUCTANCE

LESSON R-7

One of the fundamental and basic parts of every radio or electronic circuit is the coil in one of its many forms. A coil, or inductance as it is commonly called, is a vital part of every radio transmitter and receiver. Without the inductance economical transmission and reception of radio signals would not be possible. The use of the coil is not confined to radio or electronic circuits only. If it were not for the inductive effect the electric motor, the generator, the buzzer, the vibrator, the doorbell and many other electric devices would not be possible. In fact, the process of efficiently and economically generating the electric current that is so much a part of our daily lives is made possible by the simple inductance.

As you have learned in your previous lessons, the principle of inductance is based on certain fundamental laws of nature. Two of the most important, briefly stated, are:

1. *When an electric current is caused to flow through a conductor, a magnetic field is set up around that conductor.*
2. *When a conductor is cut by moving lines of magnetic force, a current is caused to flow in the conductor.*

You have studied the principle of operation and the properties of inductance in their many forms in your SAR lessons. The purpose of this lesson is to assist you in becoming more familiar with these effects through a series of demonstrations with coils, transformers, and inductance in general. Many of the effects studied in other lessons will be demonstrated.

Many students of radio pay strict attention to electricity by studying Ohm's and Kirchoff's laws and by observing the effects of resistance, voltage and current in a circuit, but pay very little attention to magnetism, inductance and their effects. This is understandable as it is much easier and simpler to measure the current (amperes) in the circuit than to measure the flux density (lines of force or gausses) in a magnetic field. Yet without a small magnet in the meter, the measurement of current would be costly and difficult. All of these physical effects are interrelated, yet there is a natural tendency to let the design engineers worry about reluctance or reactance, which is correct. You are not interested in engineering design at this point in your SAR course but rather in gaining a working knowledge of magnetism and inductance. A completely trained radio electronician must be interested in understanding electronic theory in its entirety. Therefore it is suggested and urged that the lessons on lines of force, coils, resonance, transformers, choke-coils and filter systems be reviewed and coordinated with this lesson.

Ordinarily, you cannot see, hear, or feel what is occurring in the magnetic field of a transformer or choke-coil, any more than you can see the current flow in an electrical circuit. What must be done, therefore is to observe and measure the effects of inductance just as you observed the effects of an electric circuit. From the two fundamental laws previously stated, you can see that magnetism and electricity are inseparable. Where you find one you will find the other.

DEMONSTRATION No. 1
A Source Of DC Power

Your circuit continuity tester and rectifier which you have used in previous demonstrations should now be wired in accordance with Fig. 1. This is a rectifier circuit which is to provide a DC output at the test lead terminals for use in the demonstrations that follow. Although the coil depends upon an alternating or changing current for its operation, much can be learned about its properties by observing its action when a direct current is applied. The rectifier or power supply is wired on the small chassis 1R1. Part of the wiring may be included from Lesson R-6, however the complete wiring instructions are given. All of the parts are mounted on the chassis.

A—Pass the AC line cord through the rubber grommet in the rear of the chassis and secure it by means of a knot in the cord on the inside flange of the chassis. Solder one end of the line cord to pin 2 on the octal socket. Fasten the other end of the AC line cord to the left hand terminal on the incandescent lamp socket.

B—Solder a lead to pin 7 on the octal socket, and pass this lead up through the hole in the chassis so that the other end can be fastened to the right hand terminal on the lamp socket. This completes the filament circuit of the rectifier tube.

C—Insert the 25-watt lamp into its socket and a 35Z5 tube into the octal socket. Insert the line cord plug into an AC outlet. The 25 watt lamp should light brightly at first and then gradually decrease in brilliance as the tube filament heats. It may be difficult to see the

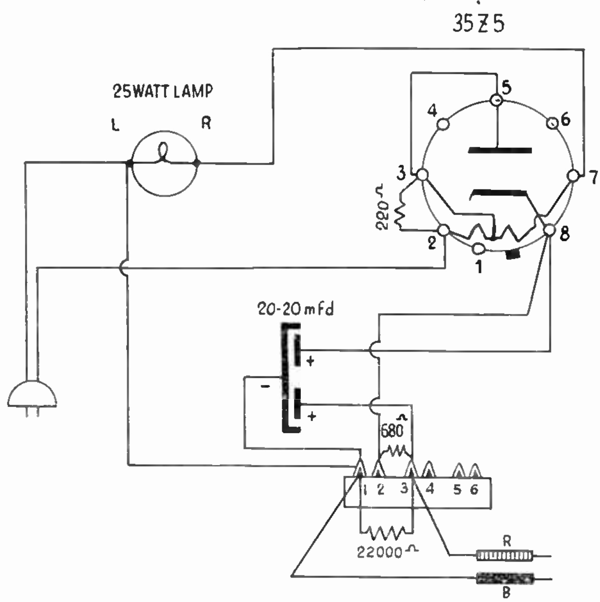


FIG. 1

tube filament from the top, but a red glow can be seen on the inside of the tube at the bottom of the filament. This indicates that the tube filament circuit is correctly wired. Remove the plug from the AC outlet. Remove the lamp and the tube from their sockets and proceed with the wiring.

D—Solder one end of a 220 ohm resistor to pin 2 of the octal socket. Connect the other end of the 220 ohm resistor to pin 3 of the octal socket. Also connect pins 3 and 5 of the tube socket together with a short length of wire, or with the pigtail lead of the resistor. Solder the connections to pins 3 and 5 of the octal socket.

E—Solder the negative lead of the 20-20 mfd. electrolytic condenser to terminal 1 of the terminal strip. Solder one of the positive leads of the condenser to pin 8 of the octal tube socket. Pass the other positive lead of the condenser to the top of the chassis through the hole directly under terminal 3 of the terminal strip and solder this lead to terminal 3.

F—Fasten a length of wire to the left terminal of the lamp socket. Solder the other end of this wire to terminal 1 of the terminal strip. There should now be two leads to the left terminal of the lamp socket and one lead to the right terminal.

G—Now solder a length of wire to pin 8 of the octal tube socket. Pass the wire to the top of the chassis through the hole directly under terminal 2 of the terminal strip. Solder the end of this wire to terminal 2.

H—Solder one end of a 680 ohm 1 watt resistor to terminal 2 of the terminal strip and solder the other end of this same resistor to terminal 3.

I—Solder the tip ends of the two test leads to terminals 1 and 3 as shown in Fig. 1.

J—Solder a 22,000 ohm 1 watt resistor between terminals 1 and 3 on the terminal strip. This is called a *bleeder* resistor, and is placed across the output of the power supply to provide a discharge path for the two electrolytic condensers. In later demonstrations this resistor will be removed and then the condensers will have to be discharged by other means.

This completes the wiring of the power supply unit. Insert the 25 watt lamp into its socket and the 35Z5 rectifier tube into the octal socket. Be sure that the ends of the two test leads that are soldered to terminals 1 and 3 of the terminal strip are not touching, as this would short the power supply.

Insert the power plug into the AC receptacle and allow the circuit to warm up for a minute. While the circuit is heating, observe the components closely, any error in wiring may cause the circuit to overheat and some part may begin to smoke. If this happens, the line cord plug should be pulled from the socket at once and the circuit checked.

Use your multimeter to measure the DC voltage output of the power supply. Set the meter to a high DC range and connect the negative lead of the meter to the black test lead on terminal 1 of the terminal strip. Connect the positive meter lead to the red test lead terminal 3. The reading will be about 148 volts DC. This DC voltage output can be dangerous if proper precautions are not taken. *Be careful that you do not come* *into contact with any part of the circuit or with the test lead terminals when performing the demonstrations in this lesson.*

The alternating current supplied for home use varies between 110 and 120 volts in most cases. This value is not the average but rather the RMS (root-mean-square) value. This RMS or effective value means that the AC will have the same heating effect on a resistance such as the lamp as an equal value of direct current. Actually the alternating current is changing from zero to a peak value at its frequency rate (in most cases 60 cycles). The condenser input type of filter circuit such as you are using takes advantage of this property of alternating current. The condenser charges to the peak value on every half cycle that the tube conducts. The net result is that the output DC voltage which is filtered by means of the two condensers and the resistor, is greater than the RMS value of the input although no step-up transformer is used. In the discussion of transformer action you will see how the inductive action of the transformer can be used to give a greater output voltage when an alternating current input is applied.

Plug the neon bulb into the pilot light assembly. Solder a 680 ohm resistor to one of the leads. Place the black test lead on the other end of the 680 ohm resistor, and touch the red lead to the other wire on the pilot light assembly. Note that just one side of the neon bulb glows. This indicates that there is direct current present in the output. Reverse the test leads to the neon bulb and the opposite side of the bulb will glow. Now touch the leads of the neon bulb with the 680 ohm resistor still in series across the terminals of the lamp socket. Here there is alternating current present, so both sides of the neon bulb glow.

DEMONSTRATION No. 2
Magnetic Effects With DC

Before beginning this next demonstration, examine the transformer that is supplied. Note it is an ordinary interstage AF transformer consisting of two sets of windings, which are bound together in layers on a laminated iron core. The entire transformer is held together by a metal frame. The core and its purpose will be discussed in the demonstration on the transformer action. For this section, consider the transformer as two separate coils, which in fact it is. On the top of the frame there may be some marking to show the primary and secondary impedance rating. For example, if the transformer has a rating of 10,000 to 100,000 ohms marked on it, this is its impedance ratio and not its DC resistance. With the ohmmeter, measure the resistance of the primary and secondary windings. This is a step-up transformer, so it will have more turns in the secondary than in the primary winding. The primary winding therefore has the lowest resistance. Since a coil is designed to operate on AC, the DC resistance reading will be no indication of its properties. This is why the manufacturer usually gives the ratio of the primary to the secondary impedance.

If this transformer is placed across a *DC voltage*, a magnetic field will be set up around the core. The iron core will act as the path of least reluctance to the magnetic lines of force and so they will be concentrated within the core. For best results, in the following tests the metal shell should be removed from the transformer so that the iron core is available. Note it can be removed by prying up the tips of the shell frame—bending the tips back until the shell will slip off the core. You will also need a small nail. Use one about 1 and ½ inches long. A nail is made of soft iron and can be easily magnetized.

Pull the plug from the wall receptacle, and fasten one of the primary winding leads of the transformer to the tip of the red test lead on terminal 3 of the terminal strip. Bend a hook on the end of a 680 ohm 1 watt resistor and fasten it to the other primary winding lead of the transformer. Solder this connection after it is made. Now fasten the other end of the 680 ohm resistor to the tip of the black test lead which is soldered to terminal 1 of the terminal strip. Bend the secondary winding leads aside so that they do not touch. Because the resistance of the primary winding is usually quite small the 680 ohm resistor is used in series as a current limiting resistor. These connections are shown in Fig. 2.

Plug the AC line cord into the power receptacle and let the circuit heat for about a minute. Now touch the nail to the various parts of the iron core of the transformer. You can feel the pull of the magnetic field as the nail is brought close to the iron core. You will also notice that there are certain parts of the core where the magnetic attraction is greater. These are the poles of the magnet. In other words, the primary coil with its iron core is acting as an electromagnet. Set the nail against the core so that it is held tight by the magnetic attraction. Now remove the red test lead from the primary winding wire so that the direct current circuit to the primary coil will be broken. This causes the magnetic field to collapse, since current is no longer flowing through the primary. As a result the nail will drop off. Once again, fasten the tip of the red test lead to the wire from the primary coil and attach the nail to the core. The magnetic force is present because of the current flowing in the primary. Remove the red test lead from the primary wire. The magnetic field collapses and the nail falls off. To restate the law of electromagnetism: *Whenever current flows through a conductor, a magnetic field will be set up around the conductor.* The strength of the magnetic field depends upon both the number of turns of wire and the amount of current flowing in the coil.

To show how the current affects the strength of the magnetic field, turn off the power and remove the 680 ohm resistor from the circuit. In its place put a 40,000 ohm resistor. Because of the great in-

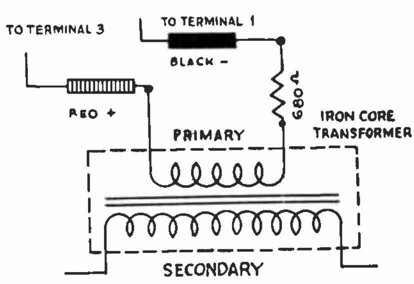


FIG. 2

crease in resistance, the current in the circuit will be greatly decreased. (From Ohm's law, $I = E/R$). So you would expect that the magnetic field would decrease in proportion. Turn on the power, and after the circuit warms up, touch the nail to the core. You can note that the pull of the magnetic field is now much weaker. It may be so weak that the nail will not stay tight against the core unless it is held in place. Disconnect the red test lead from the primary coil winding and connect it to one lead of the pilot light assembly with the neon bulb in the socket. Now touch the other lead of the neon bulb assembly to the lead of the primary coil. This places the neon bulb in series with the circuit. The bulb will now glow much dimmer because of the reduced current. So it can be stated that: *The strength of the magnetic field surrounding a conductor is directly proportional to the current flow through the conductor.*

Turn off the power by removing the plug from the wall socket. Remove the red and black test leads and the neon bulb from the circuit. Unsolder the end of the 40,000 ohm resistor that is connected to the primary lead of the transformer and lay it aside.

The strength of the magnetic field around the coil will increase as the number of turns of wire is increased. This can be demonstrated by the circuit shown in Fig. 3. Here the primary coil has been placed in series with the secondary coil so that their windings will combine to increase the number of turns. Fasten one of the primary coil leads to one of the secondary coil leads. Attach the black test lead to the other coil lead and turn on the AC power. Allow the circuit to warm up. The resistance of the two coils in series is large enough so that a current limiting resistor is not needed. Now touch the core with the nail and notice the strength of the magnetic field. You will find that the magnetic field now exerts a much greater pull or attraction to the soft iron nail because of the greater number of turns. This will hold true only if it happens that you have connected the primary and secondary so that they are 'series aiding'. If you do not get an increased magnetic effect it means that you have connected the two coils 'series opposing'. To correct this effect, simply reverse the secondary connections and you will have the two coils connected so that their magnetic effects combine or aid one another. The strength of the magnetic field will increase with an increase in the number of turns of wire. Set the nail against the core and let it stay there for about 5 minutes. At the end of this time turn off the power and you will find that the nail has become permanently magnetized by the process of magnetic induction. If the nail is left in the magnetic field for a longer period of time it will become even more strongly magnetized.

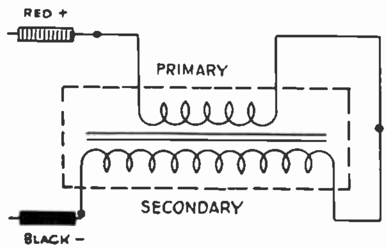


FIG. 3

The direction of current flow in the coil will determine the polarity of the electromagnet. As suggested in the foregoing, either the nail or a small compass can be used to determine this polarity. If the nail is used, tie a piece of string around it in the center so that it can be suspended and will balance and free to rotate like a compass. In fact the magnetized nail will act as a compass. If left free to rotate it will turn and align itself with the earth's magnetic field. Using the same circuit shown in Fig. 3, turn on the power. Bring the nail or compass close to one end of the magnetic field of the coil.

Depending upon the polarity of the electromagnet, the end of the compass (or nail) will be attracted or repelled. (*Unlike magnetic poles will attract, like poles will repel*). Now bring the compass near the other end of the electromagnet and the opposite end of the compass will be attracted. Note carefully which end of the compass is attracted by the north and south poles of the electromagnet. Now reverse the red and black test leads so that the direction of current flow through the coils will be reversed. Once again bring the compass or the suspended nail close to the coil. The direction of current flow through the coil has been reversed so the polarity of the electromagnet formed by the coil will also be reversed. You will find that the north and south poles of the electromagnet have been reversed. *The polarity of an electromagnet is determined by the direction of current flow through the coil.* Remember the right and left hand rules mentioned in a previous lesson. This is the type of circuit used to develop these rules. Replace the metal shell on the transformer. Bend the tips of the shell frame over the core.

DEMONSTRATION No. 3
Inductive Effects With DC

The magnetic lines of force through the windings and laminated core resulting from a steady uninterrupted flow of direct current through these coils produced a definite area of magnetic stress as shown by the previous demonstration. As you have learned in the lessons on transformers and coils, whenever magnetic lines of force cut or pass through an electrical conductor, an electric current is induced in that conductor. When no motion is present, no current is induced, but when either the magnetic field or the conductor is in motion a current will flow through the conductor.

The direction of the current flow is determined by the relative motion of the coil and the magnetic field. When the motion is reversed, the direction of the current flow will reverse. If the direction of the induced current were determined, it would be found to be of such a direction that it would produce a force which is opposite to the direction of the applied voltage. When a direct current is applied across a coil, the voltage does not rise at once to the full value as in a resistor. Rather the rate of the rise of voltage depends upon the effect of the induced voltage of the *counter EMF*. This is shown graphically in Fig. 4.

When voltage is applied across a coil current begins to flow through the windings. As soon as current begins to flow, an expanding mag-

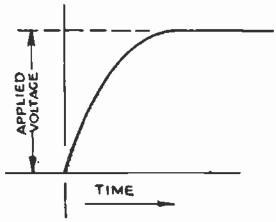


FIG. 4

netic field is set up around each turn. This magnetic field cuts the adjacent turns and induces a current which is of the opposite direction to the applied current. The induced current therefore tends to oppose the applied current. The applied current, being greater, will overcome the effect of the induced current but this action takes a short time, depending upon the inductance of the coil and the resistance. That is why the voltage across the coil, indicated by the shaded area in Fig. 4 does not rise at once to its full value. This same action causes the current to lag the voltage by 90 degrees when an alternating current is applied across the coil. It is the action of the current that causes this effect so it is often stated that *the coil is a current operated device.*

To demonstrate this effect which is described as 'Lenz's Law', the circuit shown in Fig. 5 is used. The rectifier circuit which is not shown remains as is. For this demonstration a second 25 watt lamp is needed. A second lamp socket may be used, or two wires can be soldered to the lamp bulb on the side and the bottom. This lamp is placed in series with the primary winding of the transformer as shown in Fig. 5. Fasten one wire from the lamp to one side of the primary winding. Fasten the black test lead to the other primary lead. Do not touch the red test lead to the other wire from the lamp yet. On the chassis, the lamp bulb in series with the filament of the 35Z5 tube should be covered with a small box or bag so that its light will not interefere with the results of the demonstration. The room should be as dark as possible because the glow of the 25 watt lamp in series with the primary coil winding is to be observed.

Now touch the red test lead to the other wire from the 25 watt lamp in series with the primary winding, and watch it carefully. The lamp will slowly increase in brilliance to its maximum value (which is dimmer than normal because of the coil in series). Remove the red test lead and the light goes out at once. Once more touch the red test lead to the wire from the lamp, and notice the length of time that it takes for the lamp to reach its full brilliance. There is a time lag of about 1 or 2 seconds. This time lag is due partly to the length of time it takes the filament of the lamp to heat, and partly to the induced counter EMF in the

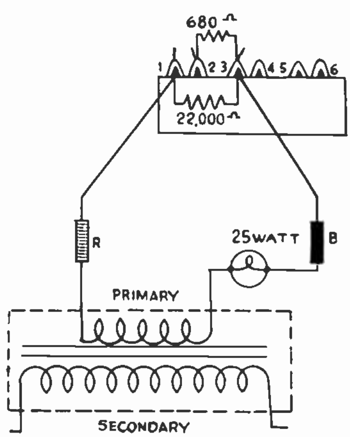


FIG. 5

coil. As shown in Fig. 4, when the current begins to flow, a changing magnetic field is produced. This magnetic field in turn induces a voltage in the coil which is opposite in direction to the applied voltage. It takes a little less than 1 second for the applied voltage to completely overcome this counter EMF. This time, plus the time it takes for the lamp filament to heat accounts for the time lag seen in the increase of intensity of the lamp. In other words, *when the current is induced in a coil as a result of a variation of the magnetic field, the current induced, is of such a direction that it tends to prevent the change that caused it.* This is a generalized statement of Lenz's Law.

Not only is there a counter EMF produced when the voltage is applied across the coil, but also when the voltage is removed. This is the result of the energy stored in the magnetic field. As the voltage increases to maximum across the coil, a magnetic field is built up around the coil. If the source voltage is removed, this magnetic field will collapse. As the lines of force collapse, they will again cut the turns of the coil and will induce a current which will be of the same direction as the applied current. This can be likened to the law of inertia, that a body in motion tends to remain in motion.

Arrange the circuit as shown in Fig. 6. Place the pilot light assembly in the ¾ inch hole in the top of the chassis. Connect the two leads of this assembly to terminals 5 and 6 of the terminal strip. Pass the leads through the small holes directly beneath these terminals. Then solder a wire to terminal 6.

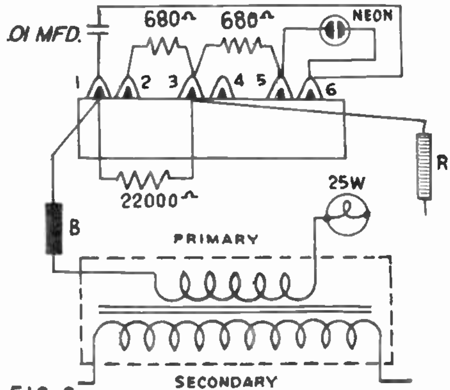


FIG. 6

Solder one lead of a .01 mfd. capacitor to the other end of this wire and solder the other capacitor lead to terminal 1 of the terminal strip. To the terminal 5, solder one end of a 680 ohm resistor. Solder the other end of this 680 ohm resistor to terminal 3. This will place the neon bulb and its protective resistor across the output of the rectifier and also across the primary coil and the 25 watt lamp.

With the lamp on the chassis still covered, insert the AC plug in the socket. Once again touch the red test lead to the end of the wire connected to the 25 watt lamp in series with the primary coil, and watch the neon bulb. When the connection is made, one side of the neon bulb will light for an instant. Then it goes out because the output voltage is decreased when the load builds up. Now remove the AC wall plug and watch the neon bulb. As the circuit is opened, the other side of the neon bulb will glow. Repeat this several times, watching the action of the neon bulb. When the circuit is broken, the magnetic field of the coil collapses. This causes the magnetic lines of force to move across the coil in the opposite direction, and so a voltage is induced in the opposite direction. This voltage will last for only the length of time that it takes for the magnetic field to collapse. Once again Lenz's law has been demonstrated.

If you watch the neon bulb carefully when the circuit is broken you can see two changes in direction of the induced voltage. First one side, then the other, then the first side of the bulb light. This all happens very fast but the action is there. What is occurring is that the collapsing magnetic field induces a current in one direction. This induced current has a magnetic field which builds up and induces a current in the opposite direction. If you could observe the action of the current with a very sensitive instrument, you would find that this action repeats itself a great number of times, growing smaller each time to produce a whole train of damped oscillations. This effect can be compared to dropping a rubber ball. The ball will bounce a number of times, with a little less force each time until it comes to rest. Turn off the power of the circuit.

The effect of the induced current in the coil is used when an alternating or changing current is applied. Then the counter EMF which is developed will react with the changing current to produce an opposition to the flow of alternating current that is known as *Inductive Reactance.*

DEMONSTRATION No. 4
The Reactance Of A Coil

The reactance of a coil, or its opposition to the flow of alternating current depends upon a number of factors. First of all, an alternating current for the purpose of the demonstration must be assumed to be a sine wave. That is, it varies at a definite rate from zero to maximum in one direction, then back to zero and to maximum in the opposite direction, then back to zero for each complete cycle. The shape of the wave is constant. Mathematically, this can be expressed in terms of a constant number or value. In this case, the value is equal to 2 times pi or 2 times 3.14.

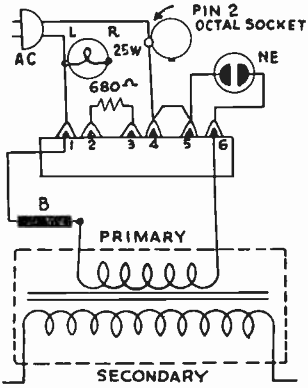


FIG. 7

The reactance also depends upon the total value of inductance of the circuit. As the inductance increases, the reactance will increase, and as inductance decreases, reactance will decrease. The frequency of the applied sine wave will also affect the reactance. As the frequency increases, the reactance will increase. This can be seen from the previous demonstration, for as the frequency increases, the rate of change of applied current will increase. This will cause the rate of change of the counter EMF to increase, and therefore the total opposition to the flow of alternating current or reactance will increase.

Remove the 35Z5 tube from the socket. The rectifier is now disabled, as AC is to be used. Refer to Fig. 7. Solder a wire from pin 2 on the tube socket to terminal 4 of the terminal strip. This will bring the 110 volt AC input from the line to the terminal strip between terminals 1 and 4, so be careful not to come in contact with these terminals. Unsolder the red test lead from terminal 3 and lay it aside. Unsolder the wire between terminal 1 and terminal 6 and remove it from the circuit. Unsolder the 680 ohm resistor from between terminals 3 and 5 and lay it aside. Also remove the 22,000 ohm resistor from between terminals 1 and 3 and set it aside.

Solder a length of wire between terminals 4 and 5 as shown in Fig. 7. Solder one of the primary leads of the transformer to terminal 6. Fasten the other lead of the transformer primary coil winding to the black test lead. This places the primary coil in series with the neon bulb which acts as a resistor. Figure 8 is an equivalent schematic diagram of the circuit which you have wired. The resistor represents the neon bulb. The voltage drop across the coil is labeled E_L and the voltage drop across the resistor is labeled E_r.

Turn on the AC power and observe the neon bulb. Both sides of the bulb glow indicating that an alternating current is flowing in

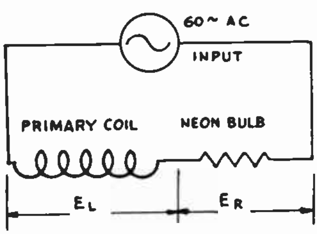


FIG. 8

the series circuit. Note its brilliance so that this may be compared in the next step. To measure the voltage drops in the circuit, set your meter to read AC. Turn the range scale to a high value since you are not sure what the voltages will be. In this way you will protect the meter. It is easier to turn the range switch down to a lower value than it is to replace a damaged meter movement.

Measure the input voltage from the AC line between terminals 1 and 4. Touch these terminals with the meter leads, being careful that you do not short out any of the other terminals with the meter leads. The reading will vary between 110 and 120 volts depending upon the voltage supply from the power station. Because there is a variation in the supply voltage, the readings which are given in this and later demonstrations may not be exactly equal to the readings you obtain. However, the readings will be somewhat close since there is not too great a variation in the input voltages. (Our readings were made with 110 volts at 60 cycles.)

Now measure the voltage across the coil (E_L). This voltage is also AC so the meter should still be set to read on the AC range. Measure the voltage between terminals 1 and 6. This is the voltage drop across the inductive reactance of the coil. The reading will be about 70 volts AC. Across the resistance (which is the neon bulb) the voltage reading is taken between terminals 5 and 6. The reading here gives the voltage (E_r) of about 80 volts. If you add these two values, you will find that they will total 150 volts or 40 volts greater than the input. Remember that in an AC

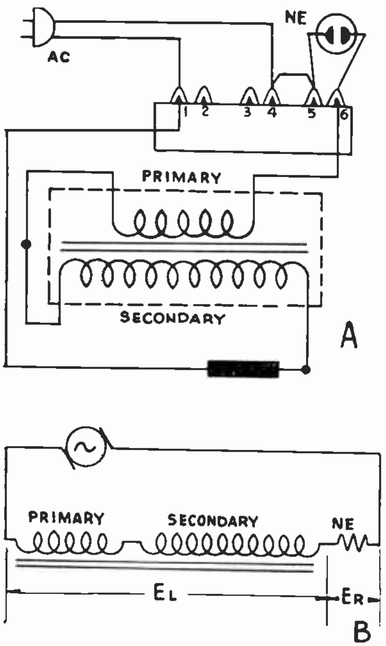


FIG. 9

circuit, you cannot add the voltage across an inductance to that across a resistance and get a correct value because the two voltages are not in phase with each other. They have to be added vectorially. The voltage across the primary winding is out of phase by an angle of slightly less than 90 degrees (because of the ohmic resistance of the wire in the coil). Therefore, this would all have to be calculated in order to get a true vector sum. However, for purposes of this demonstration, the coil will be considered to be a pure inductance with inductive reactance only.

The important thing to note is that both a resistive and an inductive voltage is present since the sum of the two voltages (not added vectorially) is greater than the input. Turn off the power by removing the plug from the wall socket.

If the inductance is increased, then the inductive reactance will increase. This is done by use of the circuit shown in Fig. 9A. Here the two coils, primary and secondary are placed in "series aiding." Since this demonstration deals with general effects, the coefficient of coupling is not considered. If you were to determine the actual resulting inductance of placing the two coils on this core in series, then the coupling would have to be calculated. However, from previous study you know that by connecting the two windings series aiding the total inductance will increase. This will cause the inductive reactance to increase. With the same voltage applied, a larger inductive reactance will cause the current to change. So the voltage drop across the coils should increase.

To wire the circuit, disconnect the black test lead from the primary wire. Connect this primary lead to the secondary coil leads as shown in Fig. 9A. Touch the black test lead to the other lead to the secondary coil. This will complete the series circuit. Figure 9B is the equivalent schematic diagram. Note that the neon bulb now is slightly dimmer, indicating that there is a smaller voltage drop across the inductive reactance. This voltage is labeled E_L in Fig. 9B. Set the meter to read AC volts, and measure the voltage drop across the coil. Place one of the meter leads on terminal 1 and the other on terminal 6. The reading will be about 80 volts. Now measure the voltage across the resistance of the neon lamp between terminals 5 and 6. This reading (E_R) is about 65 volts.

From the brilliance of the neon bulb and the voltage readings, it can be concluded that when the inductance of a coil is increased its inductive reactance will increase. Once again the algebraic sum of the voltages is greater than the applied voltage by about 35 volts. Remember that you have also added the ohmic resistance of the secondary winding in series so the true vector sum cannot be calculated without considering this. The result was as expected, however, when the inductance was increased, the inductive reactance increased. Turn off the power.

The opposite of this is also true. When the inductance is decreased, the inductive reactance will decrease. Make the changes in the circuit you have wired as shown in Fig. 10A. Here the two coils are placed in parallel and so the total inductance will decrease. Once again the mutual inductance is not considered since general results are desired.

To wire this circuit, unfasten the black test lead from the secondary coil wire. Fasten this lead of the secondary coil to the lead of the primary winding on terminal 6. Touch the black test lead to the junction of the primary and secondary windings as shown in Fig. 10A. This will complete the circuit. The two coils are now in parallel and they are in series with the resistor as shown in the schematic diagram Fig. 10B. Turn on the AC power.

Note the brilliance of the neon bulb. It is now very bright, indicating that there is a greater voltage drop across the bulb. Measure the AC voltage drop (E_R) across the neon bulb. Place one of the meter leads on terminal 5 and the other lead on terminal 6. The meter will read about 85 volts AC. This indicates that the current in the circuit has increased. Now measure the AC voltage drop (E_L) across the coils in parallel. Place one of the meter leads on terminal 6 and the other lead on terminal 1. Across the coils in parallel, the voltage has decreased to about 30 volts. This low voltage is due to the low value of inductive reactance which in turn is due to the lower value of inductance obtained by placing the two coils in parallel. Turn off the AC power and disassemble the circuit.

Unsolder the primary coil lead from terminal 6. Unsolder the wire from between terminals 4 and 5. Unfasten the primary and secondary leads which were fastened together. Clean off all the extra solder from the leads and the terminals. Leave the black test lead in the circuit and leave the leads to the neon bulb soldered to terminals 5 and 6.

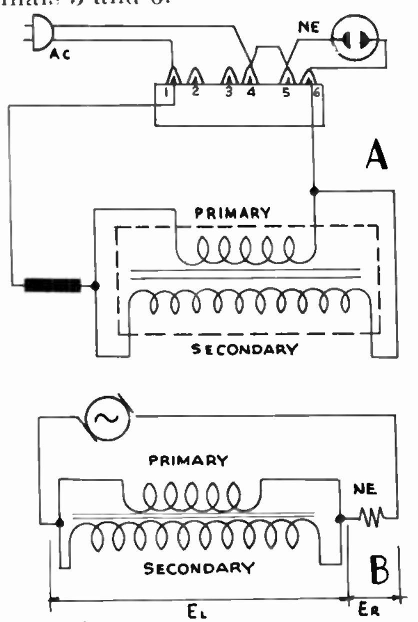


FIG. 10

The inductive reactance of the coil is determined by three factors. First, the applied alternating sine wave voltage, second the frequency of the sine wave and last by the value of inductance. This is expressed in the formula, $X_L = 2\pi fL$. Where f=frequency in cycles per second and L=inductance in Henries. From this demonstration, it can be seen that as the inductance is varied, the inductive reactance is varied. X_L could also be varied by changing the frequency of the input and keeping the value of inductance constant.

DEMONSTRATION No. 5
AC Circuit Impedance

Problems dealing with alternating current applied across a circuit containing coils, resistors and condensers have been covered in the theory portion of the course. These relationships are sometimes difficult to understand unless you can work with the actual circuits. In the last demonstration, the effect on the inductive reactance, of varying the inductance was demonstrated. You will also note that the resistance operates the same way whether alternating or direct current is applied. If a capacitance is placed in series with a coil and a resistor across an alternating current its action will be such that the capacitive voltage will lag the resistive voltage. Across the coil, the voltage was out of phase by an angle of 90 degrees, and the inductive voltage leads the resistive voltage. In the case of either the inductive or the capacitive voltage, there is a phase difference, and when the three circuit elements are combined into a series circuit, the total voltage across the components, if added is found to be greater than the applied voltage. All of these effects can be demonstrated by use of the circuit shown in Fig. 11.

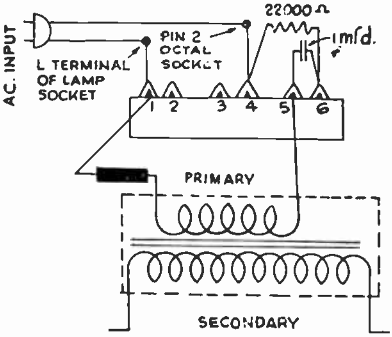


FIG. 11

This circuit consists of a coil, a condenser and a resistor in series across an alternating current source. To wire this circuit, begin by disconnecting the two wires from the neon bulb which are now soldered to terminals 5 and 6 of the terminal strip. The 35Z5 rectifier tube is not used so it remains out of the socket. The AC input is taken from terminals 1 and 4 of the terminal strip. Solder one end of the 22,000 ohm resistor to terminal 4. This is one side of the AC input. Solder the other end of this resistor to terminal 6, and also solder one end of a .1 mfd. condenser to this same terminal. The other end of the condenser, and one of the primary leads of the transformer are soldered to terminal 5. Contact to the other end of the primary winding coil is made by means of the black test lead which is connected to the other side of the AC source. The secondary coil is not used. Bend the leads aside so that they do not touch. This completes the series circuit which is shown in Fig. 11.

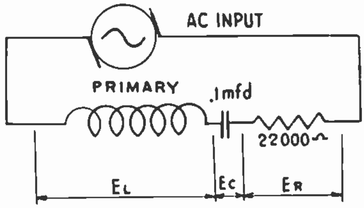


FIG. 12

Check your wiring to be sure that it is correct before you turn on the power. The input to the circuit is about 110 volts at 60 cycles from the AC line. This voltage may vary slightly depending upon the voltage source you are using. Measure the input voltage with your meter. Set the meter to read AC. and touch one of the input leads to terminal 1 and the other meter lead to terminal 4. The meter will read about 110 volts AC. Now measure the voltage drop across each of the three components. For these measurements and the calculations that follow, refer to the schematic diagram of the circuit shown in Fig. 12. This is the same circuit shown in Fig. 11. The resistance voltage (E_R) is measured between terminals 4 and 6. The meter is still set to read AC. Place one of the meter leads on terminal 4 and the other on terminal 6. The reading will be about 70 volts AC. Now measure the voltage drop across the capacity (E_C) between terminals 5 and 6. Here the reading will be about 85 volts. The voltage drop across the inductive reactance (E_L) is measured between terminals 1 and 5. The reading on the meter will be about 20 volts AC. Since the voltage drop across the capacitive reactance is greater than the voltage drop across the inductive reactance, the circuit is primarily capacitive.

For the purpose of the calculations, consider the primary winding coil to be a pure inductance with no resistance. Since the resistance will follow Ohm's Law regardless of whether it is operating on AC or DC, it is possible to calculate the current of the circuit since the size of the resistance and the voltage drop across it is known. From Ohm's Law it can be stated that:

$$I = \frac{E}{R} = \frac{70}{22{,}000}$$

Dividing, the current is found to be about .00318 amperes. Since this is a series circuit, the current flow through the resistor is equal to the total current flow in the circuit. Therefore the current through the inductive reactance (X_L) is equal to .00318 amperes and the current through the capacitive reactance (X_C) is the same value.

Now determine the size of the inductive reactance by use of Ohm's Law for AC circuits.

Since $E_L = IX_L$ Then $X_L = E_L/I$

The voltage drop across the coil (E_L) is about 20 volts, and the current is .00318 amperes. Substituting these values in the formula and dividing, the inductive reactance of the coil at 60 cycles is found to be about 6289 ohms.

The value of the capacitive reactance is found in the same manner.

Since $E_C = IX_C$ Then $X_C = E_C/I$

The voltage drop across the condenser is about 85 volts and the current is .00318 amperes. Substituting these values into the formula and dividing, the capacitive reactance is found to be about 26,730 ohms.

The voltage drop across a pure inductive reactance is 180 degrees out of phase with the voltage drop across the capacitive reactance. In other words, these two voltages are exactly opposite, therefore they should cancel, and give a resultant voltage of 65 volts. This calculation is used in determining the total impedance of the circuit. Instead of calculating the total ($X_L = X_C$) to find the net reactance, it can be determined with the voltmeter. Once again measure the voltage drop across the coil. Here there is 20 volts AC. Now measure the voltage across the condenser. Here the reading is 85 volts AC. Place one of the meter leads on terminal 6 and the other lead on terminal 1. The reading across both the coil and the condenser is about 60 volts. This indicates that the two voltages being 180 degrees out of phase with each other will oppose, and the net voltage across the coil and condenser both is the difference. In this case the resistance of the coil accounts for the difference. The capacitive voltage is greater so the resultant voltage is capacitive, or it lags the resistive voltage.

The total impedance of the circuit can also be calculated by Ohm's Law for AC circuits.

Since $E=IZ$ Then $Z=E/I$

The total voltage (E) is 110 volts. The total current (I) is .00318 amperes. Substitute these values in the formula and divide. The total circuit impedance is found to be about 34,592 ohms. Note that the value of the impedance is greater than the value of any of the components.

The laws that govern the calculations of AC circuit problems can all be proven with measurements of this type. Remember as you proceed through this and other lessons that all of the effects which you are studying are based upon actual physical properties of the components. It is often easier to prove a theory by mathematics instead of setting up the circuit and measuring the effects, but this is exactly what has to be done by the serviceman when he is working in the field. A serviceman may not know all of the mathematical formulas that govern the operation of a circuit, but he should be familiar with the actual relationships between the two. For example, in the previous circuit, if you did not know about phase shifts between inductive and capacitive circuits, how could you explain the fact that the voltage across the coil is 20 volts and the voltage across the condenser is 85 volts, yet when these two voltage drops are measured together the total voltage reading is only 60 volts.

Before going on to the next demonstration, remove the condenser, coil and resistor from the terminal strip. Also remove the black test lead that is soldered to terminal 1.

DEMONSTRATION No. 6
Transformer Action

In the study of the coil, it was shown that when an alternating current is passed through an inductance a varying magnetic field will be built up around the coil. If a second coil is placed in such a position, that the varying lines of magnetic force of the first or primary coil will cut the secondary winding, a voltage will be induced in the secondary winding. *The secondary voltage will be directly proportional to the rate of change of the primary current.*

In the case of the transformer you are using, an iron core is used to provide a greater flux linkage. In this way the maximum number of lines of force from the primary winding will cut the secondary winding. If the number of turns in the secondary coil is equal to the number of turns of the primary coil then, if there were no losses, the same voltage would be induced in the secondary coil. Even considering losses in the transformer due to heat, resistance, etc., *the induced voltage is proportional to the number of turns.* These two statements are expressed mathemetically in the transformer formula:

$$\frac{N_p}{N_s} = \frac{E_p}{E_s}$$

In other words, the ratio of the number of turns in the primary coil (N_p) to the number of turns in the secondary coil (N_s) is equal to the ratio of the voltage of the primary (E_p) to the voltage of the secondary (E_s). For example, if a transformer has a turns ratio of 2:1 step-up, this means that if 10 volts is applied to the primary, then 20 volts would be produced across the secondary. If the transformer is rated as a 1:3 step-down, then 60 volts across the primary would produce only 20 volts across the secondary. So a transformer can be used to either step up or step down the AC voltage depending upon the number of turns in the primary and the number of turns in the secondary. A good example of a step up transformer is a power transformer used in many radio and electronic power supply circuits. In this type of transformer, an input voltage of 110 volts AC at 60 cycles, will produce an output voltage of 300 to 500 volts in the secondary winding. Step-down transformers are used to provide a 6 volt filament potential from a 110 volt AC source. These too are found in power supply circuits, often in the same transformer.

One point that should be noted is the effect of the turns ratio upon the current in the primary and the secondary windings. The voltage ratio of the transformer is determined by the number of turns in the primary and secondary windings. Now, if there are more turns in the primary than in the secondary, the voltage of the secondary will be less than the voltage in the primary and the transformer will act to step down the applied voltage. However, there are a greater number of lines of force present which are cutting the turns of the secondary so it follows that the current of the secondary winding will be increased. The ratio of the current in the primary to the current in the secondary will be just the opposite of the voltage. Expressed as a formula,

$$\frac{N_p}{N_s} = \frac{I_s}{I_p} = \frac{E_p}{E_s}$$

So the current will be inversely proportional to the turns ratio and to the voltage ratio. This is the complete transformer formula, and from this the ratio of the primary impedance to the secondary impedance can be calculated.

The circuit used for this demonstration consists of the transformer with a protective resistor in the primary across the 110 volt AC source, and a load resistor across the secondary. This circuit is shown in Fig. 13. Begin the wiring by disconnecting the lead from the left terminal of the lamp socket.

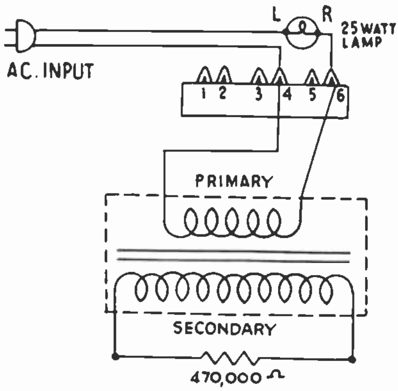


FIG. 13

The other end of this lead is soldered to terminal number 1. Do not unsolder this lead from terminal 1 but just let it hang free. There should now be only the AC input lead connected to the left terminal of the lamp socket.

Disconnect the lead that is fastened to the right terminal of the lamp socket. The other end of this lead is soldered to pin 7 of the tube socket. Do not unsolder this lead from pin 7 but just let it hang free. Connect a length of wire to the right side of the lamp socket, and solder the other end of the wire to terminal 6 of the terminal strip. This places the lamp in series with the AC input to the primary winding which is taken between terminals 4 and 6 on the terminal strip. The reason for using the lamp is to limit the current through the primary winding. The total current through the primary winding and the 25 watt lamp will be so small that the lamp will not light. Solder one of the primary coil wires to terminal 4 and solder the other lead of the primary to terminal 6 on the terminal strip. This completes the primary circuit of the transformer.

To one end of the secondary lead, solder one of the leads of the 470,000 ohm resistor as shown in Fig. 13. Solder the other end of this resistor to the other secondary lead. The 470,000 ohm resistor is now across the secondary winding and acts as a load resistor. Without a load resistor no current would flow in the secondary even if a voltage were applied to a primary winding.

Plug the AC line cord into the wall socket. There is now about 110 volts being applied across the primary at 60 cycles. The current being drawn by the primary is very small due to the series lamp. Touch the ends of the neon bulb leads which is in the pilot light socket to the primary leads of the transformer, between terminals 4 and 6 of the terminal strip. Note the degree of brightness. Now touch the neon bulb leads across the two terminals of the 25 watt lamp. Here the voltage is so small that the neon bulb will not light at all. Now touch the neon bulb leads across the 470,000 ohm resistor in the secondary and notice how bright it glows. This is a definite indication that there is a voltage step-up from the primary to the secondary of the transformer.

Set your voltmeter to read AC and measure the voltages in the circuit. Across the primary winding, from terminal 4 to 6 the reading is about 100 volts. This reading will vary slightly depending upon the input voltage from the AC line. Measure the voltage drop across the 25 watt lamp in the primary, and you will find that the voltage is about 10 volts. Here again the reading may vary slightly. Now measure the voltage drop across the 470,000 ohm resistor in the secondary circuit. Switch the meter to a higher range AC and touch the meter leads to the secondary winding. The voltage reading here is about 300 volts. So there is a voltage step-up of about 3 to 1 across the transformer. This indicates that the turns ratio is also about 3 to 1 because the ratio of voltage is equal to the ratio of the turns.

If there is 300 volts across a 470,000 ohm resistor, the current flow through the resistor can be found by use of Ohm's Law. (I=E/R.) Substituting these values in the formula and dividing, the current in the secondary is .000638 amperes. From the transformer formula, it is possible to calculate the current of the primary as being one-third of this value or .000212 amperes. Turn off the AC power.

Reverse the leads of the transformer as shown in Fig. 14. The secondary winding is now in series with the 25 watt lamp across the AC input source and the primary winding has the 470,000 ohm resistor across it. The transformer has now been reversed so that the input is applied across the secondary and the transformer will act

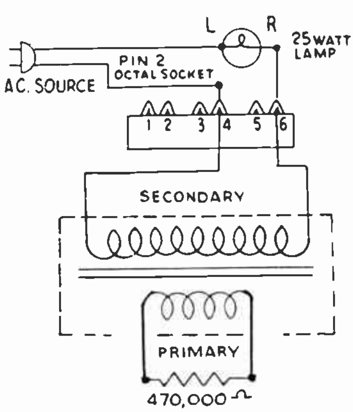


FIG 14

to step-down the voltage input. To wire this circuit, unsolder the primary leads from terminals 4 and 6 of the terminal strip. Also unsolder the 470,000 ohm resistor from across the secondary leads. Solder the secondary leads to terminals 4 and 6. Solder the 470,000 ohm resistor across the primary winding leads. When the circuit is wired, insert the AC plug into the wall socket to turn on the power. Test the input voltage to the transformer with the neon bulb. Place the leads of the bulb holder across terminals 4 and 6. The bulb will glow brightly. Now place the leads of the neon bulb across the 470,000 ohm resistor in the output of the transformer. Here the bulb will not light at all because the voltage induced is very small.

Measure the voltage drop across the two halves of the transformer with the meter. Between terminals 4 and 6, the meter, which is set to read AC, gives an input voltage of about 100 volts just as before. Now measure the output voltage across the 470,000 ohm resistor. Here the AC voltage reading has decreased to about 33 volts, indicating that the input voltage has been stepped down. It follows, therefore that the current in the secondary has been increased by the same ratio. In the previous circuit, the 300 volts across 470,000 ohms in the secondary the current was calculated to be .000638 amperes. In this circuit, the current is equal to the voltage, 33 volts, divided by the resistance, 470,000 ohms or .0000702 amperes, or 70.2 microamperes.

Remove the plug from the socket to turn off the power.

To restate the relationships in

the transformer; *the ratio of the number of turns of the primary to the number of turns in the secondary is directly proportional to the ratio of the voltage in the primary to the voltage across the secondary and inversely proportional to the ratio of the current in the primary to the current in the secondary.*

DEMONSTRATION No. 7
Mismatched Impedance

There are many complex actions and counter effects that take place within the windings of a transformer depending upon the voltage applied, the load, the coupling between primary and secondary, the frequency, etc. For example, in a previous demonstration, it was shown how the magnetic field induces a voltage in the secondary. The induced voltage in the secondary also produces a magnetic field which will cut the turns of the primary thereby causing a voltage to be induced. This is termed *reflected impedance*, because it can set up an opposing current. In electronic circuits, one of the principal uses of the transformer is as an impedance matching device. A good example of this is the output transformer that is used to couple the audio output of the last tube in a radio to the speaker. The output impedance of the tube is usually very high as compared to the low impedance of the speaker. The transformer is used to match the two. It acts as sort of a bridge so that the output power can be transferred to the speaker where it is converted from electrical energy into sound energy. If the output impedance is mismatched, the transformer is unable to function properly and the result in this case would be a distorted sound output. The subject of impedance matching is very complex and will be gone into in detail in later lessons. However, with the transformer arrangement you are using in this lesson, the effects can be clearly seen.

The circuit used is the same as in Fig. 13. The primary of the transformer is connected across the AC source in series with the 25 watt lamp. Disconnect the secondary leads from terminals 4 and 5 of the terminal strip and unsolder the 470,000 ohm resistor from across the primary winding. Solder one of the leads of the primary winding to terminal 4 and solder the other primary lead to terminal 6. The input circuit is now complete. Solder one end of the 470,000 ohm resistor to one of the secondary leads and connect the other end of the resistor to the other secondary lead. When the circuit is complete, the transformer is arranged to give a step up voltage ratio of 3 to 1. The 470,000 ohm resistor is the proper output or load impedance for this transformer so the circuit will operate normally. Turn on the AC power and observe the circuit operation. The current drawn from the primary is small and so the 25 watt lamp in series with the primary winding will not glow. The voltage across the primary winding is about 100 volts and across the secondary the voltage is about 300 volts AC.

Turn off the power and remove the 470,000 ohm resistor from across the secondary leads. In place of the 470,000 ohm resistor, solder a 680 ohm resistor. This will cause the impedance of the output to decrease thereby giving a bad mismatch. Now turn on the AC power. Note that the 25 watt lamp in the primary circuit now glows to about half its normal brightness. This indicates that there is a greater current in the primary circuit with the mismatched impedance in the secondary. From the transformer formula, given in the previous demonstration, it is clear that if the primary current has increased the primary voltage must decrease for the turns ratio has remained the same. Measure the voltage drop across the primary between terminal 4 and 6. Set the meter to read AC and touch the leads to the two terminals. The voltage across the primary has dropped to about 82 volts. Measure the voltage drop across the bulb between the two terminals on the socket. The voltage here has increased to about 24 volts AC. This change in the impedance of the primary has been caused by the 'reflected' impedance of the mismatched secondary. Measure the voltage across the 680 ohm resistor in the secondary circuit. The voltage will now be 15 volts AC. So the transformer is not acting normally at all, instead of giving a stepped up voltage ratio there is actually a step down ratio. The turns ratio has not changed because this is a physical property based upon the actual number of turns in each of the windings. The change in the transformer action that has taken place here is due to the load of the secondary being too small. In most transformers that are used without a current limiting resistor in the primary, a low impedance of this type across the secondary will overload the primary to such an extent that the current drain will be excessive causing the windings to burn and become open. If you will note, the core of the transformer does get warm after the circuit is in operation for a few minutes. Turn off the power. Disconnect the 680 ohm resistor from across the secondary and in its place solder a 15 megohm resistor.

Turn on the power. The current drain in the primary has decreased as indicated by the fact that the glow of the 25 watt lamp has decreased to the point where it can not be seen. Measure the voltage across the primary winding between terminals 4 and 6 and across the 15 megohm resistor in the secondary. You will find that the voltages are close to normal. The 15 megohm resistor is acting almost like an open circuit. The voltage drop across the primary is about 110 volts and across the secondary the voltage is about 320 volts AC.

The effect of placing too small a load across the primary of a transformer are most evident in the form of a voltage drop, and a current overload in the primary. Since the transformer is essentially a current operated device, this will cause the core to become saturated very easily and the action of the transformer to be very erratic. If too great a load is placed across the secondary, then the effect will be most evident in the frequency of the output rather than the voltage or current The voltages will be almost normal. In the case of a transformer where the frequency of the input is critical such as the intermediate frequency transformer in a television receiver, an overload will cause a distorted output. In the case of the television receiver, the effect would be seen in a distorted picture on the screen.

DEMONSTRATION No. 8

The Auto Transformer

The auto transformer is a special type which is used in electronic circuits where a large voltage with a small current drain is needed. In this transformer, part of the primary and secondary windings are physically common. Because of the fact that the windings are common the transformer can be easily overloaded. For this reason it is not often used as a power transformer. In radio circuits, it is used as a means of coupling between stages of an amplifier. In this case the transformer used is actually an inductance with a single tap placed somewhere off the center of the winding. The primary winding is made up of the turns between one end and the tap, and the secondary consists of the entire inductance.

Another place where this transformer is widely used is in the high voltage circuits of the television receiver. Here, a large voltage, about 20,000 volts is developed with a very small current. This large voltage is used to operate the picture tube. In this case, the transformer uses an iron core, and the frequency of the applied voltage is very high.

The iron core transformer which you are using in this lesson can be wired as an auto transformer. This circuit is shown in Fig. 15. Move the wire to the right terminal of the lamp (from terminal 6) to the left terminal of the lamp. Leave the other end of the wire connected to terminal 6 on the terminal strip. The full AC input voltage is now applied across terminals 4 and 6. The two leads of the primary winding of the transformer are connected across the AC input on terminals 4 and 6. In connecting the secondary leads, be sure to observe the way they are connected in the diagram. In other words the two windings must be connected series aiding. One of the secondary leads is connected to the opposite primary lead on terminal 6. The other secondary lead is connected to one end of a 470,000 ohm resistor. The free end of the 470,000 ohm resistor is soldered to terminal 4.

The primary of the auto transformer is the same as the primary of the step-up transformer. Trace out the secondary leads. Since the output load resistor is connected between one of the primary leads and one of the secondary leads, the secondary of the auto transformer consists of the entire windings of the transformer. This is shown in schematic form in Fig. 16. In Fig. 16 the terminal points are indicated to help you trace out the circuit. S-1 is the secondary of the step-up transformer and S-2 is the secondary of the auto transformer. When the circuit is wired, turn on the AC power.

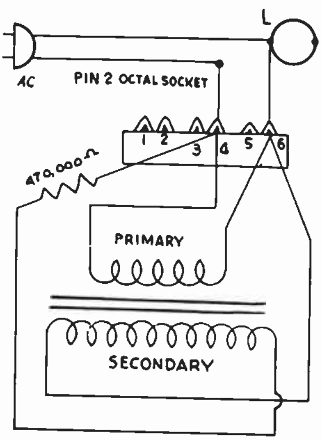


FIG. 15

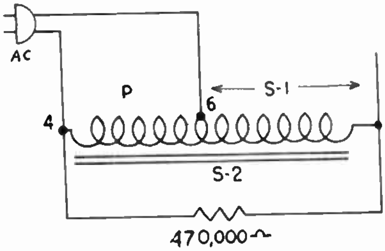


FIG. 16

Set the voltmeter to read AC and measure the input voltage. Since the primary winding is directly across the source, the input voltage will equal the voltage of the AC source. Now set the meter to a higher AC range and measure the output voltage of the auto transformer across the 470,000 ohm resistor. If the secondary is connected correctly (series aiding) the reading will be over 400 volts. The very large step-up ratio is due to the fact that the entire winding of the transformer is being used as a secondary. This action is also based on the transformer formula, for in this case, the turns ratio has been increased and so the output voltage has been increased. If you do not get the high output voltage reading in the secondary, you may have the leads of the transformer reversed. Be sure that you do not short the secondary leads together because in this circuit there is no current limiting resistor. If the secondary leads are shorted, the primary can be overloaded and may burn out.

Referring again to the current ratio in the transformer, if the voltage increases, the current will decrease. This is especially true in the case of the auto transformer. A very large output voltage has been generated, and so the available current in the secondary is very small. This is why the transformer has very poor current regulation and a large current is not available in the output. Once again connect the meter across the 470,000 ohm resistor in the secondary circuit of the auto transformer. The reading will be very high. Leave the meter leads attached across the load resistor and carefully touch the two leads of the neon bulb across the 470,000 ohm resistor. The bulb will glow, but because of the current being drawn by the neon bulb the output voltage will drop down to about one-fourth the value. Remove the neon bulb from across the load resistor and the voltage will again rise to its former value.

Turn off the AC power. Unsolder the secondary lead from terminal 6. Remove the 470,000 ohm resistor from the circuit and lay it aside. Remove the primary leads from terminals 4 and 6. The circuit is now completely disassembled.

DEMONSTRATION No. 9
The Resonant Circuit

The importance of resonance in tuned circuits has been emphasized in your lessons. The condition of resonance in an electric circuit is caused by the ability of both the coil and the condenser to store energy. The coil stores energy in the magnetic field as you have seen in the previous demonstrations. The condenser stores energy in the form of a voltage charge. Both of these components store energy for one half cycle and return it during the next half cycle. The condenser charges during the half cycle that the magnetic field of the coil is collapsing. The coil builds up its magnetic field during the half cycle that the condenser is discharging. At the resonant frequency these actions occur in such a manner as to aid each other. The coil and condenser pass their energy back and forth with a small loss due only to the internal resistance of the circuit components.

The voltage drop across the coil leads the current by 90 degrees while the voltage drop across the capacity lags the voltage by 90 degrees. In a series circuit, the current is the same through all circuit components. Since both the inductive and the capacitive reactance will vary with frequency there is one frequency value at which $X_L = X_C$ and at which the energy stored in the coil equals the energy stored in the condenser. This is the resonant frequency.

A series circuit is resonant at the frequency at which the inductive reactance of the circuit neutralizes the capacitive reactance so that the resulting impedance is due only to the resistance of the circuit.

In a series resonant circuit the voltage across the inductive reactance (E_L) and the voltage across the capacitive reactance (E_C) are equal and opposite. Therefore they will cancel each other and the only opposition to the flow of current will be the resistance of the circuit. Therefore the total current flow in the circuit will be maximum and the voltages across the inductive reactance and the capacitive reactance will be at their highest value at the resonant frequency. Where $E_L = E_C$ the applied voltage will appear across the resistance of the circuit. This is true regardless of the applied frequency. A series resonant circuit will therefore offer the least opposition to its resonant frequency and will offer a high opposition or impedance to all other frequencies. For this reason the series resonant circuit is often referred to as an *acceptor circuit.*

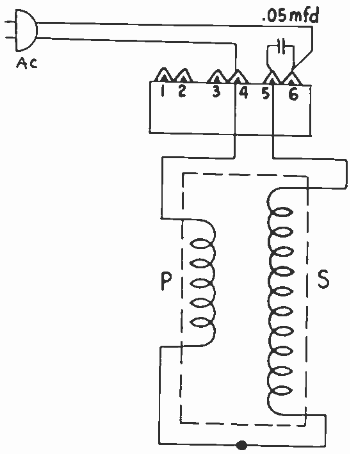


FIG. 17

As you have learned, in any AC circuit there are a number of variables each of which can affect the operation of the circuit. Since you are using a fixed frequency input, and a fixed value of inductance, the capacity of the series circuit will be varied and the effects noted. Remember that the capacitive reactance rises as the capacity decreases. First of all, a circuit in which the inductive reactance is greater than the capacitive reactance will be wired. This circuit is shown in Fig. 17.

Solder one of the leads of the primary to terminal 4 which is one side of the AC input. Connect the other primary lead to one of the secondary leads as shown in Fig. 17. The other lead to the secondary winding is connected to terminal 5. The transformer is now connected so that the primary and the secondary coils are in series to give the largest value of inductance. Solder one lead of a .05 mfd. condenser to terminal 5 and solder the other end of this condenser to terminal 6 which is the other AC input lead. This completes the series circuit. The only resistance in the circuit is the resistance of the windings of the two coils of the transformer. Turn on the AC power.

For this demonstration, assume that the inductance of the coil is 35 henries. This value takes into account, the mutual inductance of the iron core and the connection of the primary and the secondary winding in parallel. Measure the voltage drop across the inductance between terminals 4 and 5. Set the meter to read AC and touch the leads to these terminals. The meter will read about 160 volts. This is E_L. Now measure the voltage drop across the .05 mfd. condenser, between terminals 5 and 6. The reading will be about 50 volts AC. This is E_c. The greater voltage across the inductive reactance indicates that this value is greater than the capacitive reactance. X_c and X_L can be calculated using the formulas. The applied frequency is 60 cycles. Substituting in the formula $X_L=2\pi fL$ you will find that the inductive reactance is equal to about 13,198 ohms. The capacitive reactance of the .05 mfd. condenser at 60 cycles is about 5,307 ohms. The ratio of X_L to X_c is just about equal to the ratio of E_L to E_c which is as it should be.

Turn off the power and remove the .05 mfd. condenser from the circuit. In its place solder a .01 mfd. condenser between terminals 5 and 6. Calculate the value of X_c using a .01 mfd. condenser at 60 cycles. You will find the value of the capacitive reactance is now about 26,539 ohms. The value of X_L has not changed. So with a .01 mfd. condenser in the circuit, the ratio of X_L to X_c is about 2 to 1. Therefore the ratio of the voltage drops across these two components will be about the same. The voltage across the condenser will be about twice that of the coil. Turn on the AC power and measure these voltages. Across the coil, between terminals 4 and 5 the voltage reading is about 120 volts AC. Across the condenser the voltage reading, between terminals 5 and 6 is about 225 volts. So the ratio of E_L to E_c is just about equal to the ratio of X_L to X_c. The capacitive reactance is now greater than the inductive reactance so the greatest voltage drop will be across the largest component.

Turn off the AC power and remove the .01 mfd. condenser from the circuit. In its place, solder a .02 mfd. condenser, between terminals 5 and 6.

Once again calculate the value of the capacitive reactance. Substituting the values .02 mfd. and 60 cycles into the formula $X_c=1/2\pi fc$ you will find that the value of the capacitive reactance is now about 13,280 ohms, or just about equal to the inductive reactance. Since X_L now equals X_c this is a resonant series circuit. Turn on the AC power. Set the meter to a higher range AC voltage scale and measure the voltage drop across the coil between terminals 4 and 5. You will read a very high value of voltage, somewhere near 500 volts. Now measure the voltage drop across the capacity between terminals 5 and 6. The voltage reading here will also be the same high value. Since this is a series resonant circuit, these two voltages are equal and opposite in direction. Therefore if the voltage across both components is measured, the reading will be equal to the line voltage. Measure the voltage across both components between terminals 4 and 6. The reading is the line voltage. This is the voltage drop that appears across the resistance in the circuit. So the total impedance of the series resonant circuit is equal to the resistance of the components. The greatest current will flow in the circuit at this resonant frequency. This current is still quite small as the internal resistance of the coils and the condensers is quite high. Turn off the AC power by removing the line cord from the wall socket.

In later lessons you will use the coil and condenser combination to give a resonant circuit for various frequencies with various oscillator circuits. Both series and parallel resonant circuits will be used. *In a parallel resonant circuit, the total current supplied by the source of power is less than the current flow in either branch of the circuit.* In order to demonstrate this effect it would be necessary to have three ammeters, one in the line, one in the inductive branch and one in the capacitive branch. However, the decrease in the total current at resonance can be seen by use of the neon bulb.

Unsolder the end of the .02 mfd. condenser that is connected to terminal 6 and solder it to terminal 4. Now unsolder the lead from the secondary of the transformer that is connected to terminal 5 and let it hang free. Solder the two leads of the neon bulb socket to terminals 5 and 6. This will place

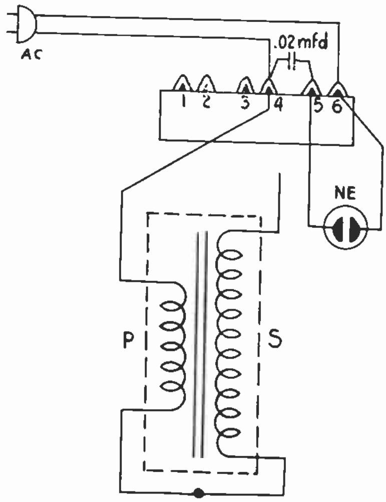


FIG. 18

the neon bulb in series with the condenser across the AC input terminals 4 and 6. The circuit is shown in Fig. 18. Turn on the AC power.

Note the brilliance of the neon bulb with just the condenser in the circuit. The brilliance of the bulb indicates the amount of current flow in the circuit. Now carefully touch the free end of the secondary winding to terminal 5. This will place the inductance in parallel with the condenser. From the previous calculations, you know that the capacitive and the inductive reactances are equal so this will form a resonant circuit. Note how the brilliance of the lamp decreases as the coil is placed in the circuit. This indicates that the current flow in the circuit has decreased. Turn off the AC power.

In a parallel resonant circuit, the only current drawn from the line is a small, in phase current (at the resonant frequency) which supplies the losses of the circuit. The energy transfer from the coil and the condenser is enough to keep a large current flowing in the parallel circuit. A parallel resonant circuit offers a high impedance to its resonant frequency and a low impedance to all other frequencies.

DEMONSTRATION No. 10
Filter Circuits

In your earlier lessons, you have studied choke coils, filter systems, choke-input filters, condenser input filters and the effects of the various combinations of reactance and capacity in smoothing out the pulsating DC from the rectifier tube. To demonstrate these effects, the rectifier circuit is used. This circuit is the same as was wired in the first demonstration, and is shown in Fig. 1. Because of the number of changes that have been made in the circuit in this lesson, the wiring is reviewed.

Unsolder the leads of the 0.02 mfd. condenser from terminals 4 and 5 and also the leads to the transformer winding which are connected to these same terminals. Unsolder the wire from between pin 2 of the tube socket and terminal 4. Remove this wire from the circuit. Pin 2 should now have only the AC input lead soldered to it.

Remove the wire from terminal 6 and the left side of the lamp socket. Reconnect the lead from terminal 1 to the left side of the lamp socket. Also reconnect the lead from pin 7 of the tube socket which was left hanging, to the right terminal of the lamp socket. There should now be two leads to the left terminal of the lamp socket and only one lead to the right terminal. Check your wiring with Fig. 1. The connections to the terminal strip are shown in Fig. 19. Solder a 680 ohm resistor between terminals 4 and 5. This will be used in series with the neon lamp in this demonstration. Solder the black test lead to terminal 4 and the red test lead to terminal 6, as shown in Fig. 19.

When you have correctly completed the wiring, turn on the power. After the rectifier tube has had time to heat, touch the black test lead to terminal 1 and touch the red test lead to terminal 3. The neon bulb with the 680 ohm resistor in series is now across the filtered output of the rectifier. The neon bulb will glow brightly because of the large current being drawn by the 680 ohm resistor. Only one side of the bulb will glow, indicating that the output is direct current. Remove the test leads from the terminals 1 and 3 and turn off the power.

The filter circuit that is now being used consists of two condensers in parallel and a resistor in series. The output of the rectifier tube is a pulsating DC. This voltage consists of the positive half cycles of the alternating current input. The purpose of the filter circuit is to smooth out these pulsations to give as pure a direct current as possible for use in an electronic circuit. The amount of filtering depends upon the components used and their arrangement in the circuit.

The amount of filtering can be measured by means of an 'output

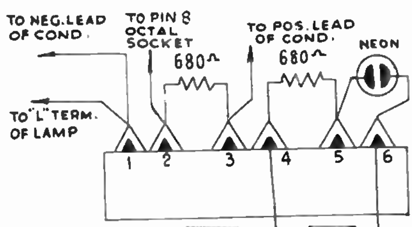


FIG.19

meter.' This consists of an AC voltmeter with a 0.25 mfd. condenser in series with one of the leads. The 0.25 mfd. condenser will block the DC and allow only the AC to pass. Solder one end of a 0.25 mfd. condenser to terminal 6. Fasten one of the leads of the voltmeter to the other end of this 0.25 mfd. condenser. Set the meter to the AC range. Use a medium voltage scale until you are sure of what the reading will be. Turn on the power and allow the rectifier tube time to begin to operate. Fasten the black test lead from terminal 4 to terminal 1. Touch the red test lead to terminal 3. The neon bulb will now glow. Leave these two leads fastened to terminals 1 and 3 and touch the free meter lead to terminal 4. The AC meter with the 0.25 mfd. condenser in series is now across the output. The voltage reading will be very small as the meter is measuring the amount of AC ripple only and not the DC output. The reading will be less than 1 volt indicating that the circuit has good filtering. Remove the meter lead from terminal 5. Also remove the red and black test leads from terminals 1 and 3. Turn off the power.

To check the filtering with just a single condenser in the circuit, unsolder the end of the 680 ohm resistor that is connected to terminal 2. Turn on the power. Fasten the black test lead to terminal 1. Fasten the red test lead to terminal 2. The neon bulb will again glow on one side only giving no indication that the filtering of the circuit has varied. Now touch the free meter lead to terminal 4. Once again the meter with the 0.25 mfd. condenser in series is across the output. The

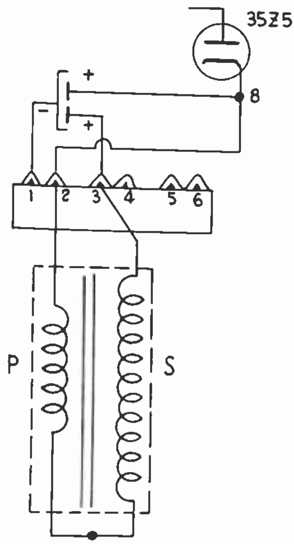


FIG. 20

voltage reading has now increased to about 2 volts AC. This indicates that the single condenser has very poor filtering action. Turn off the power and remove the test leads from terminals 1 and 2.

Now unsolder the other end of the 680 ohm resistor that is connected to terminal 3. In place of the 680 ohm resistor, solder the leads of the transformer as shown in Fig. 20. The primary and the secondary of the transformer are connected in series so that the transformer will act as a choke. Turn on the power and again fasten the black test lead to terminal 3. Now touch the free lead of the meter to terminal 4. The filtering action of the circuit with the coil and the two condensers in a 'Pi-Type' circuit arrangement is very good. There is no indication of any AC at all. This indicates that the combination of the two condensers and the coil has effectively filtered out all of the pulsations. This is the type of filter circuit arrangement that you will find is most widely used in electronic circuits.

Turn off the AC power. Remove the red and black test leads from terminals 1 and 3. Unsolder the other end of the test leads from terminals 4 and 6. Also unsolder the 680 ohm resistor from terminals 4 and 5. Leave the neon bulb connected to terminals 5 and 6. The rectifier circuit with the pi-type filter as you now have it wired will be used in the next lesson as a source of high DC voltage. The voltage output is about 148 volts and as you have seen in this demonstration the filtering action is very good.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. The strength of the magnetic field of a coil depends upon what two main factors?

No. 2. To produce a constant magnetic field, must a coil have AC or DC current flowing through it?

No. 3. What is the effect of increasing the number of turns on the magnetic field of a coil?

No. 4. When the voltage source is removed from the circuit shown in Fig. 6, the neon bulb will flash. What causes this to occur?

No. 5. Will the inductive reactance of a coil increase or decrease when the inductance is decreased?

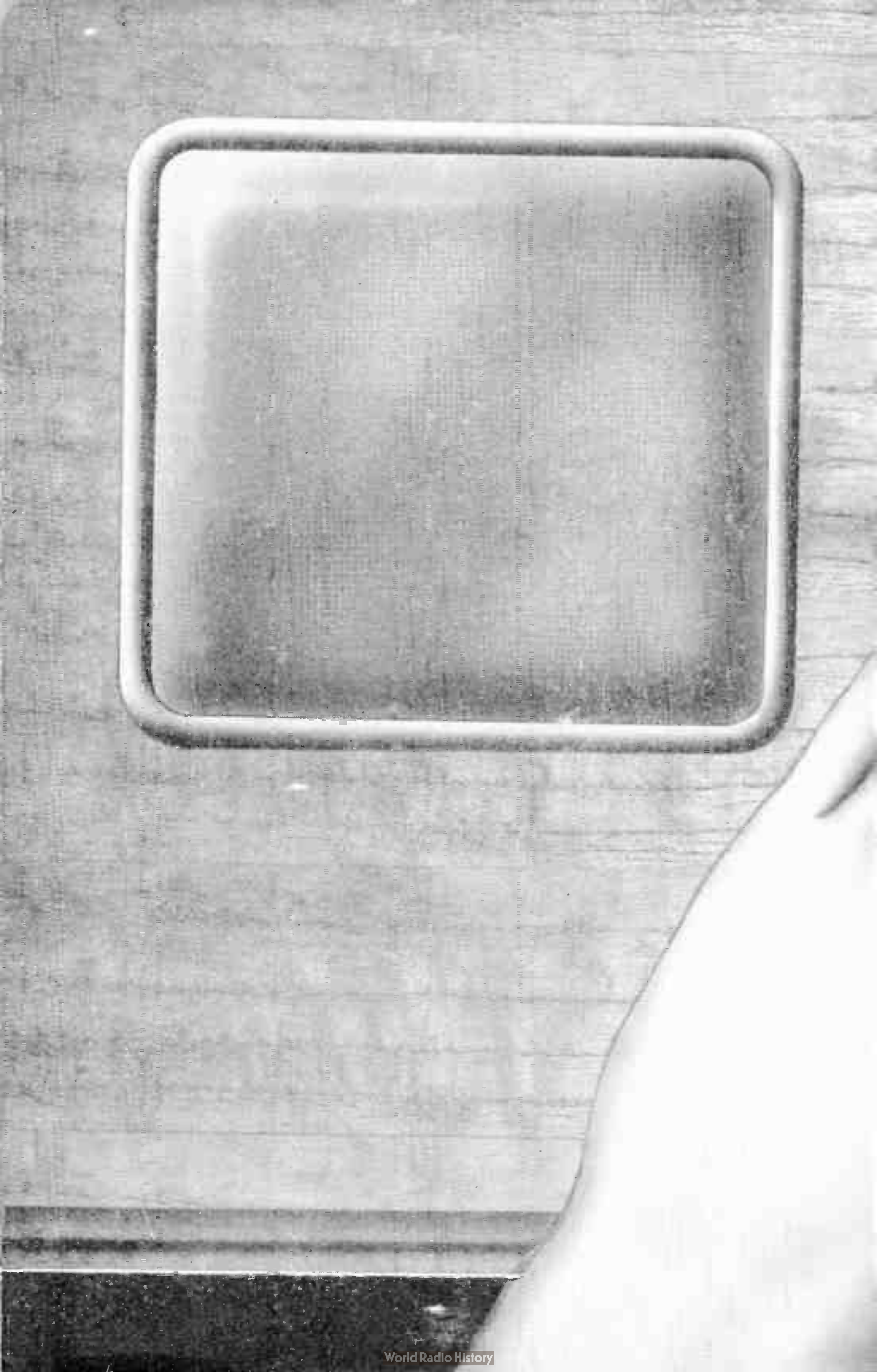
No. 6. A step-up transformer has a turns ratio of 1-10. If 10 volts is applied to the primary, what will the secondary voltage be?

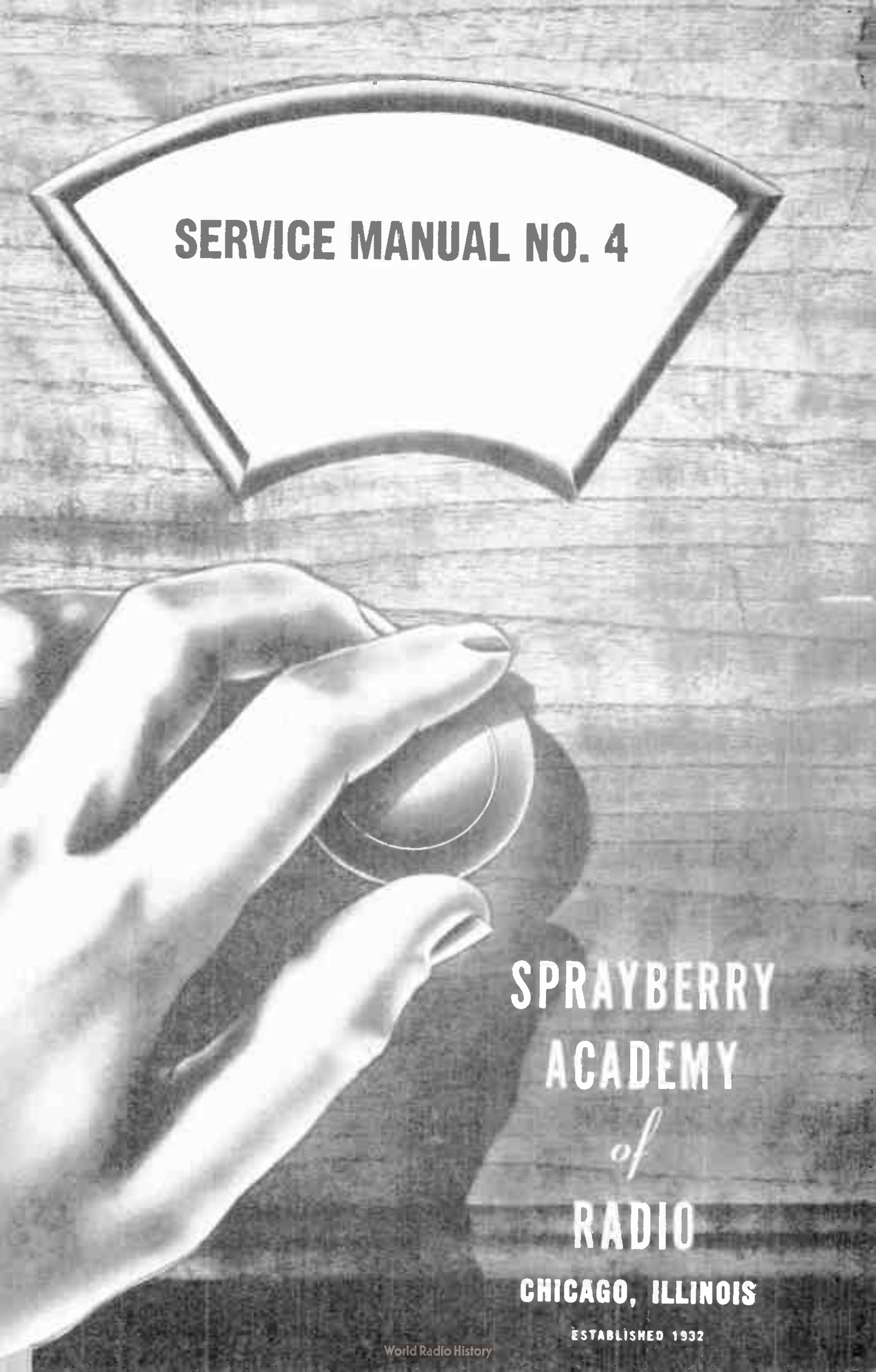
No. 7. How must the voltage drops in a circuit containing resistance and reactance in series be added in order to obtain the correct value of total voltage?

No. 8. How does an auto transformer differ from an ordinary transformer?

No. 9. Why is the impedance of a series resonant circuit equal to the resistance of the circuit only?

No. 10. Does a coil have inductive reactance when direct current flows through it?





SERVICE MANUAL NO. 4

SPRAYBERRY
ACADEMY
of
RADIO

CHICAGO, ILLINOIS

ESTABLISHED 1932

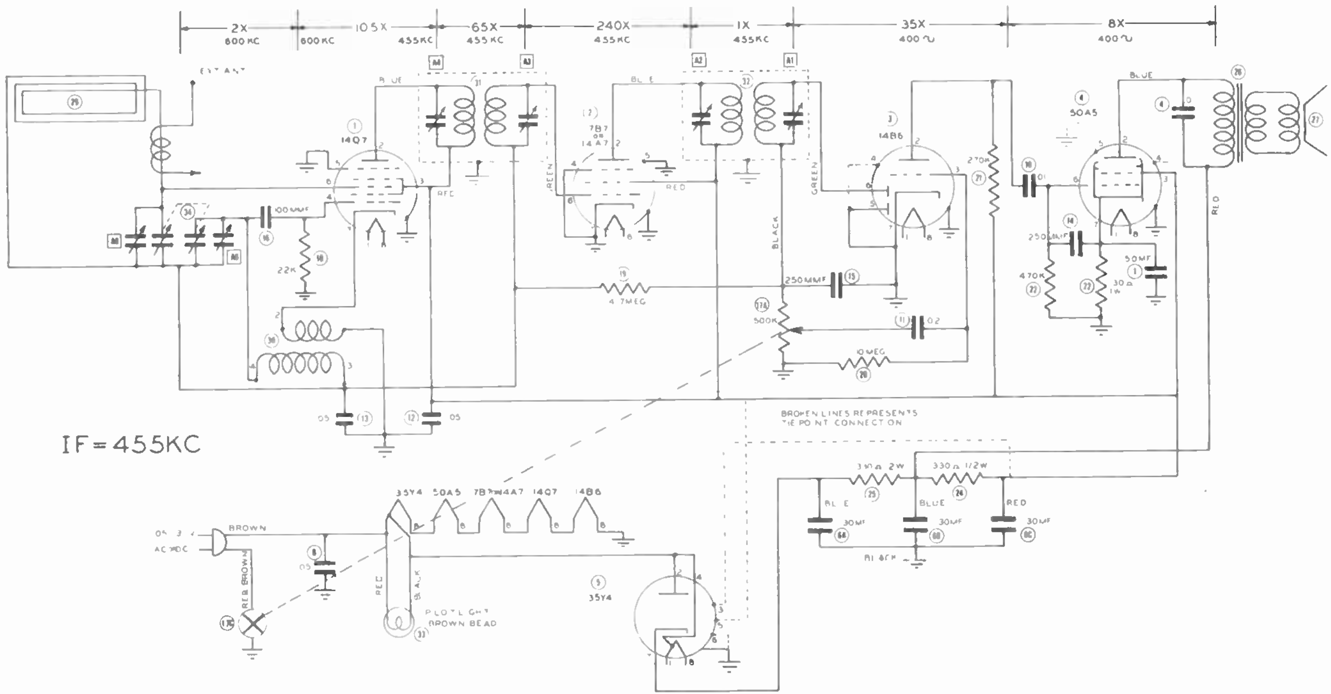
SERVICE MANUAL NO. 4

This is the fourth in a series of Service Manuals of wiring diagrams and service information on radio receivers in general use.

The following brief descriptions of these receivers may be used as references for the purpose of comparison and analysis of similar receiver circuit types.

PREMIER

MODEL 15LW



2

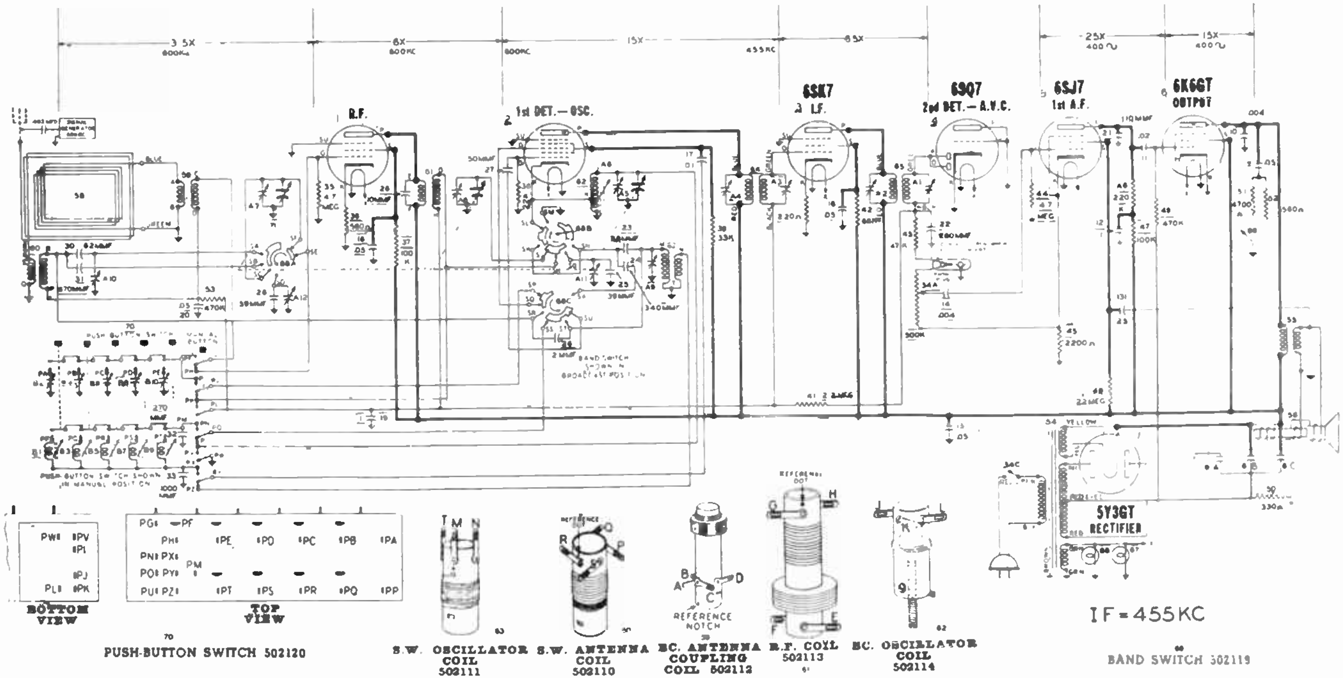
IF=455KC

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	14Q7	27VAC	87VAC	87VDC	47VDC	0V	-.35VDC	0V	35VAC
2	7B7	33.5VAC	87VDC	87VDC	0V	0V	.35VDC	0V	27VAC
3	14B6	13.5VAC	55VDC	.65VDC	0V	0V	.75VDC	0V	0V
4	50A5	84VAC	88VDC	87VDC	95VDC	0V	0V	48VDC	33.5VAC
5	35Y4	117VAC	12VAC	87VDC	2VA	87VDC	0V	5VDC	84VAC

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	14Q7	24Ω	75KΩ	75KΩ	20KΩ	0Ω	4.5MEG	5Ω	125Ω
2	7B7	30Ω	75KΩ	75KΩ	0Ω	0Ω	4.5MEG	0Ω	24Ω
3	14B6	12.5Ω	340KΩ	8MEG	0Ω	0Ω	530KΩ	0Ω	0Ω
4	50A5	73Ω	75K	75KΩ	75KΩ	0Ω	520KΩ	115Ω	30Ω
5	35Y4	100Ω	97Ω	75KΩ	97Ω	75KΩ	0Ω	75KΩ	73Ω



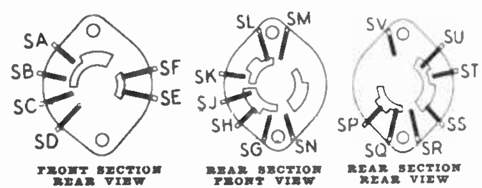
The [illegible] values listed above are approximate values [illegible]

1 – Use the 60 [illegible] signal with [illegible] cycle mod [illegible]

2 – For RF and [illegible] measurements [illegible] negative terminal [illegible] positive terminal [illegible]

3 – [illegible] carefully tuned [illegible] signal [illegible]

The audio system of this receiver utilizes a [illegible] feed-back arrangement [illegible] necessary to replace the speaker or output transformer [illegible] feed-back circuit. If the connections of the output transformer are reversed [illegible] the system will be [illegible] primary of the output transformer.

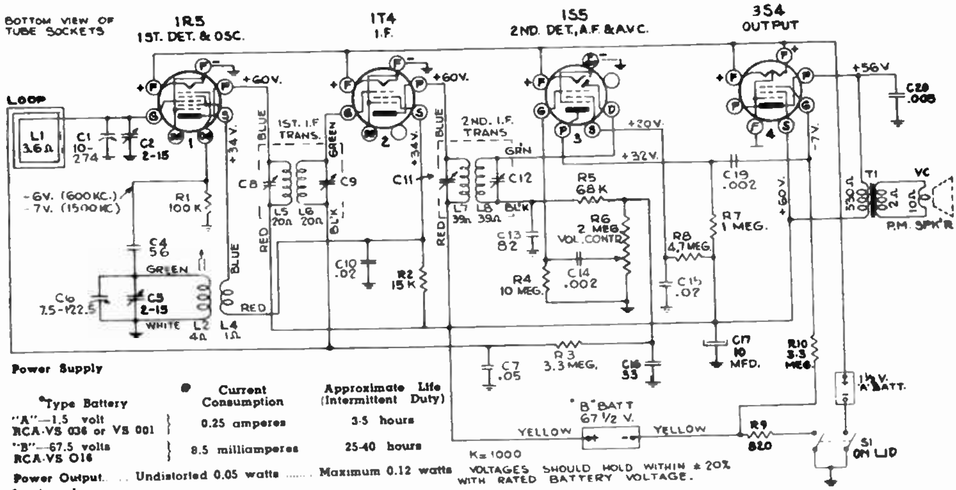


3

PURITAN

RCA

MODELS 54B1 54B1-N 54B2 54B3
CHASSIS RC-589



K=1000 VOLTAGES SHOULD HOLD WITHIN ± 20% WITH RATED BATTERY VOLTAGE.

ALL VOLTAGES ARE MEASURED WITH RESPECT TO CHASSIS GROUND.

Power Supply

*Type Battery	Current Consumption	Approximate Life (Intermittent Duty)
"A"—1.5 volt RCA-VS 036 or VS 001	0.25 amperes	3-5 hours
"B"—67.5 volts RCA-VS 016	8.5 milliamperes	25-40 hours

Power Output ... Undistorted 0.05 watts ...... Maximum 0.12 watts

Loudspeaker

Type Permanent-Magnet Dynamic Elliptical .... 2 x 3 in.

Voice Coil Impedance .... 1¾ ohms at 500 cycles

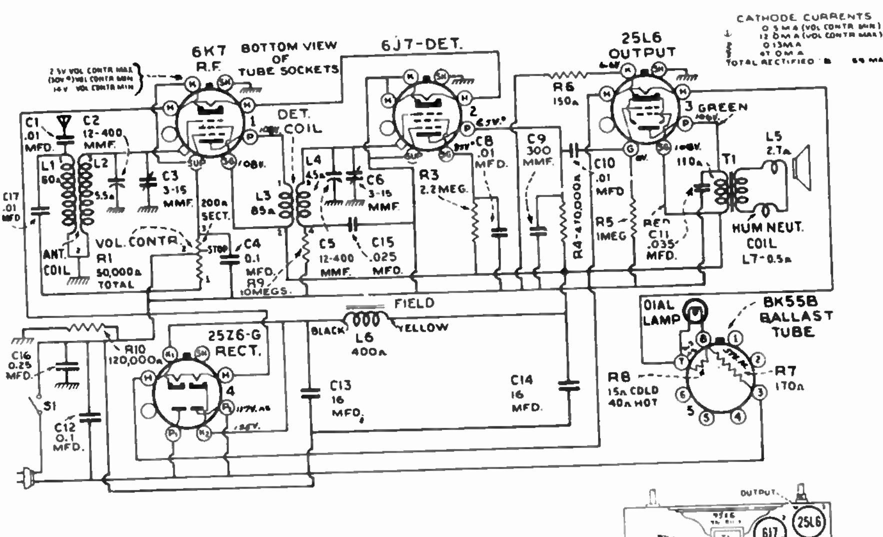
Cabinet Dimensions (inches) .... 3-3/16 x 6½ x 4-3/16

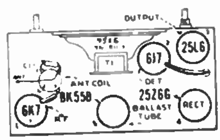
Weight ... 3¼ lbs. (net) Tuning Drive Ratio ....1 to 1

Frequency Range .... 550-1,600 kc

Intermediate Frequency .... 455 kc

MODEL 95X6

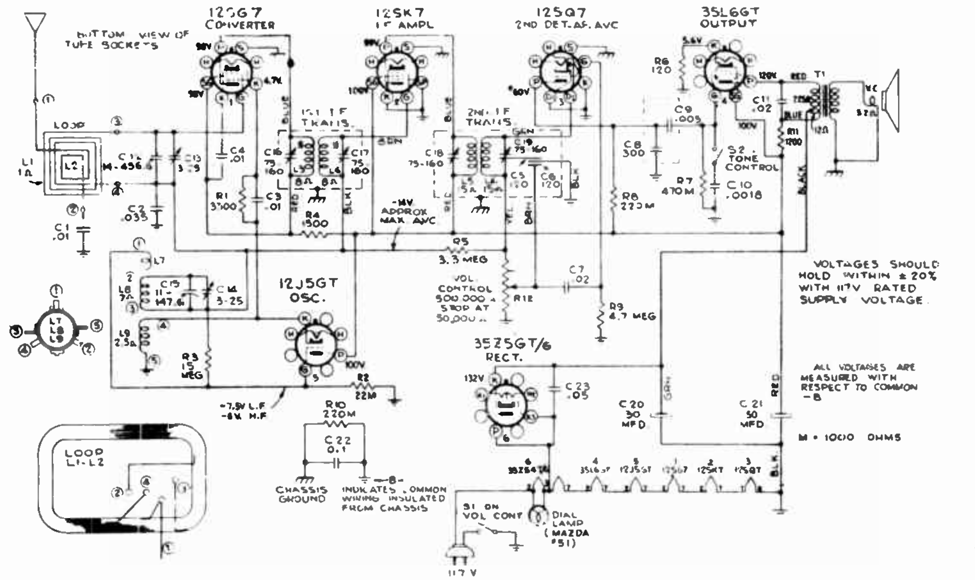




MODELS 56X 56X2 56X3 61-1 61-2 61-3

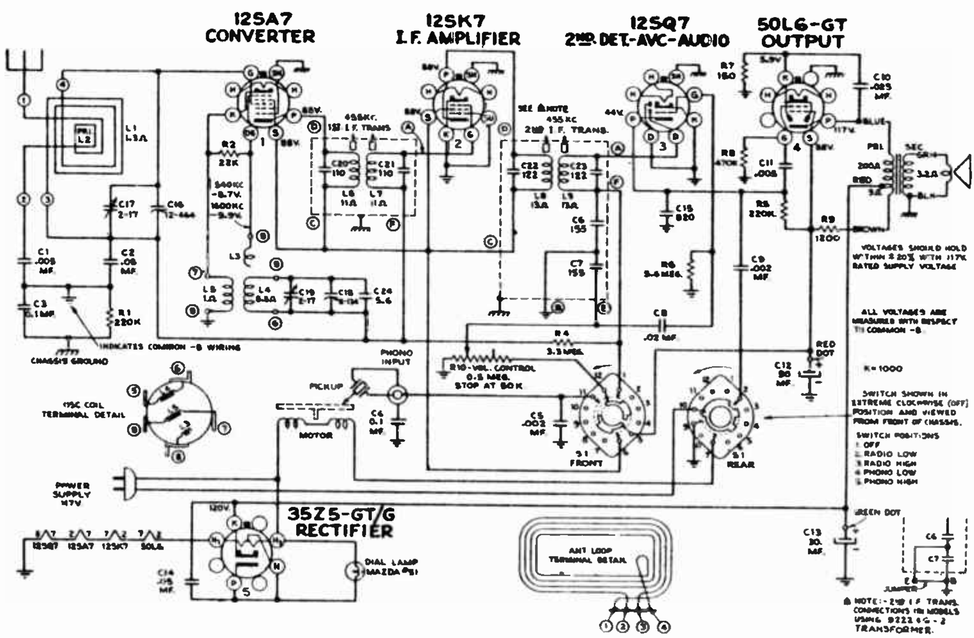
CHASSIS RC-1011

RCA

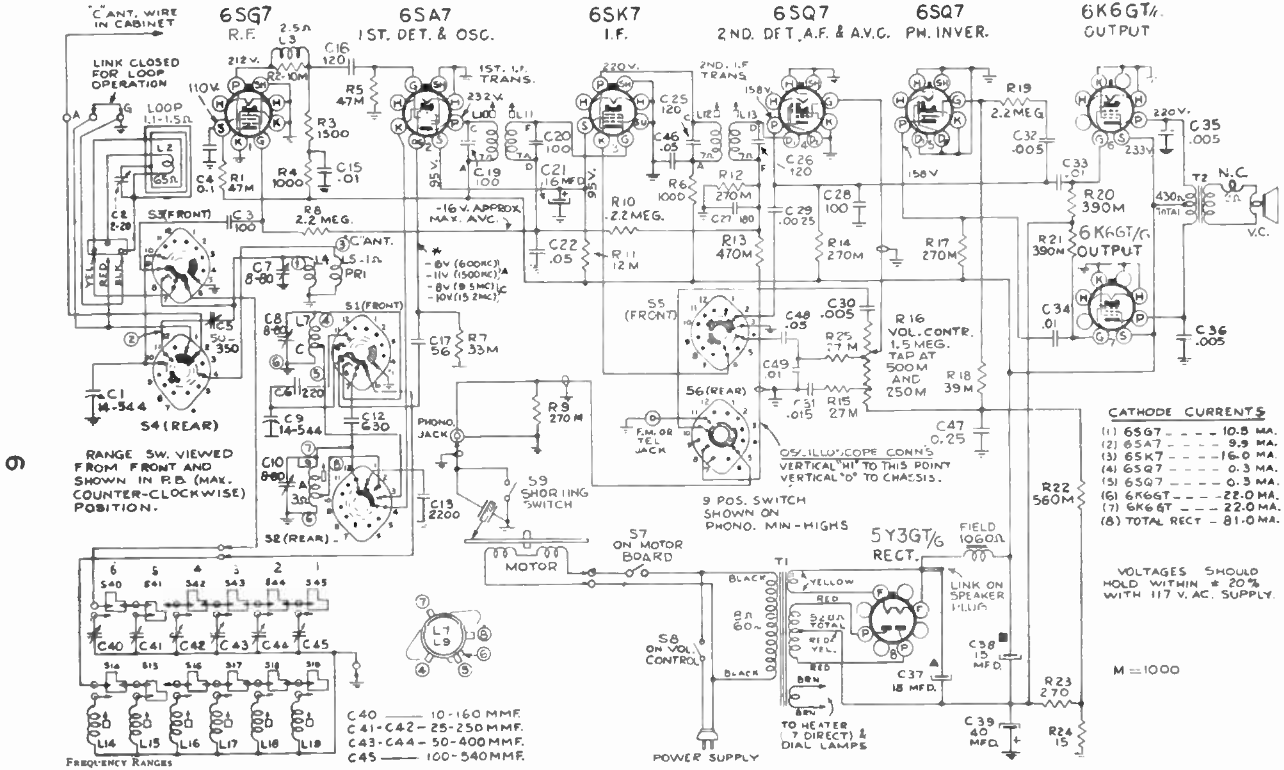


MODELS 55U 55AU

CHASSIS RC-1017



MODELS 58V 58AV CHASSIS RC-604



Frequency Ranges
Standard Broadcast "A" — 540-1,600 kc
Short Wave "C" — 9.4-15.4 mc

Intermediate Frequency — 455 kc

Power Supply Rating
105-125 volts, 60 cycles — 115 watts

Pilot Lamps — (2) Mazda No. 51, 6-8 volts, 0.2 amps

Compartment Lamp — (1) Mazda No. 55, 6-8 volts, 0.4 amps

Loudspeaker
Electrodynamic — 92512-1
Size — 12-inch
V.C. impedance at 400 cycles — 2.2 ohms

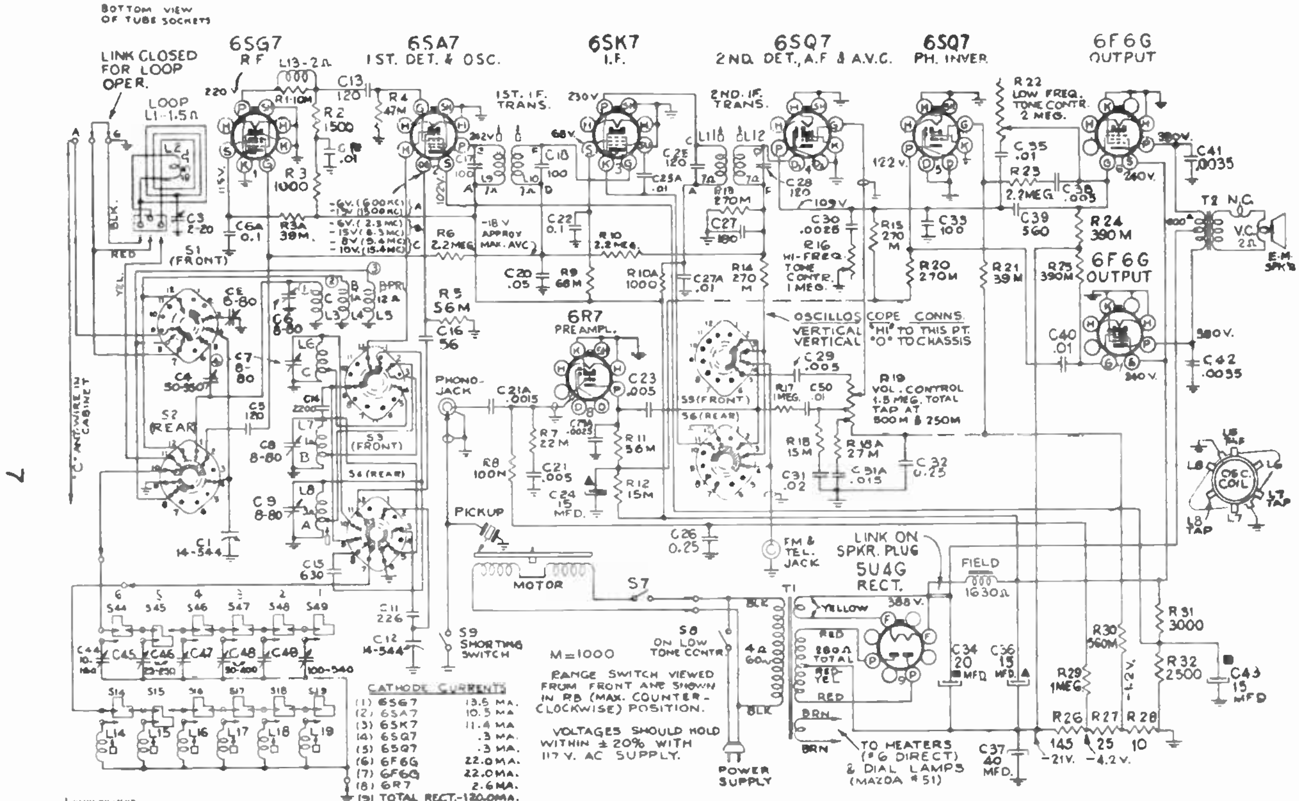
Power Output Rating
Undistorted — 5 watts
Maximum — 5.5 watts

Phonograph*
Type — Automatic 960001-1
Record Capacity — Fourteen 10-in., Twelve 12-in.
Turntable — 78 r.p.m. type
Type Pickup — Crystal
Motor Power consumption (125 v. 60 cycles) — 30 watts

*This mechanism can be converted to operate on 50 cycles.

RCA

MODELS 59VI 59AVI CHASSIS RC-605



7

IF PEAK 455 KC

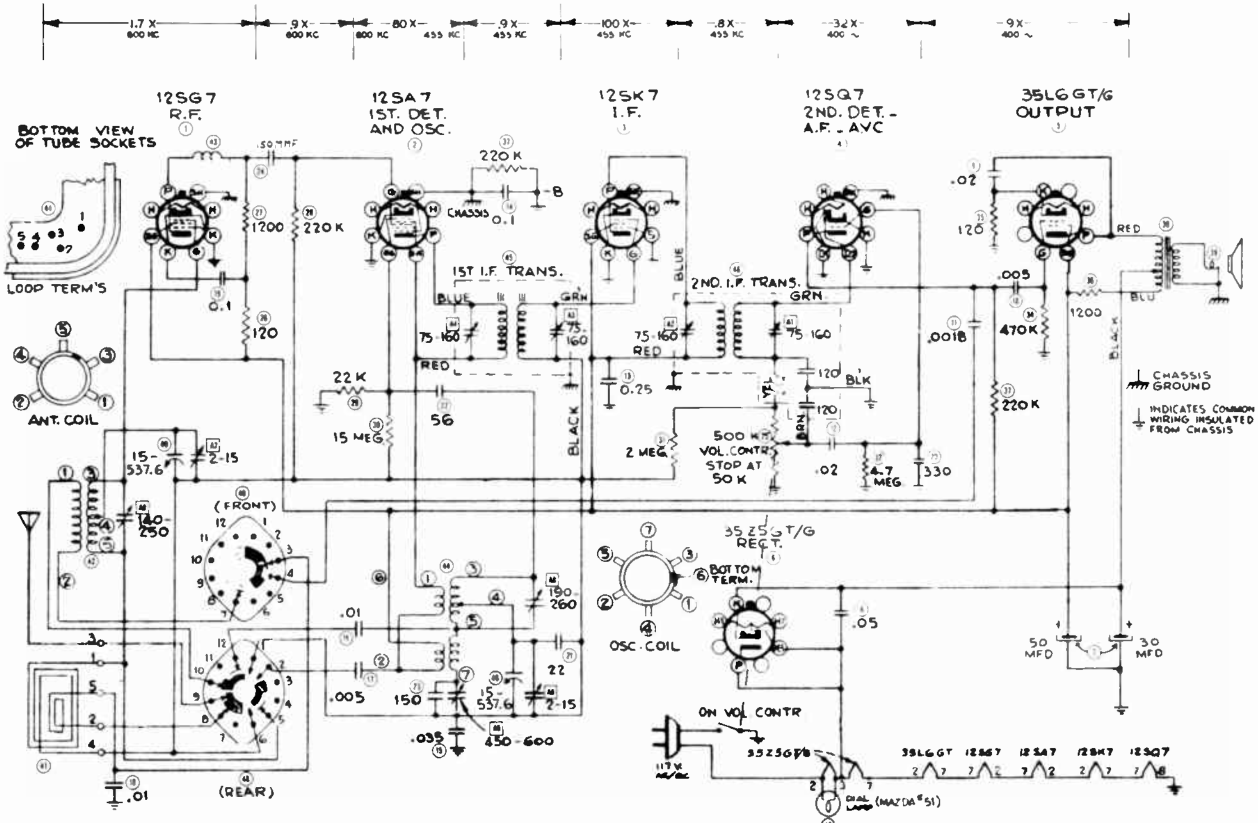
Loudspeaker	
Type	12 [illegible] dynamic
Voice Coil Impedance	2.2 ohms at 400 cycles
Identification Number	92513-1
Power Supply Rating	
105-125 volts, 50-60 cycles	145 watts*
Pilot Lamps	(3) Mazda No. 51, 6.8 volts, 0.2 amps
Chassis Base Dimensions (inches)	[illegible] 11 [illegible] 10 [illegible]
Over all Chassis Height (inches)	7
Tuning Drive Ratio	18-1

Frequency Ranges	
Standard Broadcast (A)	540-1,600 kc
Medium Wave (B)	2,300-8,300 kc
Short Wave (C)	9,400-15,400 kc
Intermediate Frequency	455 kc
Power Output Rating	
Undistorted	10 watts
Maximum	12 watts

AUTOMATIC CHANGER

Type Pickup	Crystal
Record Capacity	Fourteen 10 in., Twelve 12 in.
Power Consumption (125 v., 60 cycles)	90 watts

*This instrument can be converted to operate on 50 cycles.



IF=455KC

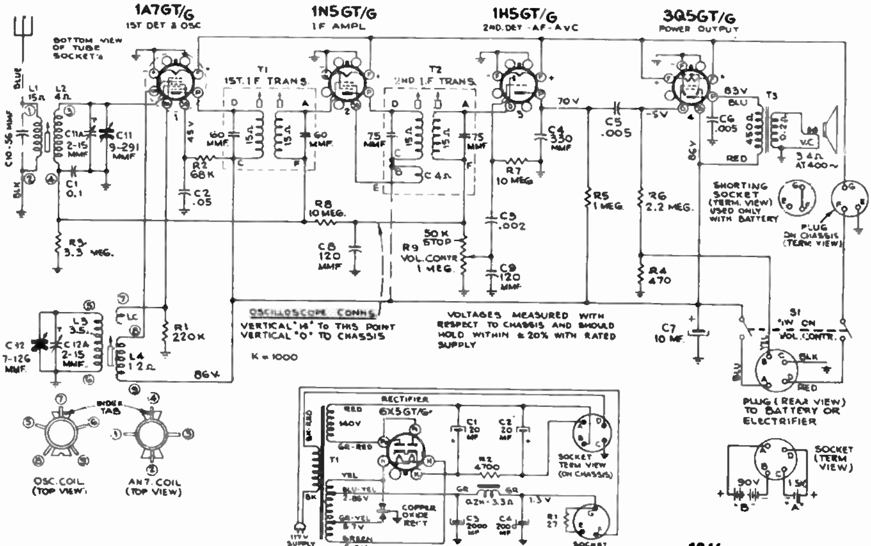
VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SG7	-1 V.DC	38 V.AC	0V.	-.6 V.DC	0V.	85 V.DC	50 V.AC	77 V.DC
2	12SA7	-1 V.DC	24 V.AC	84 V.DC	85 V.DC	-4 V.DC	0V.	38 V.AC	-1.5 V.DC
3	12SK7	-1 V.DC	24 V.AC	0V.	-.6 V.DC	0V.	85 V.DC	12 V.AC	85 V.DC
4	12SQ7	-1 V.DC	-.5 V.DC	0V.	-.4 V.DC	0V.	60 V.DC	12 V.AC	0V.
5	35L6GT	0V.	88 V.AC	118 V.DC	85 V.DC	0V.	124 V.DC	50 V.AC	4.8 V.DC
6	35Z5GT	0V.	117 V.AC	113 V.AC	0V.	113 V.AC	84 V.DC	88 V.AC	124 V.DC

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SG7	190 KΩ	37Ω	0Ω	.9 MEG.	0Ω	90 KΩ	46Ω	90 KΩ
2	12SA7	190 KΩ	24Ω	90 KΩ	90 KΩ	23 KΩ	0Ω	37Ω	2 MEG.
3	12SK7	190 KΩ	24Ω	0Ω	.9 MEG.	0Ω	90 KΩ	2Ω	90 KΩ
4	12SQ7	190 KΩ	4.8 MEG.	0Ω	460 KΩ	0Ω	310 KΩ	12Ω	0Ω
[illegible]	35L6GT	INF.	77Ω	90 KΩ	90 KΩ	400 KΩ	90 KΩ	46Ω	110Ω
6	35Z5GT	INF.	102Ω	100Ω	INF.	100Ω	70 KΩ	77Ω	90 KΩ

MODELS 64F1 64F2 64F3 CV45



Frequency Range 540 KC.—1600 KC.
Intermediate Frequency 455 KC.

Tube Complement

(1) RCA—1A7 GT/G ... 1st Det. Oscillator
(2) RCA—1N5 GT/G ... IF Amplifier
(3) RCA—1H5 GT/G ... 2nd Det., A.V.C., and A-F Amplifier
(4) RCA—3Q5 GT/G ... Power Output

Power Output Rating

Undistorted ... 160 MW.
Maximum ... 270 MW.

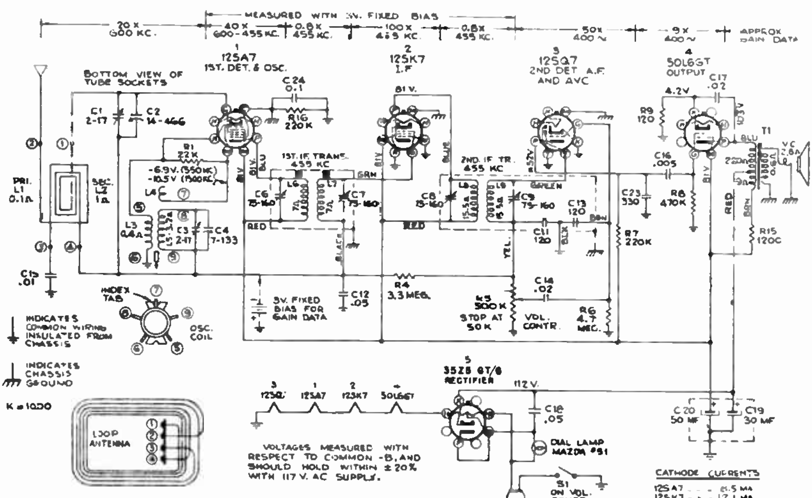
Loudspeaker (922258-2)

Size ... 4 x 6 inch PM
V.C. impedance at 400 cycles ... 3.4 ohms

Power Supply Rating

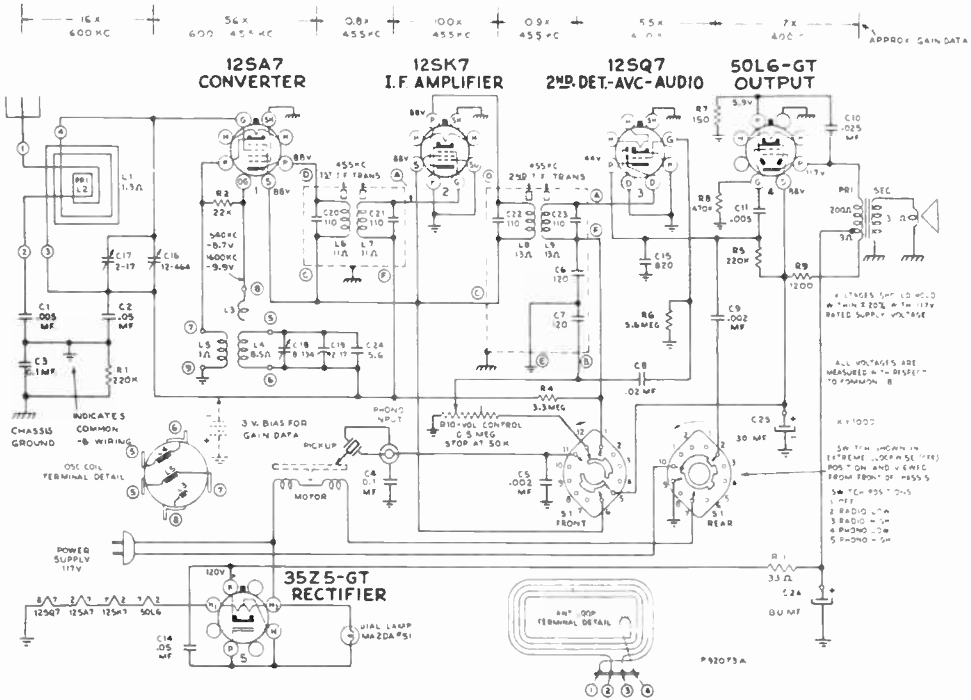
(1) RCA Farm Battery Pack—VS022 or equivalent. "A" Battery 1½ volts, Drain—0.24 amperes, "B" Battery 90 volts, Drain—10.5 MA.
(2) Electrifier—(CV-45) 105 to 125 volts AC, 50-60 cycles only.

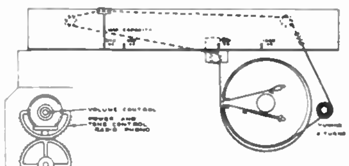
MODELS 65X1 65X2
CHASSIS RC-1034



Power Supply Rating
105-125 volts, AC, 50 or 60 cycles, or DC

30 watts





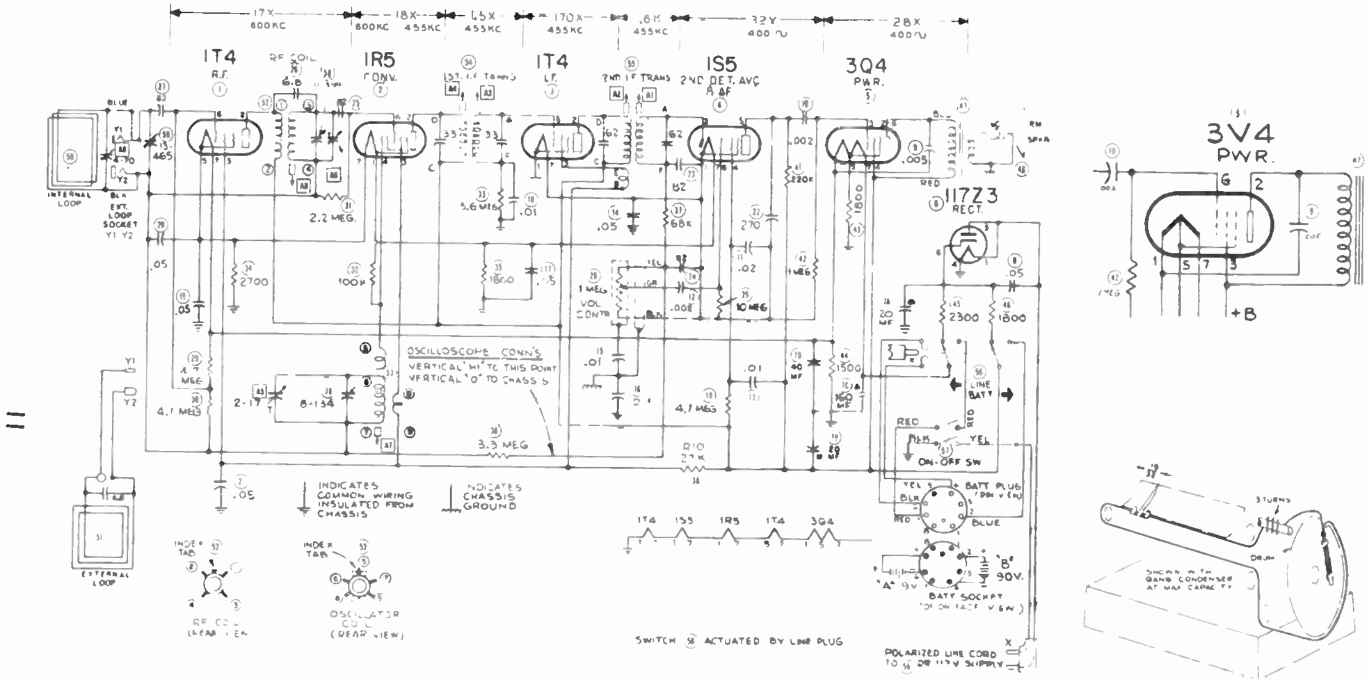
Dial Pointer Adjustment.—Rotate tuning condenser fully counter-clockwise (plates fully meshed). Adjust indicator pointer to left (max. cap.) mark on dial back plate.

Frequency Range	540-1,600 kc
Intermediate Frequency	455 kc
Power Output	
Undistorted	1.5 watts
Maximum	2.4 watts
Loudspeaker (922279-1) "PM"	
Size	4 x 6 inch elliptical
V.C. Impedance	3.4 ohms at 400 cycles
Power Supply Rating	
105-125 volts, AC, 60 cycles	60 watts

IMPORTANT—Do not plug chassis into a d-c power supply.

REFER TO SERVICE DATA FOR MODEL 960260-2 FOR INFORMATION AND PARTS ON RECORD CHANGER

MODELS 66BX
CHASSIS RC-1040, 1040A

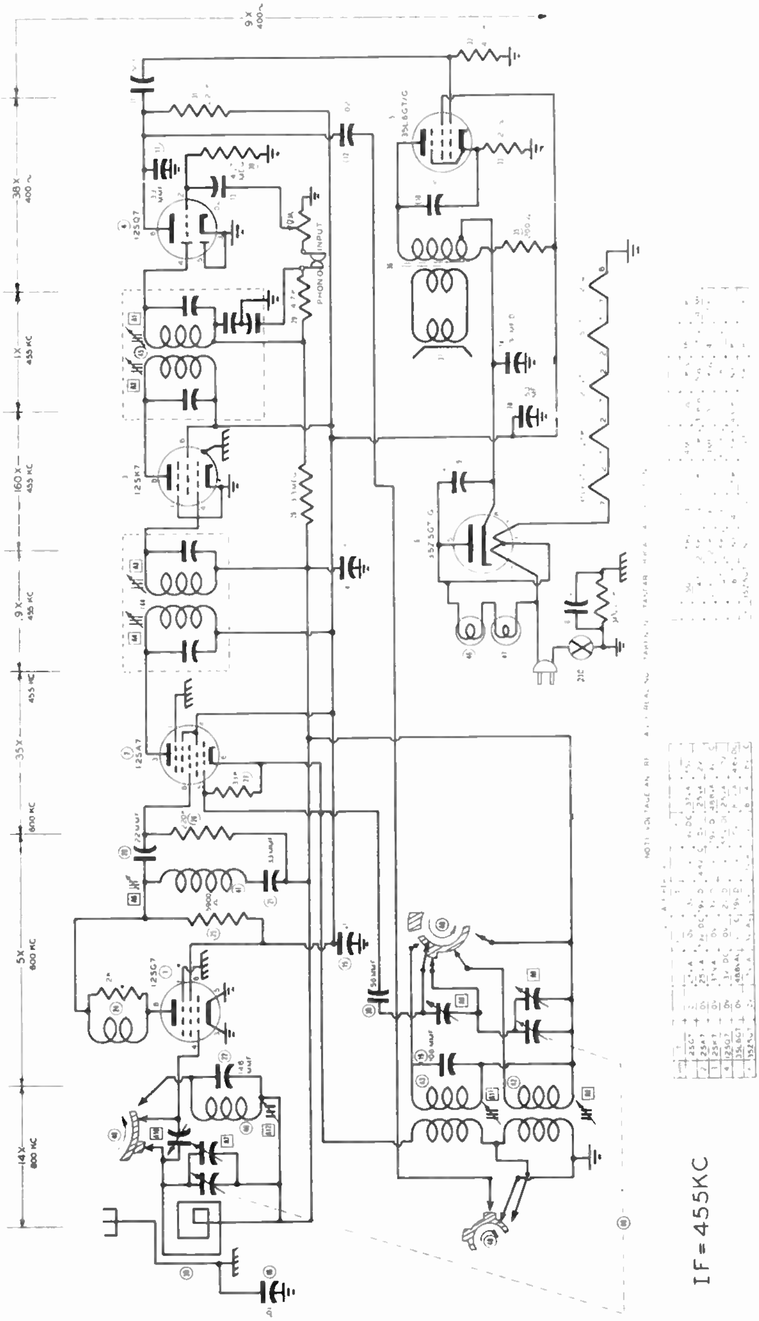


IF=455KC

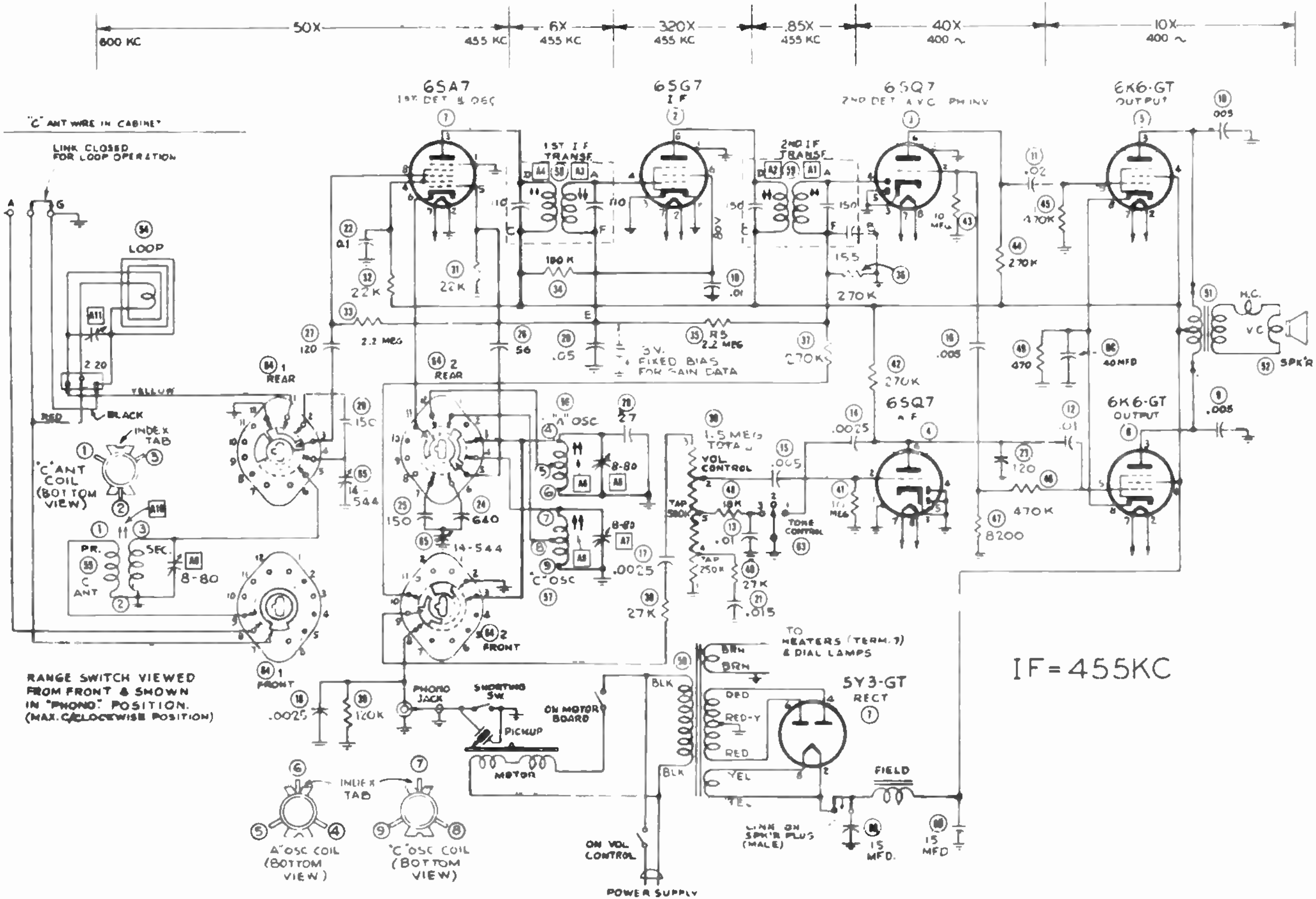
1T4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1R5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1T4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1S5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3Q4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

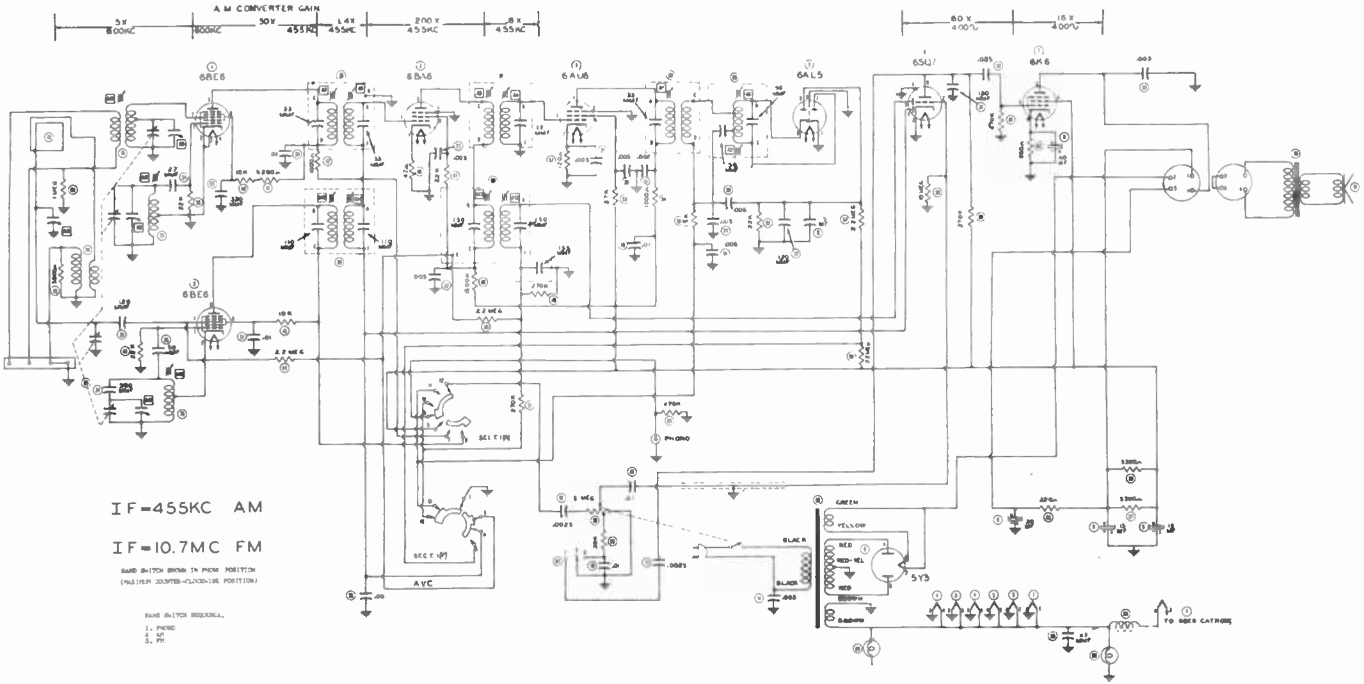
1T4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1R5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1T4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1S5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3Q4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

RCA


12SQ7
12SK7
12SA7
12SG7
35L6GT/G
35Z5GT/G
PHONO INPUT
IF = 455KC

RCA MODELS 67VI 67AVI



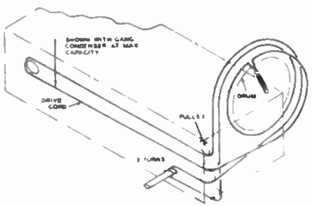


IF=455KC AM

IF=10.7MC FM

BAND SWITCH SHOWN IN PHONO POSITION (MAXIMUM COUNTER-CLOCKWISE POSITION)

BAND SWITCH SEQUENCE.
1. PHONO
2. AM
3. FM



VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	6BE6	-1.8VDC	0V.	0V.	6.6VAC	245VDC	120VDC	0V.	--
2	6BE6	-7VDC§	0V.	0V	6.6VAC	250VDC	120VDC	0V.	--
3	6BA6	-. VDC	0V.	0V.	6.6VAC	230VDC	127VDC	.8VDC	--
4	6AU6	0V.	0V.	0V.	6.6VAC	245VDC	157VDC	1.4VDC	--
5	6AL5	0V.	-.7VDC	6.6VAC	0V	-.4VDC	0V	-.3VDC	--
6	6SQ7	0V.	-.5VDC	0V.	-.6VDC	-.4VDC	107VDC	6.6VAC	0V
7	6K6GT	0V.	0V.	330VDC	270VDC	0V.	0V	[illegible] 6VAC	20VDC
8	5Y3GT	0V	350VDC	275VDC	330VAC	40VAC	330VAC	[illegible]VAC	350VDC

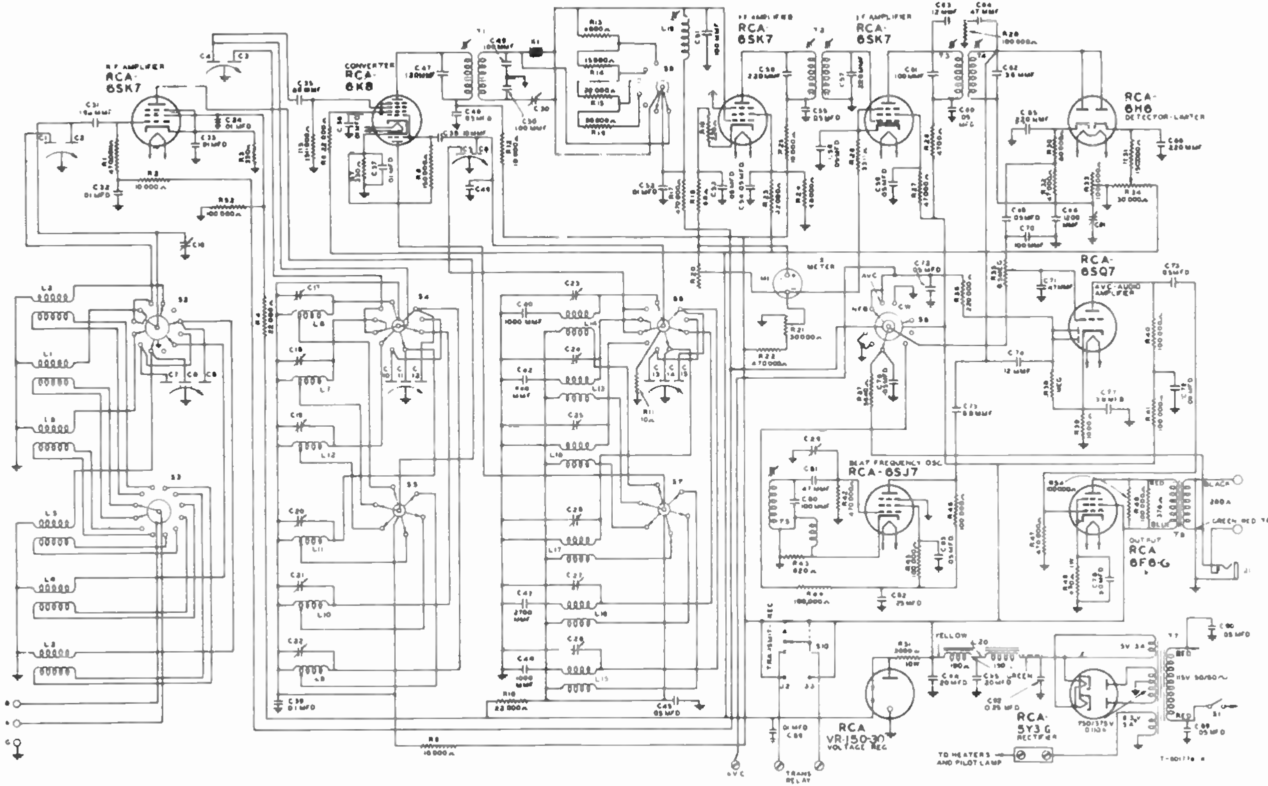
*TAKEN IN FM POSITION.

RESISTANCE READINGS

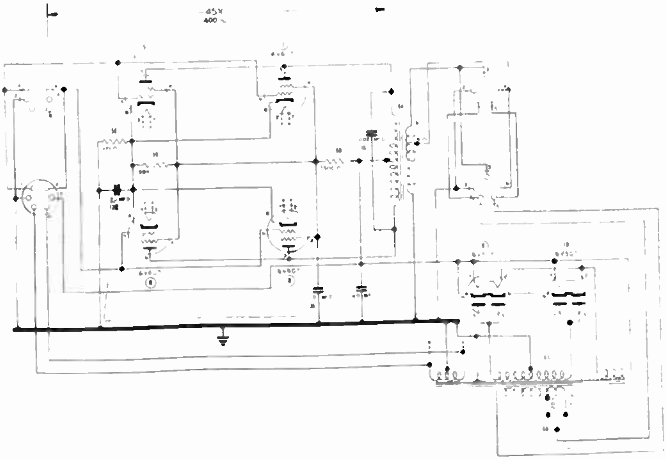
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	6BE6	22KΩ	.1Ω	.1Ω	.2Ω	100KΩ	120KΩ	0Ω	--
2	6BE6	22KΩ	.4Ω	0Ω	.1Ω	100KΩ	120KΩ	4.5 MEG.	--
3	6BA6	2.2 MEG.	0Ω	0Ω	.1Ω	100KΩ	120KΩ	47Ω	--
4	6AU6	.6Ω	3Ω	0Ω	.1Ω	100KΩ	130KΩ	120Ω	--
5	6AL5	.6Ω	20KΩ	.1Ω	0Ω	INF	0Ω	INF	--
6	6SQ7	0Ω	10 MEG.	3Ω	2.2 MEG.	280KΩ	300KΩ	.1Ω	0Ω
7	6K6GT	0Ω	0Ω	100KΩ	100KΩ	470KΩ	INF	.1Ω	680Ω
8	5Y3GT	0Ω	100KΩ	100KΩ	250Ω	INF.	250Ω	.1Ω	100KΩ

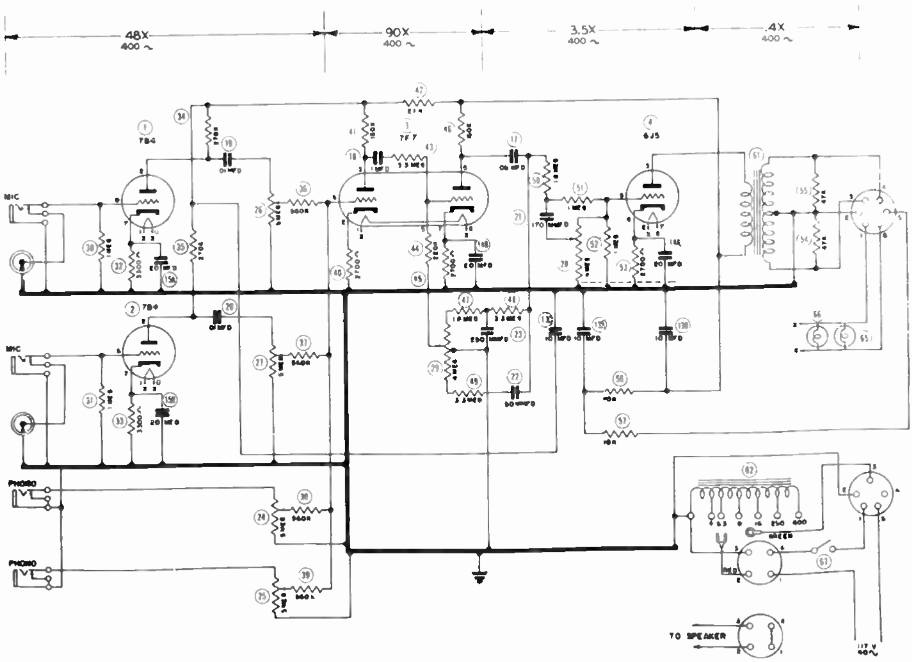
§TAKEN WITH VACUUM-TUBE VOLTMETER.

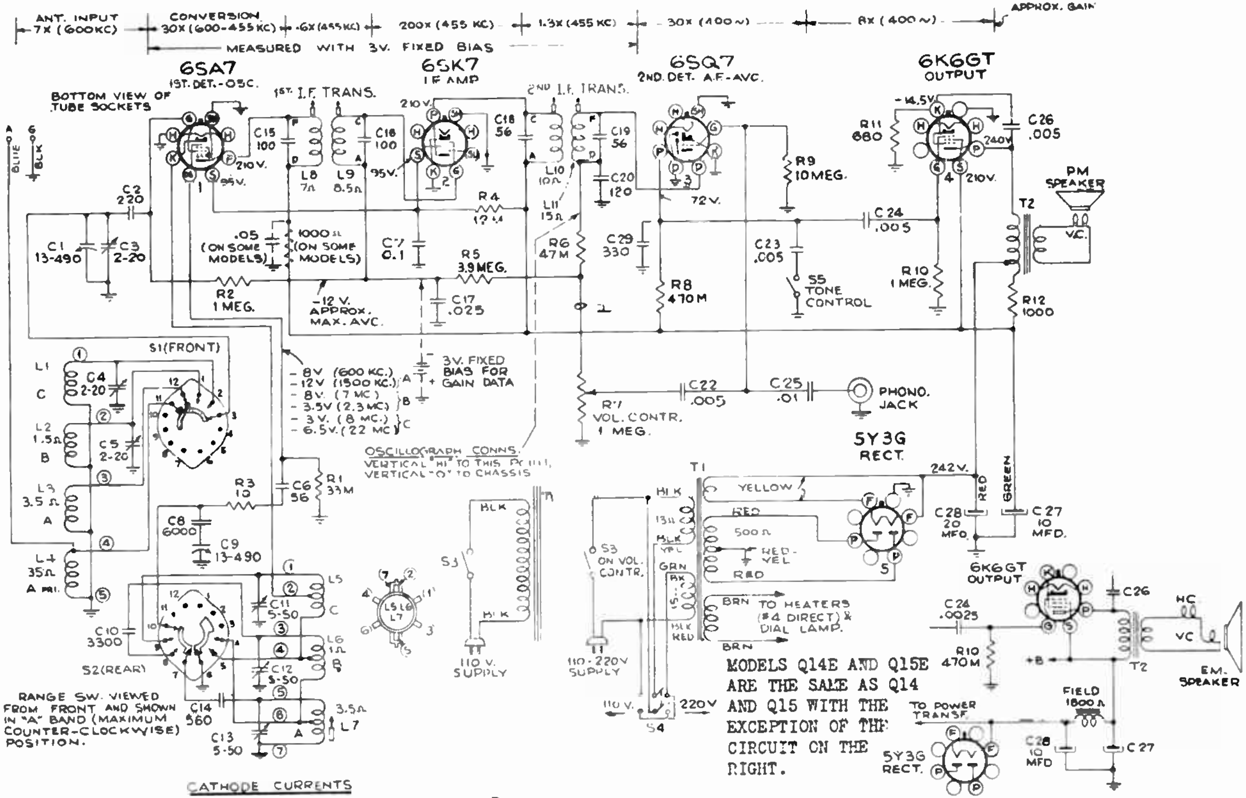
MODELS 68R1 68R2 68R3 68R4



IF PEAK 455 KC




48X
400 ~
90X
400 ~
3.5X
400 ~
.4X
400 ~
7B4
7F7
6J5
MIC
PHONO
TO SPEAKER



CATHODE CURRENTS

(1)	6SA7	8.7 MA.
(2)	6SK7	15.1 MA.
(3)	6SQ7	0.3 MA.
(4)	6K6GT	22.6 MA.
(5)	TOTAL RECT.	46.7 MA.

VOLTAGES SHOULD HOLD WITHIN ± 20% WITH RATED SUPPLY VOLTAGE.

Frequency Ranges

Standard Broadcast ("A" Band)	540-1,720 kc (555 174 m)
Medium Wave ("B" Band)	2.3 7.0 mc (130 42.9 m)
Short Wave ("C" Band)	7.0-22 0 mc (42.9-13.6 m)

Intermediate Frequency .... 455 kc

Pilot Lamp .... Mazda 44

Power Supply Ratings

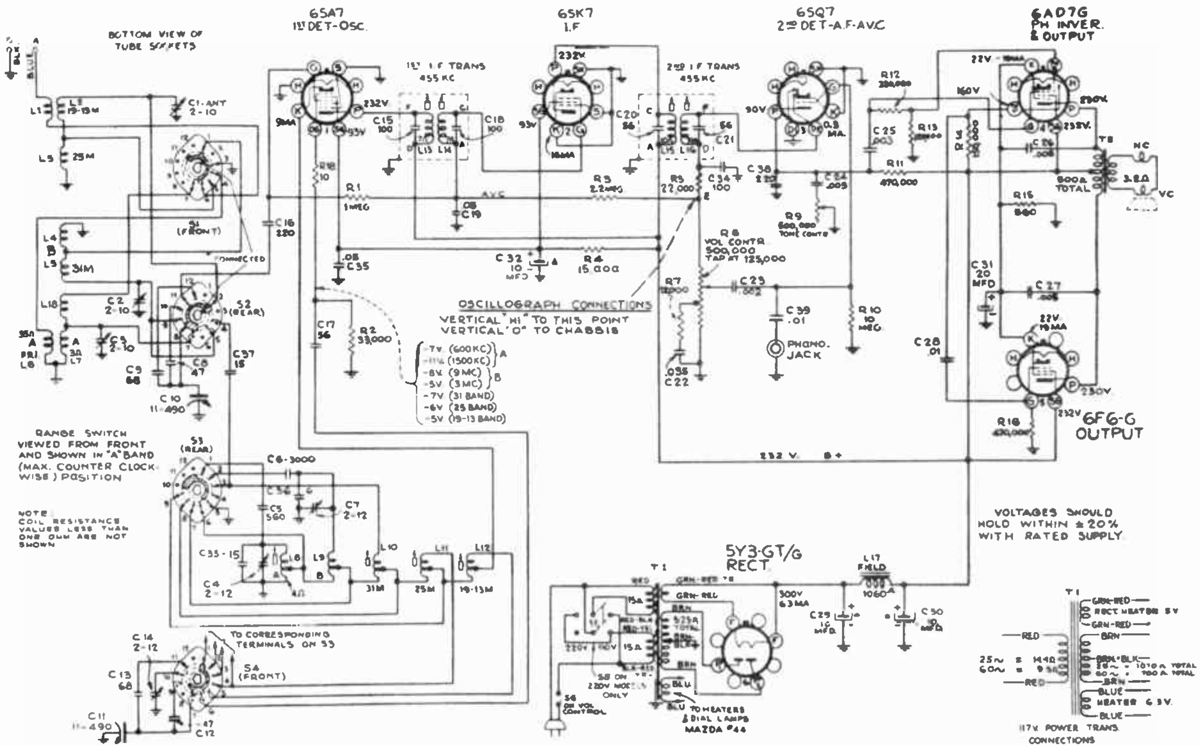
105 125 volts, 50-60 cycles	50 watts
105-125 volts, 25-60 cycles	50 watts
105 125, 200 250 volts, 50 60 cycles	50 watts

Power Output

Undistorted	1.4 watts
Maximum	2.8 watts

Loudspeakers	Q14, Q15	Q14E, Q15E
Speaker No.	RL-92A2	RL-79C1
Type	6-in. PM	6-in. EM
Field coil resistance	—	1,800 ohms
V.C. Impedance at 400 cycles		3.4 ohms

RCA



Precautionary Lead Dress.—

1. All leads between antenna coils and switch must be as short as possible and kept away from oscillator coil, leads and switches.
2. All oscillator coil leads must be kept apart from each other and other leads and parts.
3. Blue plate lead of 2nd I-F transformer should be dressed under other leads and against chassis.

NOTE.—On some sets C23 may be .0015 mf., C25 may be .0025 mf.

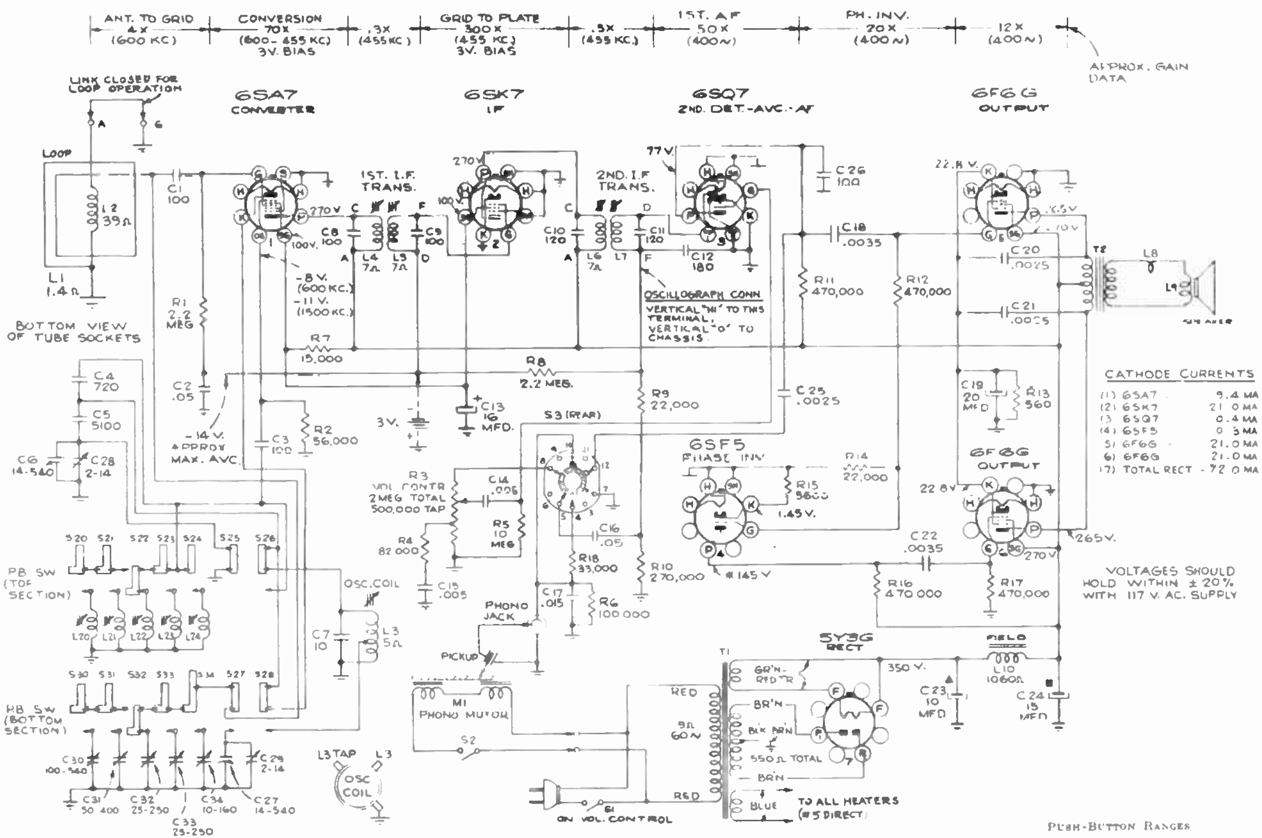
Loudspeaker.—

To center the loudspeaker voice coil, first remove the dust cover. Then loosen the center suspension by thoroughly soaking the outer edge of this suspension with repeated applications of acetone.

(Caution: Keep acetone from flowing to other parts of the loudspeaker.)

Keep the outer edge of the suspension soaked, and lift the cone, near the voice coil, up and down until the suspension is pulled away from the cone housing.

Insert 3 feelers, equally spaced, between the voice coil and the pole piece, and allow the center suspension to re-cement itself. Additional cement should be applied if necessary. Remove feelers when cement has hardened completely.



The R F and I F gain measurements were made with a 3 volt bias battery connected from the A.V.C. bus to chassis, as shown in dotted lines.

Push-Button Ranges

One station between approximately 540-1,030 kc
One station between approximately 610-1,260 kc
Two stations between approximately 740-1,430 kc
One station between approximately 880-1,550 kc

Frequency Range

Broadcast "A" ... 540-1,700 kc

Intermediate Frequency ... 455 kc

Power Output Rating

Undistorted	4.5 watts
Maximum	5.5 watts

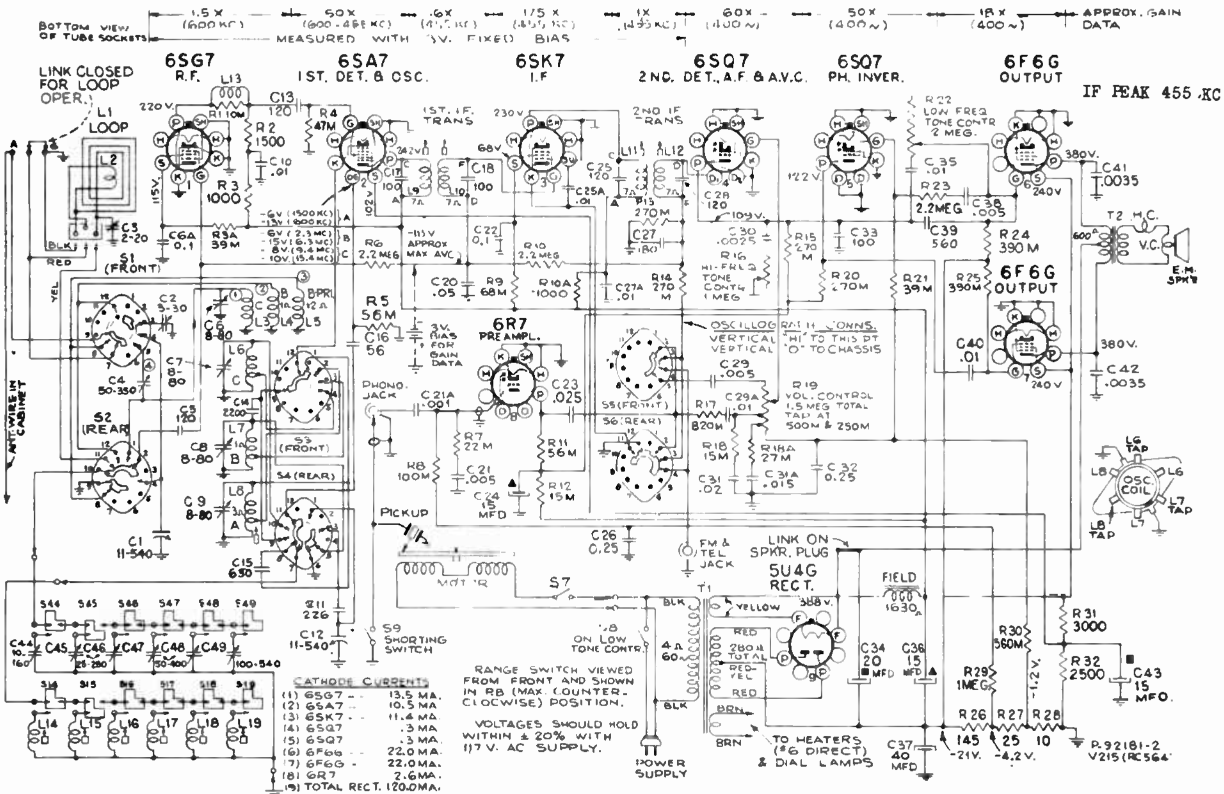
Loudspeaker (RL-79-A1)

Type	6-inch Electrodynamic
V C Impedance	3.4 ohms at 400 cycles

Power Supply Ratings

105-125 volts, 60 cycles	110 watts
105-125 volts, 25 cycles	110 watts

RCA



In Model V-219, the loop and phono motor connections are different, as shown in separate diagram on a following page. In Model V-225, R-8 is 220,000 ohms, R-17 is 1.8 Meg., and C-21 is .0035 mfd.

Power Output Rating

Undistorted .... 10 watts
Maximum .... 12 watts

Loudspeaker

Type .... 12-inch electrodynamic
Voice Coil Impedance .... 2.2 ohms at 400 cycles
Identification Number .... (RL-70-M2)

Power Supply Ratings (V-219, V-225)

105-125 volts, 50 60 cycles .... 145 watts total

Power Supply Rating (V-215, V-221)

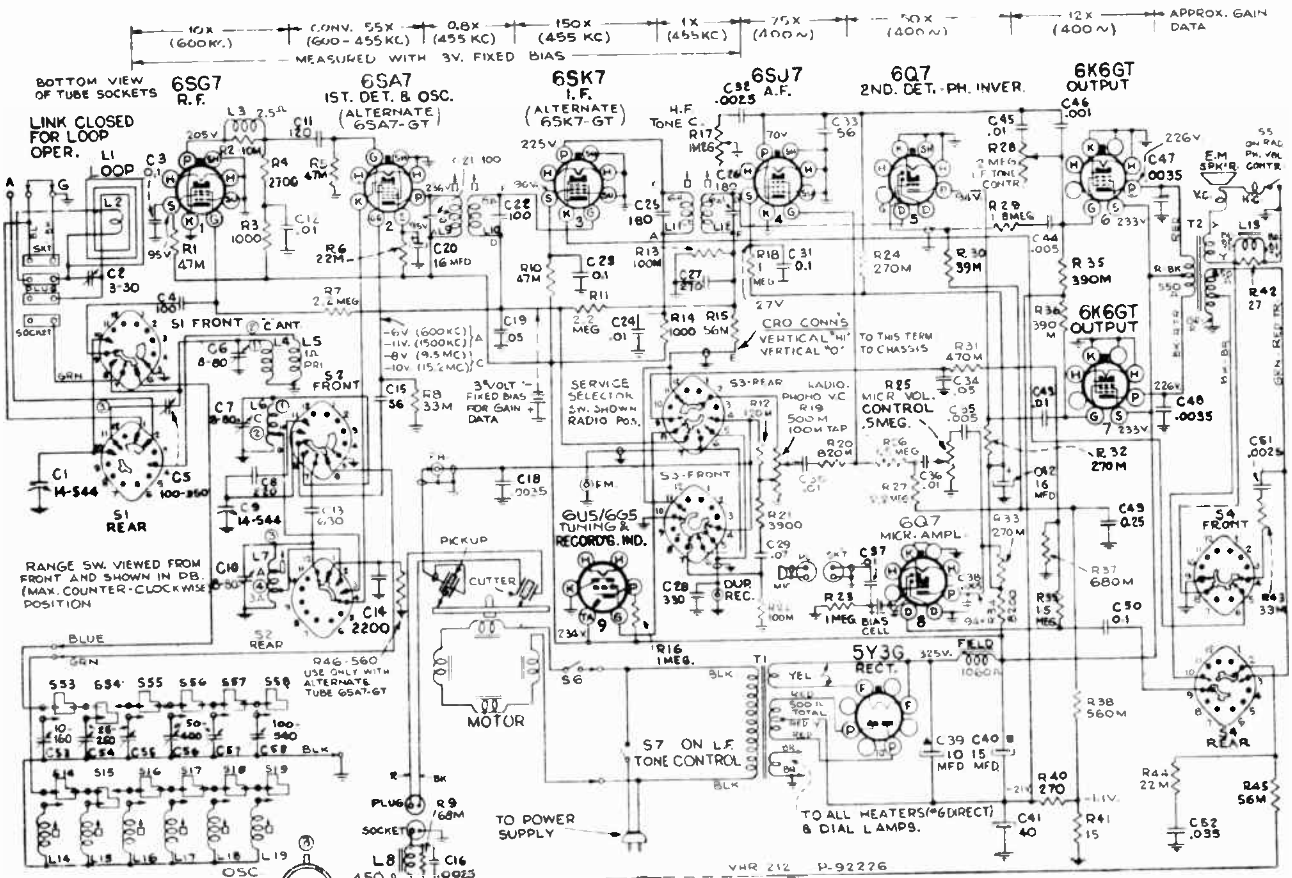
105-125 volts, 50 60 cycles .... 145 watts total
105-125 volts, 25 cycles .... 145 watts total

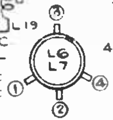
Automatic Phonograph RP 160 for V-215, RP 160A for V-219, RP 160B for V-221

Type Pickup .... Crystal
Record Capacity .... Twelve 10 in., Ten 12 in. records
Power Consumption 160 .... 17 watts
Power Consumption 160A .... 14 watts

Frequency Ranges

Standard Broadcast (A) .... 540-1,600 kc
Medium Wave (B) .... 2,300-6,300 kc
Short Wave (C) .... 9,400-15,400 kc
Intermediate Frequency .... 455 kc





Frequency Range
Broadcast "A" ..... 540-1600 kc
Short Wave "C" .9,400-15,400 kc

Intermediate Frequency .... 455 kc

CATHODE CURRENTS

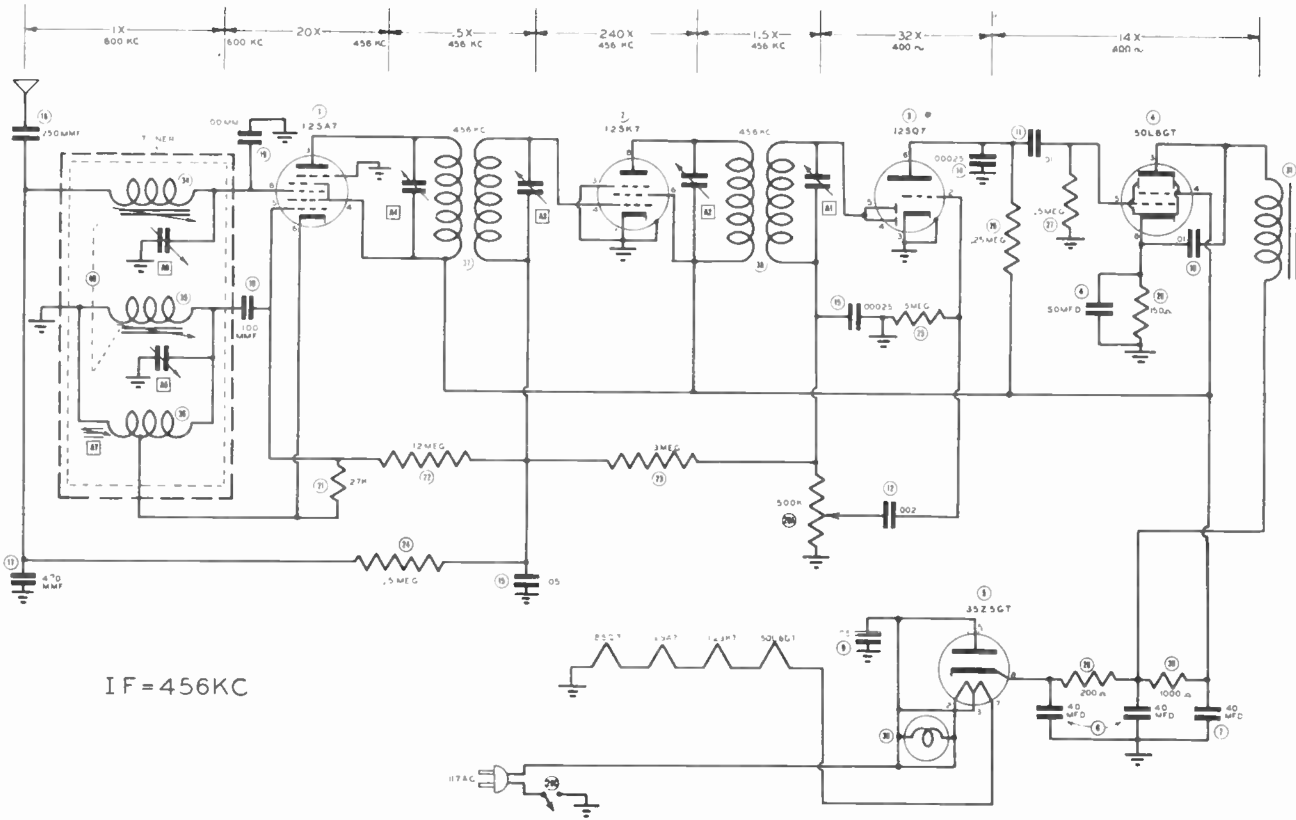
(1)	6SG7	10.9 MA	(6)	6K6GT	19.5 MA
(2)	6SA7	10.9 MA	(7)	6K6GT	19.5 MA
(3)	6SK7	13.4 MA	(8)	6Q7	0.4 MA
(4)	6SJ7	0.7 MA	(9)	6U5/6G5	0.8 MA
(5)	6Q7	0.5 MA	(10)	TOTAL RECT	77.0 MA

VOLTAGES SHOULD HOLD WITHIN ± 20% WITH 117 V. AC. SUPPLY

RCA

RAY ENERGY

MODEL AD4



VOLTAGE READINGS

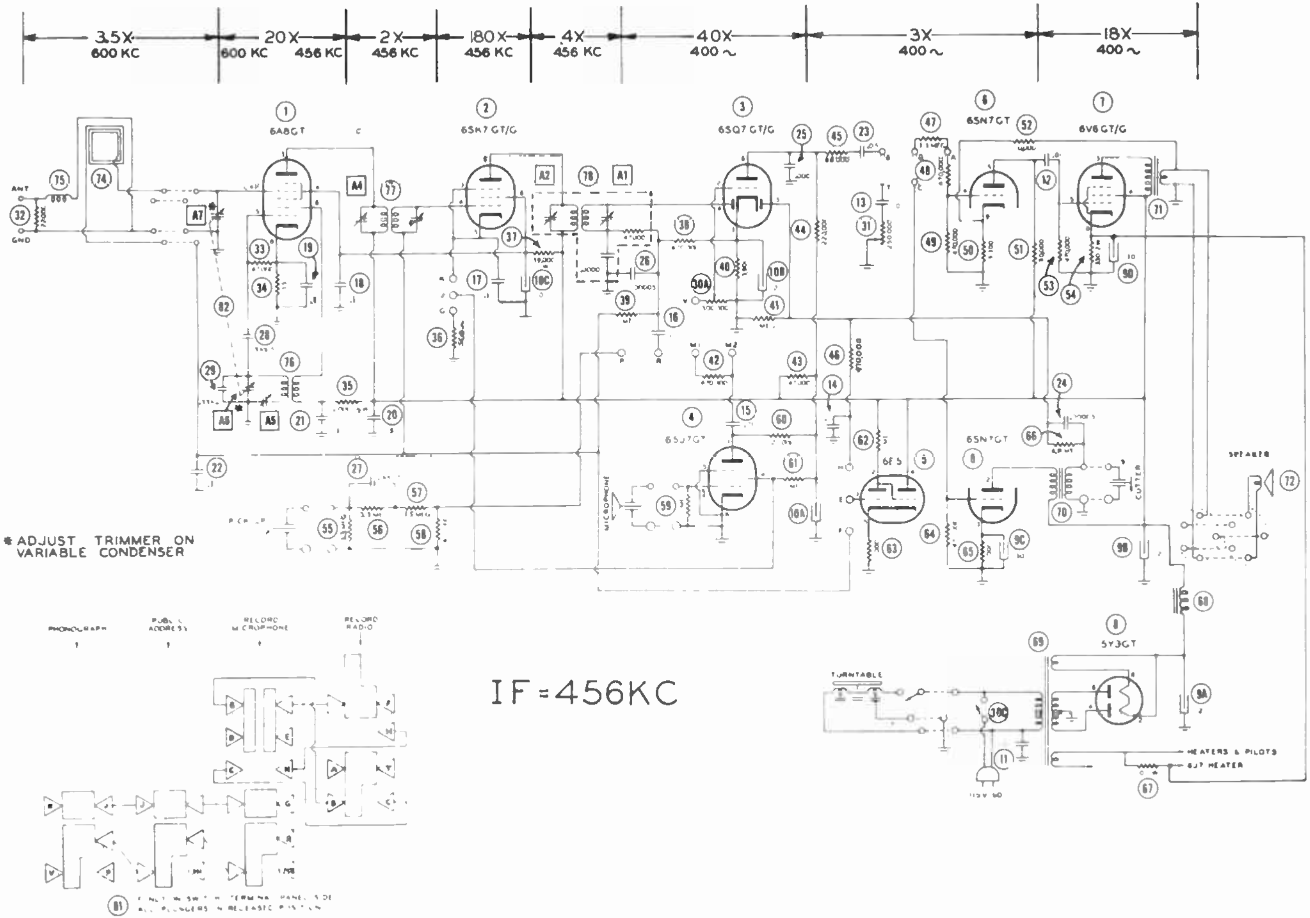
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SA7GT	0v.	11 V.AC	83 V DC	83 V.DC	-3.5V DC	0V.	23 V.AC	-1.5V.DC
2	12SK7GT	0V.	23 V.AC	0V.	-5V.DC	0V.	83 V.DC	34.5V.AC	83V.DC
3	25Q7GT	0v.	-.57 V.DC	0V.	-.57 V DC	-.57 V.DC	57 V.DC	11 V.AC	0V.
4	50L6GT	0V.	87 V.AC	103 V DC	83 V.DC	0v.	0V.	34.5V.AC	5.7 V.DC
5	35Z5GT	0V	117 V.AC	112 V.AC	0V.	112 V AC	108 V.DC	87 V.AC	119 V.DC

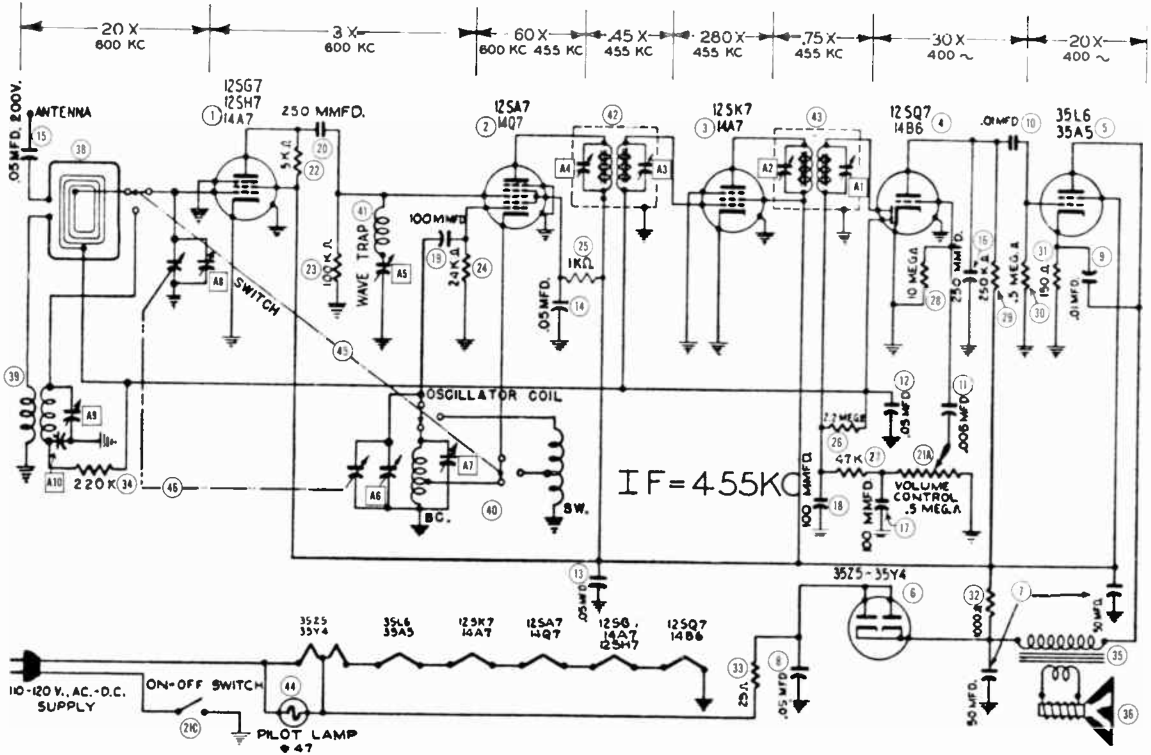
RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SA7GT	0Ω	11Ω	25KΩ	25KΩ	26KΩ	6Ω	23Ω	32 MEG
2	25K7GT	0Ω	23Ω	0Ω	2.7 MEG	0Ω	25KΩ	34Ω	25KΩ
3	25Q7GT	0Ω	.8 MEG	0Ω	410KΩ	410KΩ	275KΩ	11Ω	0Ω
4	50L6GT	INF	79Ω	25KΩ	25KΩ	510KΩ	INF.	34Ω	135Ω
4	35Z5GT	0Ω	108Ω	103Ω	INF.	0.3Ω	25KΩ	79Ω	25KΩ

RECORDIO

MODELS 6B10 6B30 6B20 6B32





NOTE: VOLTAGE AND RESISTANCE READINGS TAKEN IN STANDARD BROADCAST POSITION.

VOLTAGE READINGS

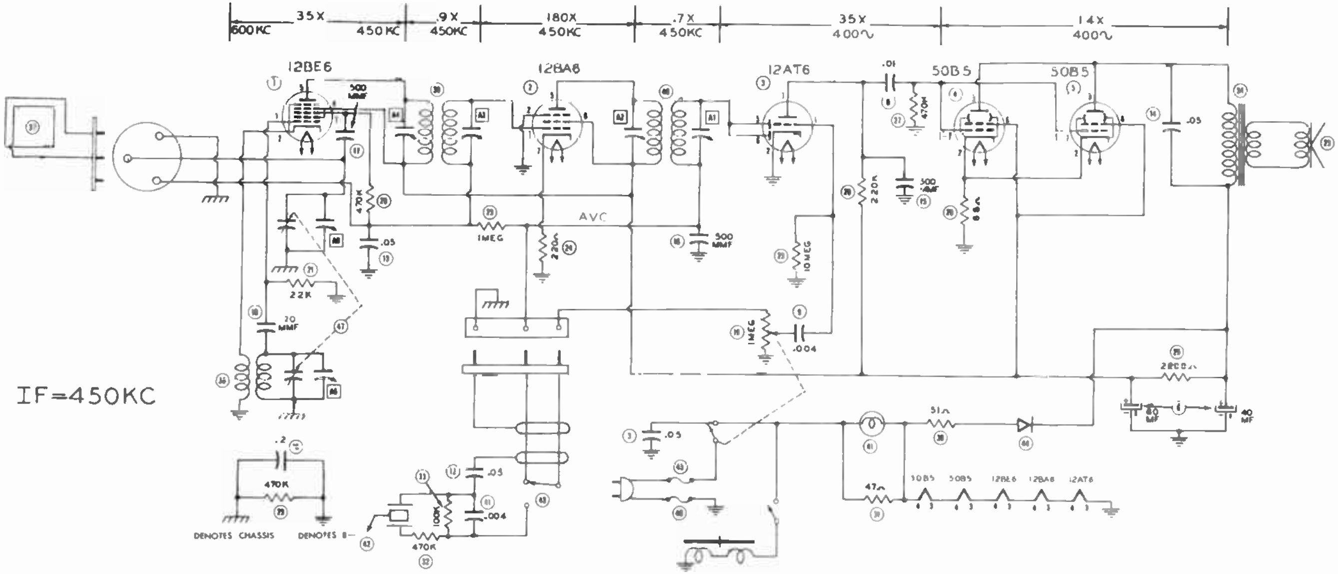
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SH7	0V.	26 V.AC	0V.	-.45V.DC	0V.	87 V.DC	38V.AC	70V.DC
2	12SA7	0V.	26 V.AC	87 V.DC	80V.DC	-4.8V.DC	0V.	13 V.AC	0V.
3	12SK7	0V.	38V.AC	0V.	-.45V.DC	0V.	87 V.DC	50V.AC	87 V.DC
4	12SQ7GT	0V.	-.65V.DC	0V.	-.6 V.DC	-.6 V.DC	62 V.DC	13 V.AC	0V.
5	35L6GT	117 V.DC	87 V.AC	109 V.DC	87 V.DC	0V.	-.45 V.DC	50 V.AC	5.2 V.DC
6	35Z5GT	0V.	117 V.AC	113 V.AC	0V.	112 V.AC	0V.	87 V.AC	117 V.DC

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
1	12SH7	0Ω	23Ω	0Ω	2.5MEG.	0Ω	35KΩ	34Ω	40KΩ
2	12SA7	0Ω	23Ω	35KΩ	36KΩ	22KΩ	.4Ω	11Ω	124KΩ
3	12SK7	0Ω	34Ω	0Ω	2.5MEG.	0Ω	35KΩ	45Ω	35KΩ
4	12SQ7GT	0Ω	10 MEG.	0Ω	510KΩ	510KΩ	285KΩ	11Ω	0Ω
5	35L6GT	35KΩ	75Ω	35KΩ	35KΩ	500 KΩ	2.5MEG.	45Ω	135Ω
6	35Z5GT	INF.	100Ω	97Ω	INF.	110Ω	INF.	75Ω	35KΩ

REMLER

MODELS 5300B 5300I 5300BI



IF=450KC

VOLTAGE READINGS

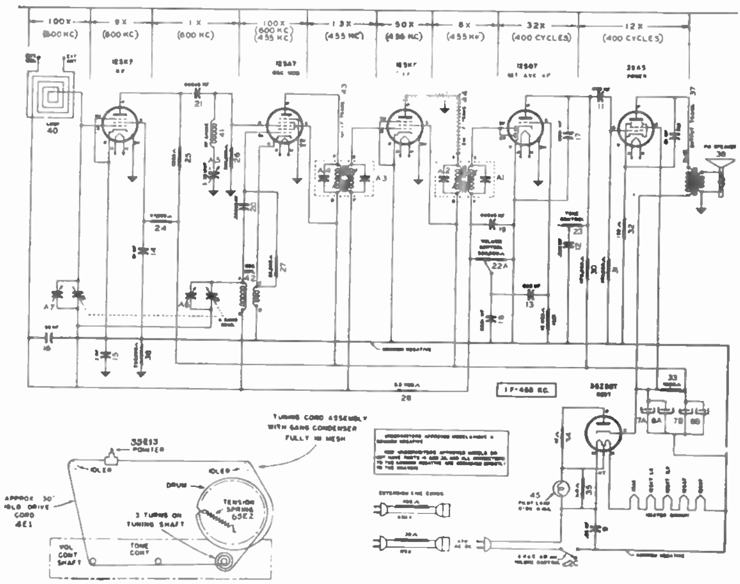
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
1	12BE6	[illegible]	V.	[illegible]	[illegible]	[illegible] VDC	75V.[illegible]	-.1.[illegible]
2	12BA6	-.1VDC	V.	11VAC	23VAC	75VDC	75VDC	1.2.DC
3	12AT6	-.1VDC	OV.	OV.	11VAC	-.[illegible]	-.[illegible]	42V[illegible]
4	50B5	OV.	4.3VDC	35VAC	75VA	112V	75V[illegible]	V
5	50B5	OV.	4.3VDC	5VAC	117VDC	11.[illegible]DC	[illegible]VDC	V

RESISTANCE READINGS

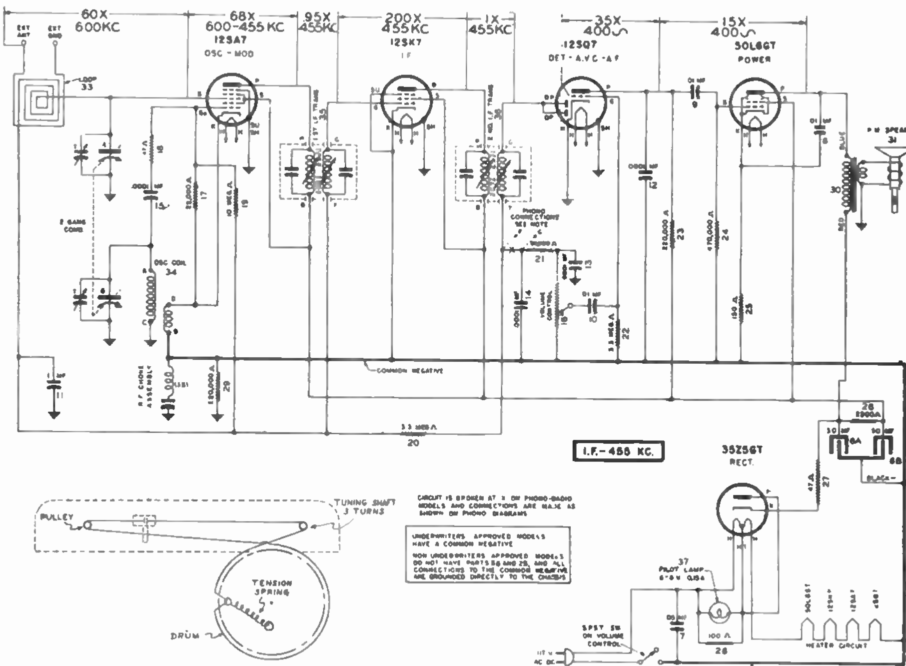
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	400K	[illegible]
2	[illegible]	[illegible]	0Ω	[illegible]	[illegible]	400K	400K	[illegible]
3	[illegible]	[illegible]	0Ω	0Ω	[illegible]	[illegible]	[illegible]	0Ω
4	[illegible]	[illegible]	70Ω	40Ω	[illegible]	400K	[illegible]	400K
5	[illegible]	[illegible]	70Ω	70Ω	[illegible]	[illegible]	[illegible]	[illegible]

SENTINEL

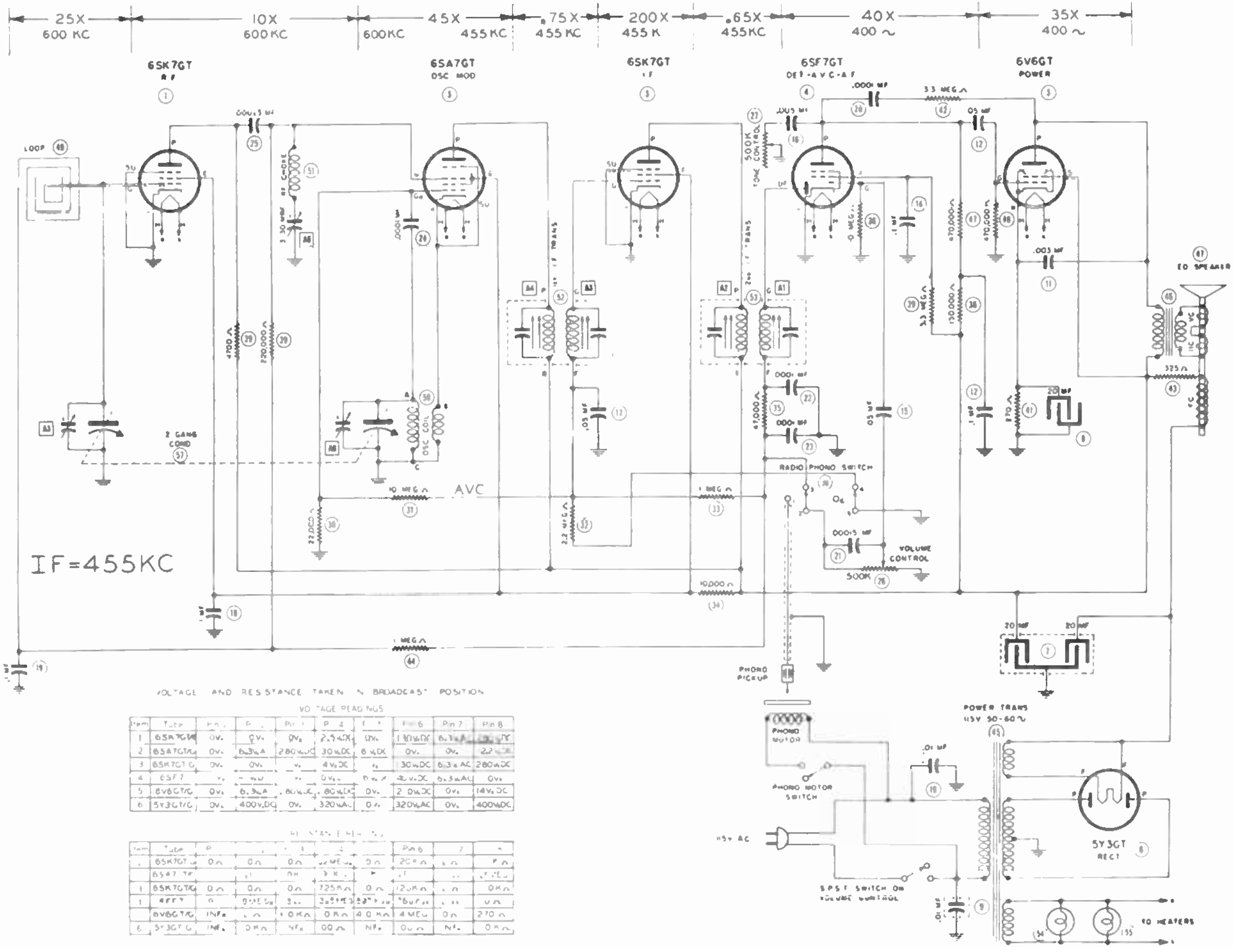
MODEL 293 SERIES



MODEL 284-1



DIAL CORD ASSEMBLY



VOLTAGE AND RESISTANCE TAKEN IN BROADCAST POSITION

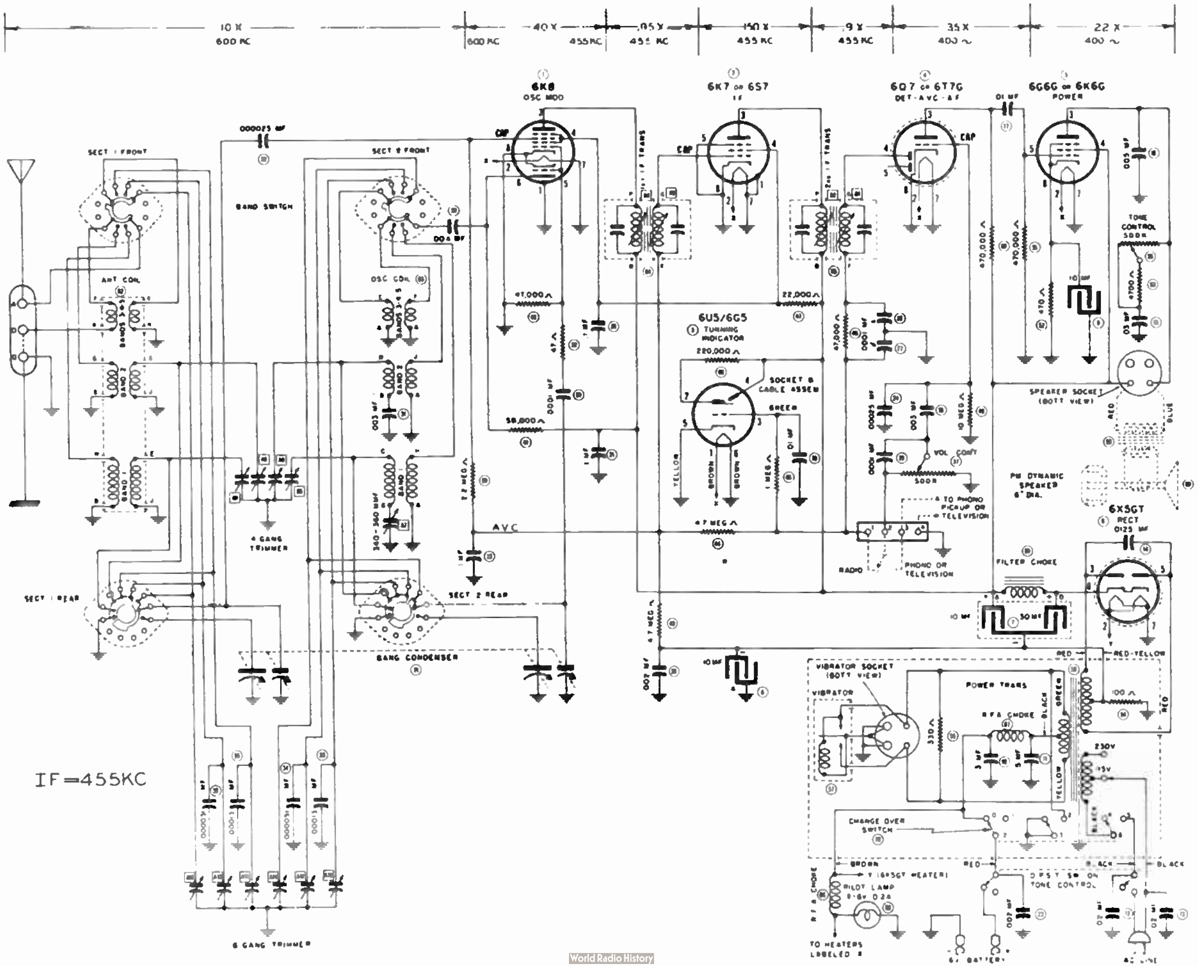
VOLTAGE READINGS

Item	Tube	[illegible]	P[illegible]	Pin [illegible]	P 4	[illegible]	Pin 6	Pin 7	Pin 8
1	6SK7GT/G	0V.	0V.	0V.	2.5V.DC	[illegible]	1[illegible]0V.DC	6.3V.A[illegible]	[illegible]
2	6SA7GT/G	0V.	6.3V.A	280V.DC	30V.DC	6V.DC	0V.	0V.	2.2[illegible]
3	6SK7GT/G	0V.	0V.	[illegible]	4V.DC	[illegible]	30V.DC	6.3V.AC	280V.DC
4	6SF7	[illegible]	[illegible]	[illegible]	0V.[illegible]	[illegible]	40V.DC	6.3V.AC	0V.
5	6V6GT/G	0V.	6.3V.A	[illegible]80V.DC	[illegible]80V.DC	0V.	2[illegible]0V.DC	0V.	14V.DC
6	5Y3GT/G	0V.	400V.DC	0V.	320V.AC	0V.	320V.AC	0V.	400V.DC

RESISTANCE READINGS

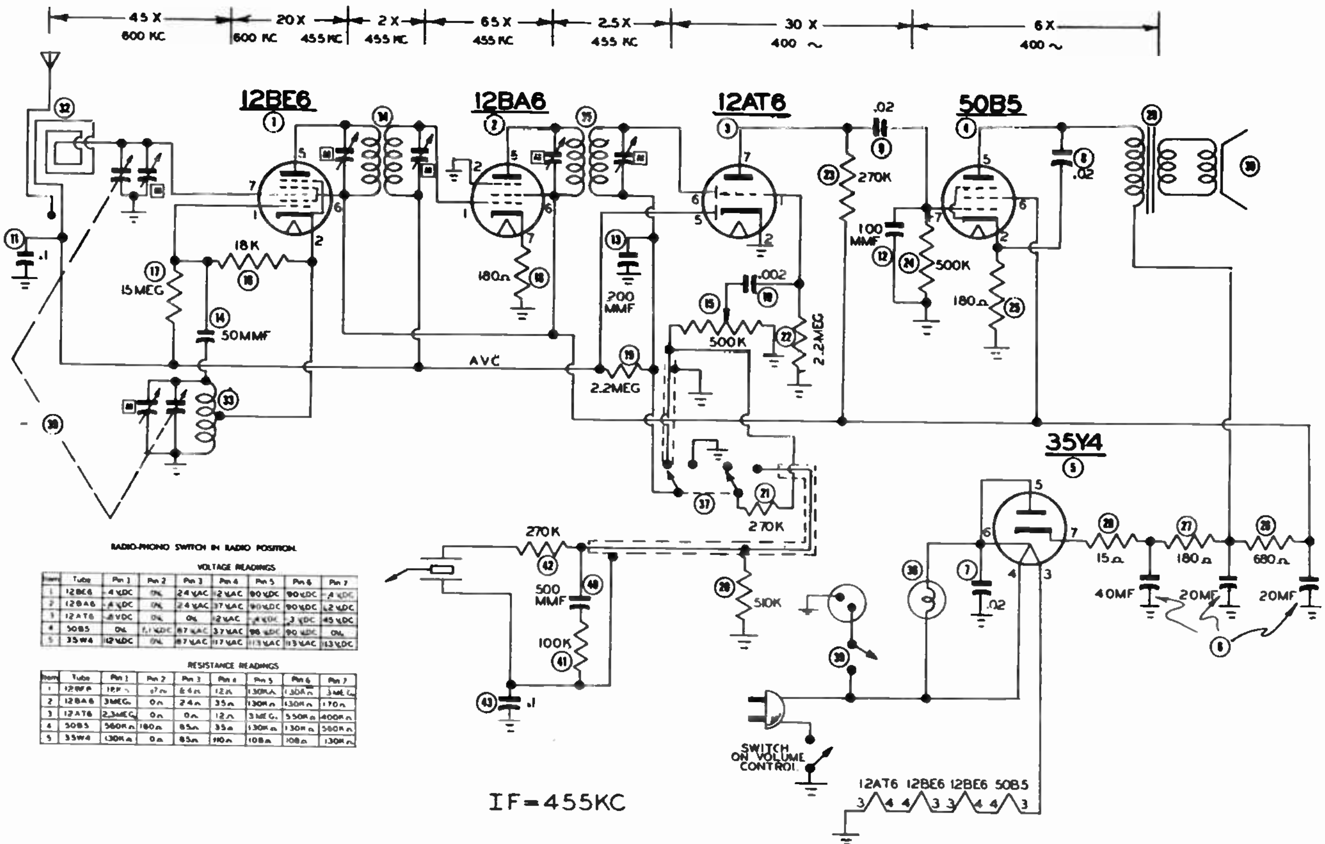
Item	Tube	P[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Pin 6	7	[illegible]
1	6SK7GT/G	0Ω	0Ω	0Ω	[illegible] MEG	0Ω	2C[illegible]Ω	[illegible]Ω	[illegible]Ω
2	6SA7GT/G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	6SK7GT/G	0Ω	0Ω	0Ω	725KΩ	0Ω	12[illegible]KΩ	[illegible]Ω	0KΩ
4	6SF7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	6V6GT/G	INF.	[illegible]Ω	[illegible]0KΩ	0KΩ	40KΩ	4 MEG	0Ω	270Ω
6	5Y3GT/G	INF.	[illegible]KΩ	INF.	[illegible]00Ω	INF.	0[illegible]Ω	INF.	0KΩ

SENTINEL



MODEL 295-T

MODEL CA-5



RADIO-PHONO SWITCH IN RADIO POSITION

VOLTAGE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
1	12BE6	-.4 VDC	0V	24 VAC	12 VAC	90 VDC	90 VDC	-.4 VDC
2	12BA6	-.4 VDC	0V	24 VAC	37 VAC	90 VDC	90 VDC	1.2 VDC
3	12AT6	-.8 VDC	0V	0V	12 VAC	-.4 VDC	-.3 VDC	45 VDC
4	50B5	0V	7.1 VDC	87 VAC	37 VAC	98 VDC	90 VDC	0V
5	35W4	112 VDC	0V	87 VAC	117 VAC	113 VAC	113 VAC	113 VDC

RESISTANCE READINGS

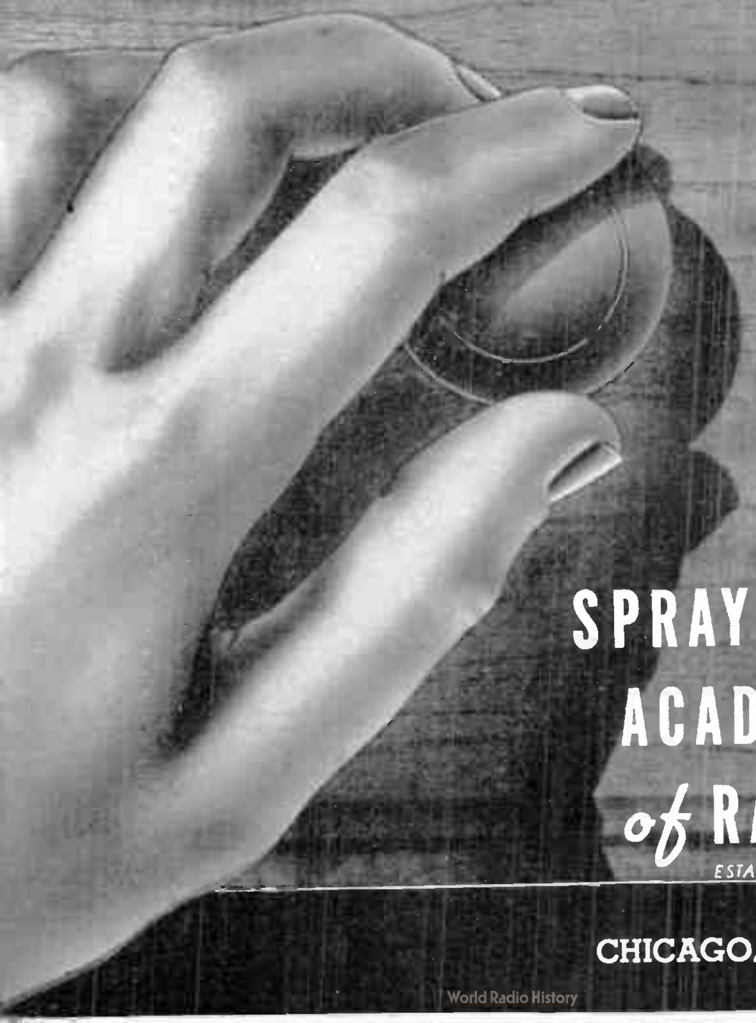
Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
1	12BE6	18K Ω	17 Ω	6.4 Ω	12 Ω	130K Ω	130K Ω	3 MEG.
2	12BA6	3 MEG.	0 Ω	24 Ω	35 Ω	130K Ω	130K Ω	170 Ω
3	12AT6	2.3 MEG.	0 Ω	0 Ω	12 Ω	3 MEG.	550K Ω	400K Ω
4	50B5	560K Ω	180 Ω	85 Ω	35 Ω	130K Ω	130K Ω	560K Ω
5	35W4	130K Ω	0 Ω	85 Ω	110 Ω	108 Ω	108 Ω	130K Ω

IF=455KC

SIMPLON

HOW TO TEST AND REPAIR RADIO SETS WITHOUT METERS

REFERENCE LESSON 1 R-1



SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

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This book was originally written as the result of a WARTIME demand for information on testing and repairing radio sets in lieu of manufactured test equipment. It has proven to be so popular that we have decided to make it a permanent part of our training program. Granted that the use of manufactured test equipment makes for more convenient and rapid testing, yet the fact remains that such equipment is not always available. The test-methods described in this book provide one answer to that problem. It is hoped that this book will aid you in your Radio-TV repair work in the absence of manufactured test equipment. Study it carefully, and you will be well repaid for the effort and time spent on it.

O'B 1-55 2M

How To Test and Repair Radio Sets Without Meters

REFERENCE LESSON 1R-1

It is a little known FACT that well trained and experienced Radio-TV technicians don't always have to rely on manufactured test equipment. Technicians, during World War II, well know this truth. Because these little known methods are so effective, and never knowing when their use might be needed, we include them in this reference lesson. Further, we know from experience that there is no better way for a student of electronics to become "circuit wise", than to practice with the methods presented in this lesson. We recommend, if you are interested, you get an old receiver (some dealers who take them in trade will almost give them to you), and put the methods described in this lesson to practical use. It will be well worth all the time and effort you put into it, and will give you practical skill in using manufactured measuring instruments.

It might be well, right at the start, to recognize seven basic test principles about radio sets, and in that way avoid possible confusion. It is safe to assume that in 99% of the cases the average radio set on the American market has the proper design—there are some few exceptions to this rule but they are of such minor consequence that you don't have to worry about them. If you recognize and accept the fact you don't need to worry about part values, etc., because if everything else is normal, you can assume these are also normal. *This is the first basis test principle.*

Now consider the radio circuit itself. Basically it contains nothing more than units of resistance, inductance, capacity and vacuum tubes. No matter how complicated the circuit, it can be resolved into these four basic items. Looked at in this way, a radio circuit is a relatively simple device. It is most important for you to remember this because it will serve you well. Every time you have a seemingly tough problem just remember this primary fact—then stop and ask yourself, "why should this problem have me stumped?" Say to yourself, "this problem involves nothing more than the four basic items of radio," then ask yourself, "what basic law have I overlooked concerning these things?" If you will do this and stop to think over your problem carefully, you are sure to solve it. *This is the second basic test principle.*

Granted that a radio circuit involves nothing more than resistance, inductance, capacity and vacuum tubes, it is well to remember how these react to the two basic forms of electrical power; namely, A.C. and D.C. Resistance will pass both A.C. and D.C., the current value being limited only by the resistance value. *This is the third* basic *test principle.*

Inductance (which includes all wire leads and *all forms of coils*) will also pass both A.C. and D.C. But remember this important fact. Inductance does not react alike to both A.C. and D.C. For A.C. inductance offers both reactance and resistance. These two terms are usually combined (reactance and resistance) and the effect of both of them is called *impedance*. Remember then for *alternating current* (A.C.) inductance offers impedance to the flow of current, and the value of the current is limited by the value of the impedance and frequency (for a given value of voltage). Remember too, an inductance may and often does carry both A.C. and D.C.

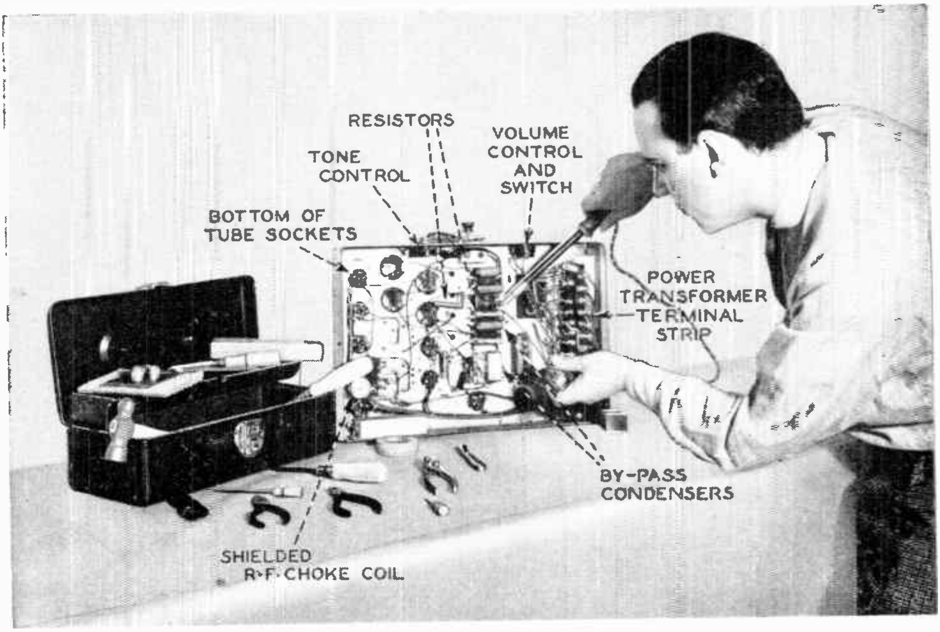
For direct current (D.C.), inductance acts similar to an ordinary resistance. From a D.C. voltage and current viewpoint simply consider an inductance (no matter what its form) as you would any other resistance. *This is the fourth basic test principle.*

Now consider capacity (condensers in many forms). First, consider all forms of mica and paper dielectric condensers. These also have impedance but not in the same sense as inductance. While inductance will conduct D.C., condensers *will not* (if they are in good condition). Every condenser no matter how good, has a minute D.C. leakage but until this assumes extreme values of current, this D.C. current leakage may be neglected entirely. Therefore, remember this important fact—for all practical purposes, a good mica or paper condenser will not pass D.C. If it does, it is defective.

For A.C., capacity will in effect conduct current. The amount will depend on the impedance of the condenser and the frequency. For practical test purposes you don't need to know the value of A.C. through a condenser but, if it passes D.C., you do want to know it. *This is the fifth basic test principle.*

One other common form of capacity is the electrolytic condenser. It is found in two forms: (1) using a liquid dielectric (called the wet type) and (2) using a thick paste form of dielectric (called the dry type). Both forms react alike to A.C. and D.C. An electrolytic condenser (of the type used in radio sets) will not operate properly when used on A.C. only. It is used in circuits having a high content of varying current but a D.C. is necessary to keep the condenser polarized and in operating order. Such condensers, therefore, have polarity, and the positive of the condenser must be connected to the positive or high potential side of the circuit with the negative of the condenser going to the negative or low potential side of the circuit. As compared to other types of condensers, the electrolytic types have high D.C. leakage current but, due to large values of capacity, the normal leakage current is not bothersome and is neglected. When an electrolytic passes abnormally large values of D.C. under normal voltage values, it is no longer useful and must be discarded. *This is the sixth basic test principle.*

The remaining basic unit in a radio set is the vacuum tube. Several different types may be used in one set. They are designed to accomplish different things, and therefore, do not all react alike. Assuming everything else in the set is normal, there are various ways to determine the condition of



Trained radio men can easily locate radio troubles without recourse to elaborate equipment. Man above installs new resistor after finding bad one through simple test.

tubes. The basic fact here is that, with all other things in the set normal, the substitution of a good tube for a bad one will correct the trouble. Later on, you will be shown how to prove that a given tube is abnormal. As for the assumption that every other thing in the set is normal, tests to be described later will fulfill this requirement. The remarks just concluded in regard to tubes cover *the seventh basic test principle.*

First, you observed that four basic items make up a radio set. Namely, these are resistance, inductance, capacity and vacuum tubes. Second, these four items, for practical test purposes, operate under seven basic principles as mentioned. If all of the foregoing is *clearly understood and memorized*, then the test procedure to be outlined makes the testing and repair of radio sets comparatively simple.

CONTROLLING POWER TO THE RADIO

Just as the foregoing has outlined the basic elements of a radio set, it follows that these are of no use unless operating power is supplied to the set, and herein lies the SAR method of testing. Instead of plugging the power line cord into an ordinary power outlet, you set up your own power control to the set, and from actions which the set exhibits, deduce what is wrong with it. In effect, voltage tests are made throughout the set just as you would do if a voltmeter were available with the same positive results.

Figures 1A and 1B show the test circuit. Both circuits are the same with 1A showing the pictorial and

1B the schematic form. As indicating and controlling devices ordinary 110-125 volt lamps of the house-lighting variety are used. You will note four lamps are shown. Ordinarily, only one lamp socket is used at a time, but four sockets may be used for convenience in changing from one lamp power value to another. Figure 1C shows the same basic testing cir-

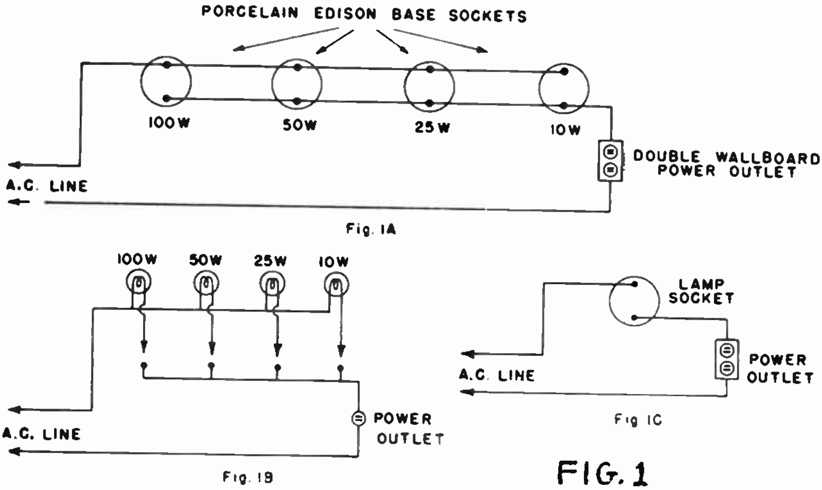


FIG. 1

cuit using only one lamp socket. You may use this arrangement if you prefer. Either arrangement will give the same results. The only difference is that each time you need to change a lamp in Fig. 1C you will have to unscrew one lamp and screw in another, whereas in Fig. 1A, it may only be necessary to screw in one more lamp of a different power rating to give a new power rating. Another advantage of Fig. 1A is that from one to four lamps may be used at a time to give different combinations of power. Thus, what follows is based on the use of Fig. 1A and 1B.

After studying these circuits, *you will note that the lamp or lamps are connected in series with one side of the line*, and if a radio set is plugged into the power outlet, *it too will be in series with the line. Thus, the radio set can draw no more power than the lamp will permit to pass.* The lamp therefore, becomes a controlling device. Even though the radio has a direct short circuit, no harm will be done because the lamp limits the current which can be drawn from the line. The range of lamp ratings in Fig. 1 will take care of all ordinary requirements for testing. We recommend the use of one each of the following: 10, 25, 50 and 100 watt lamps. Assuming a power line voltage of 115 volts, a 10 watt lamp will draw .0869 ampere from the line, 25 watts, .217 ampere, 50 watts, .434 ampere and 100 watts, .869 ampere. Thus these are the maxima of current which a full short of the radio set under test can cause to flow. *Anything less than a full short will cause less current to flow.* It is for this reason that the lamps will glow from full brilliance to less than visible light protection is given the set under depending on conditions. But no matter what the conditions, ample test if the right lamp is used—more about this further on.

A DEFINITE PROCEDURE MUST BE FOLLOWED

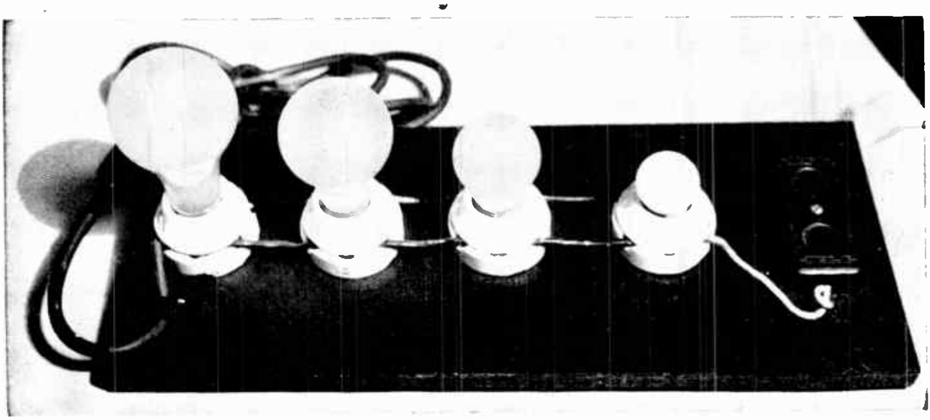
This method of testing a radio set can best be illustrated by using a standard manufactured receiver as an example. We have chosen an RCA model V-205, and V-405, using the RCA chassis RC-521 and RC-521-B. The circuit of this receiver is shown in Fig. 2. Assume that this receiver has been brought to you for repair and that you don't know what is wrong with it. All you know is that it won't operate and that the trouble may be anywhere in the set. It is your job to find the defect, not using any test instrument other than a circuit similar to Fig. 1 and a continuity tester to be described later. It is assumed of course, that you have the receiver at your work bench and turned upside down so you may work on it.

Important: Remember these same principles are applicable to all radio sets. The RCA diagram is merely used as an example to illustrate the principles of this method of testing.

REMOVE ALL TUBES FROM THE RADIO

The first thing you should do is remove all tubes from the receiver. Next plug you test circuit (Fig. 1) into an ordinary A.C. outlet. Then place the power line plug of the receiver into your power outlet on the lamp tester (disregard the power line connections in Fig. 2 to the phonomotor for the time being—leaving switch S-8 open). Next screw a 25 watt lamp into one of the sockets. Now turn on the power switch S-7 of Fig. 2 (you would go through a similar procedure for all other sets you test by this method).

If, on doing this, the 25 watt lamp does not exhibit a visible glow, remove the receiver power line plug from the power outlet. Then make a visual check on the connections to the power line plug, cord and switch (also fuse, etc., if one is used). If nothing seems to



The lamp tester From left to right are 100, 50, 25 and 10 watt lamps. Line cord at left plugs into A. C. outlet, while power cord of radio set plugs into outlet at extreme right end of board.

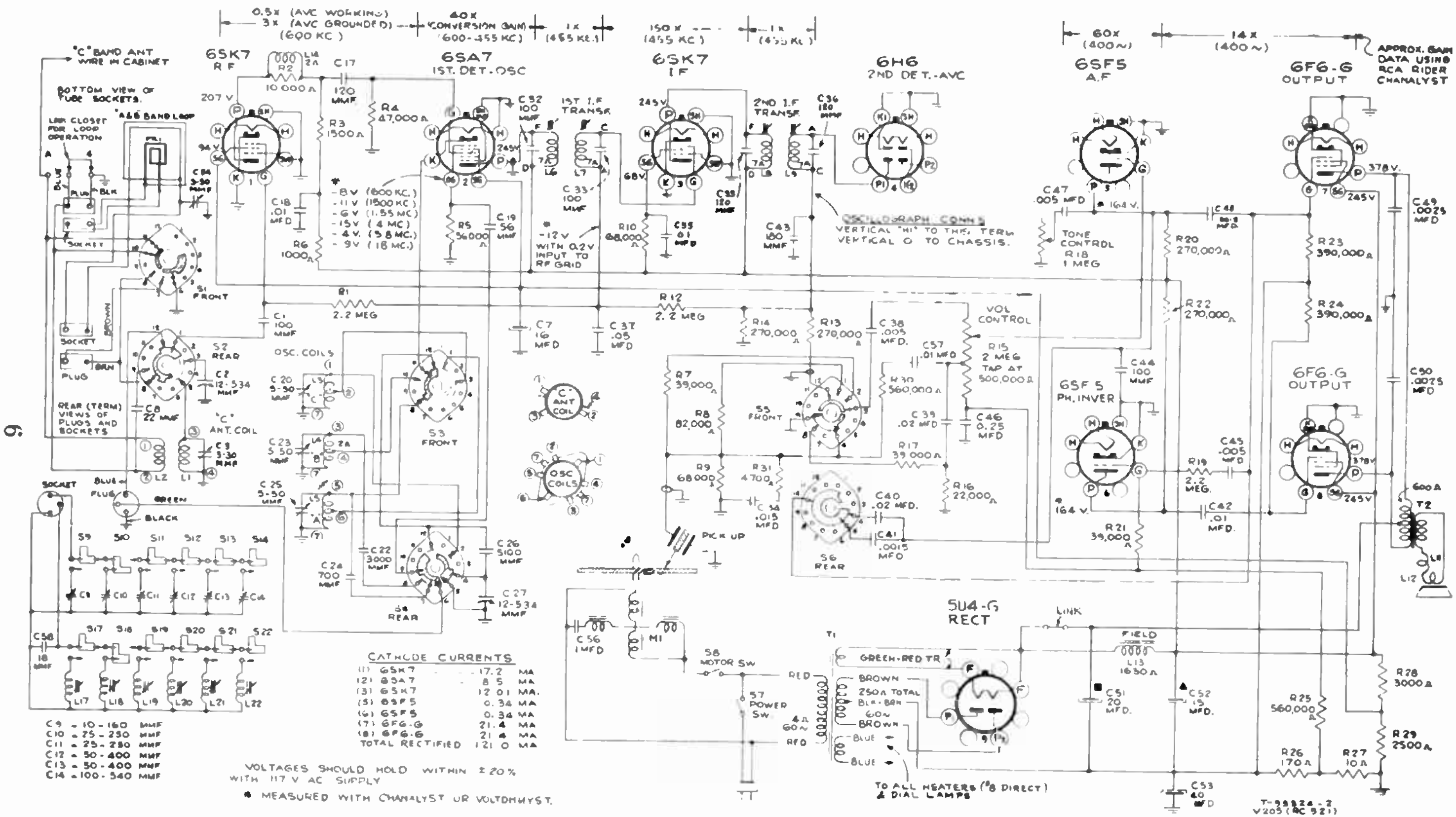


FIG. 2

On some models R31 is 3,900 ohms

Schematic Circuit Diagram

be out of order reinsert the power line cord, turn on the switch and cautiously (to avoid electrical shock to yourself) connect any 110 volt lamp across the primary terminals of the power transformer. (See Fig. 3.) If the second lamp now lights, it is a definite indication that the primary of the power transformer is open. The transformer will in this case usually have to be replaced, because it is not practical to repair an internal open of a transformer winding.

With all tubes removed, the receiver should draw little current, if in normal condition. In fact, the normal current value will be determined by the reactance of the transformer primary winding plus a negligible leakage to the secondary windings—just enough current to cause the 25 watt lamp to glow. However, you are looking for *abnormal* conditions, and therefore, must take into consideration the possibility of defects in one or more parts of the entire receiver. The logical precedure therefore, is to eliminate the possibility of a defect in any one part of the receiver. This can be done, and therein lies the virtue of this method of testing. One technique that you should develop is to learn *how to make elimination tests on as many parts as possible at one time*. This will shorten the testing time and enable you to get to the root of the trouble at once. As you gain experience, this technique will gradually come to you.

Begin tests on the power transformer by first checking the low voltage filament secondaries. This receiver has two of them, and the same procedure would be followed if more than two were used. With the receiver turned on, take a short length of insulated wire (but bare at the ends) and touch the ends across the 6.3 volt winding or to the two marked *blue* in Fig. 2. If this winding is *open*, there will be no change in the brilliance of the 25 watt test lamp and there will be no tell-tale sparks when you make the connection across the winding. *If the winding is normal, the test lamp will light up to full brilliance when you short the winding.*

While the 25 watt lamp in series with the primary will protect against the short circuit you place across the winding, nevertheless you should not maintain the short any longer than is necessary to notice the effect.

Note the foregoing test has tested for both an *open* and *short* of the winding. There remains the possibility of a partial short across the winding. This *could be* either internal or external. Regardless of what kind of short, if the leakage is enough to cause trouble, the test lamp will glow to full brilliance just as soon as the power switch is turned on (which it would not do normally). Shorting the terminals of the winding would make little if any difference in the brilliance of the lamp.

The rectifier filament winding should be tested next in the same way that you tested the 6.3 volt winding. The same conditions for an open, short or partial short would also hold true for this or any other low voltage winding that might be present. The high voltage secondary winding is checked in the same way *except you should short from each rectifier plate* to the center tap of the winding and not across the two high voltage

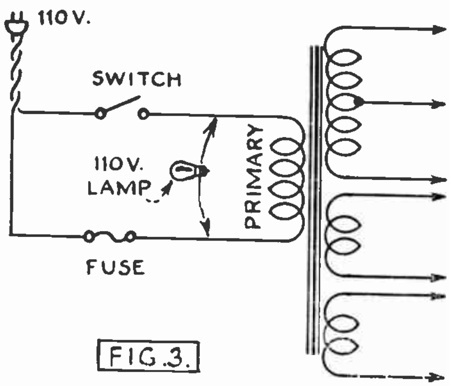


FIG. 3.

terminals of the winding. This is because the secondary center tap divides the winding and a short from the center tap to each of the other two end taps places less load across the winding than when shorting across the entire winding.

You will note that the foregoing tests have been made right at the transformer terminals — this is good practice. However, there is much more length to the filament circuits. There may be opens or other defects along the circuit to the tube sockets. Therefore, if you have any reason to suspect that such a defect does exist, short the filament terminals at each tube socket. *By this double check you determine the condition of the transformer winding itself, and also the circuits leading to the tube sockets.* The same conditions for shorts and opens apply even though you do make the test at the tube socket filament terminals. Practically speaking, it would not usually be necessary to test at more than one tube socket for each winding of the power transformer. The reason for this is that a test at one socket will establish conditions at the other sockets unless an open is present in the filament circuit. The chances for such an open are practically nil.

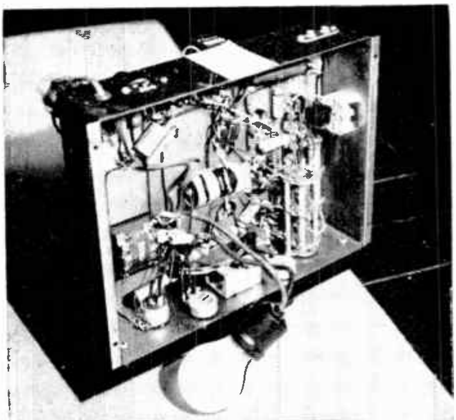
The foregoing tests will clearly establish the condition of the power transformer and all leads connected to it. Having done this, you can now eliminate it as a possible source of trouble and go to other parts of the circuit.

MORE POWER UNIT TESTS

You are now ready to test the D.C. portions of the receiver, and since these are numerous, it follows that the tests will include many circuits. Here is where the technique of testing several circuits at once comes in handy as will be explained further on.

You should begin by *inserting the rectifier tube only in its socket.* It is important too, to not use more than a 10 to 25 watt lamp in the test circuit when first making this test. The purpose of this is twofold—(1) to prevent the power unit voltage from rising to a value high enough to damage the filter condensers and (2) to prevent damage to the rectifier tube and power transformer in case of a direct short in the power unit. A 10 to 15 watt lamp will give most protection against these factors.

With the 10 to 15 watt lamp in place and the rectifier tube in its socket, turn on the power switch of the receiver. In general, for all receivers, the lamp should light to less than full brilliance for normal conditions. Assuming it lights to full brilliance then the rectifier tube is defective, one of the power unit filter condensers is shorted or the circuit is grounded in some other way. Disconnecting one lead of each filter condenser will indicate which filter condenser is



Test set-up using 25 watt lamp to check the primary of power transformer for an "open." This is the same test diagrammed in Fig. 3. and described in text. Note clips on test wires.

shorted. If, on disconnecting a filter condenser in any receiver, the test lamp noticeably *decreases in brilliance*, then you may be sure that filter condenser is shorted and needs replacing.

AN OVERALL CHECK

To return to the power unit circuit of Fig. 2; a *rough check* on the complete power unit circuit may be obtained by touching a metal screwdriver blade to the pole piece of the dynamic speaker (the pole piece is the metal core around which the voice coil fits). This same test will work for any receiver employing the field coil type of dynamic speaker. With a 10 watt lamp in the test circuit, there will only be a slight pull by the electromagnet on a screw-driver blade.

Increasing the size of the lamp will increase the pull on the screw-driver blade up to the saturation limit of the circuit. You can check this by leaving the 10 watt lamp in its socket and screwing in the 25 watt lamp, using the type of circuit in Fig. 1A. This gives a potential total of 35 watts in your test circuit, and the pull on the screw-driver blade will increase in proportion to the increase of lamp power in your test circuit. Likewise, screwing in the 50 watt lamp of Fig. 1A will increase the magnetic pull on the screw-driver, for you now have a potential of 85 watts in the test circuit. This assumes, of course, that such an increase does not reach the saturation limit of the circuit. Whether or not this saturation limit is reached *for normal conditions*, the addition of more lamps in the test circuit will cause all lamps to dim or decrease in brilliance. This is because the lamps do not actually dissipate 85 watts in the series circuit. Their presence simply means that the circuit *cannot dissipate more than 85 watts.*

Under conditions of 85 watts or less (down to 10-15 watts) of lamp power in the test circuit with only the rectifier tube in its socket, if the lamp or lamps light to full brilliance it is a sure indication of trouble—an overload. This overload may be in the form of a defective rectifier tube, a shorted filter condenser, a grounded speaker field, or it may even mean a shorted bypass condenser somewhere along the B+ circuit. At any rate, tests to be described later on will show the exact location of the defect.

In the foregoing, reference was made to a *rough test* by checking the magnetic pull of the speaker pole piece on a screw-driver blade. This gives a rough test on the entire power unit circuit. If the magnetic pull increases uniformly with an increase in lamp power, and if at the same time, the lamps decrease in brilliance, then the chances are that the power unit circuit is entirely normal and may be eliminated as a possible source of trouble. On the other hand, if there is no increase in magnetic pull with an increase in lamp power, and if the lamps increase in brilliance instead of decreasing, then it is an indication of a heavy load (representing a defect), and the cause of it will have to be found as will now be outlined.

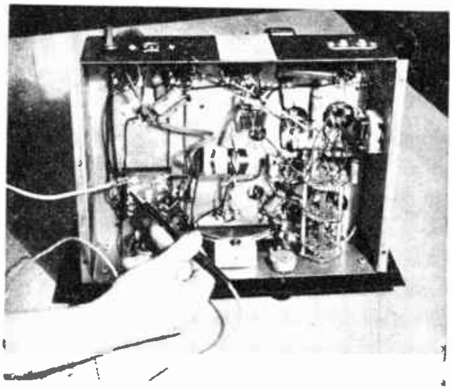
INDIVIDUAL PART TESTS

The vital parts of any power unit filter circuit are the filter condensers, choke coils or speaker field and the resistor voltage divider. In Fig. 2, these are C-51 and C-52 for condensers, the speaker field coil as a choke and R-28, R-29, R-27, and R-26 for the voltage divider (neglecting for the moment the shunt paths for current to the other tubes in the receiver). All other A. C. power unit circuits are to be regarded in like manner, because they would include these essential elements. Therefore, the tests about to be described are applicable to all other receivers which are similarly arranged.

With reference to C-53 (40 mfd.) in Fig. 2, this too, may be regarded as a filter condenser, although its prime purpose is to by-pass or filter the A.C. ripple across R-26 and R-27 because these are bias resistors for the push-pull and A.F. tubes.

To avoid confusion due to possible defects in other parts of the receiver, disconnect the B+ feed line at the output of the power unit. In this case (see Fig. 2), open the link circuit and disconnect all leads at C-52 except the one from the speaker field.

To begin the individual tests of parts in the power unit circuit, use a 10-15 watt lamp in your test circuit, place the rectifier tube in its socket and turn on the receiver switch. Now, take a screw-driver, or a short length of insulated wire or other metal tool, and short the positive terminal of C-51 to ground. If this condenser is in good condi-



Here one of the low voltage secondaries of the power transformer is being shorted with a test lead. This test is for a short or open.

tion, there will be a large spark on making the short circuit and the test lamp will increase in brilliance to its limit. On the other hand, if there is no spark and if the lamp does not increase in brilliance, condenser C-51 is definitely shorted and should be replaced.

To check C-52 or other condensers similarly connected in other receivers, proceed as before, shorting from the positive terminal of the condenser to ground. As before, for normal conditions, there should be a spark on making the short circuit and the 10 watt lamp should increase in brilliance. Testing at C-52 also at the same time checks the condition of the speaker field winding. If you get a satisfactory test for normal conditions as described, you may assume the speaker field coil (or choke coils if any are used) to be in good condition.

If it should happen that you *get no spark* and the *lamp brilliance does not increase* when making the short at C-52, then the speaker field or choke coil is open and must be replaced. If the lamp is already brightly lighted and shorting at C-52 does not increase its brilliance, then C-52 itself is shorted. But you must be careful in making this analysis. There are various degrees of a short in a condenser. It may be complete, with little D.C. resistance, or it may only be partial, with considerable D.C. resistance. With a full short at C-52 considerable current may already be flowing. As a result, a short at C-52 with a metal tool may not increase the current flow any (therefore, no increase in lamp brilliance). Thus you see there is a possible point for confusion. You can double check here to determine the absolute condition of condenser C-52. If you have any reason to suspect it, unsolder the positive lead of C-52. Then short circuit the free speaker field terminal to ground. If this time you get a large spark and the lamp increases in brilliance, it definitely shows that C-52 is at fault because before with C-52 in the circuit, the increase in lamp brilliance might not have been so evident. If the B+ feed line to the other circuits had not been disconnected at the beginning, it is possible that there may have been a short or heavy load of some kind beyond C-52 in one or more of the B+ circuits. If such a short had little or no resistance, it would draw enough current to make it appear that C-52 was at fault. This possibility can be checked by reconnecting C-52 and the lead or leads which feed the B+ circuits one at a time. It makes no difference whether you reconnect C-52 or the B+ feed line first. If things are normal with C-52 reconnected first, then the B+ circuits may be at fault (reference to small by-pass condensers for the B+ circuits will be made again further on). If the B+ feed line is reconnected first and things are normal, then C-52 is at fault. By such a process of elimination, the defect can be narrowed down to one part.

HOW TO TEST MORE LENGTHY CIRCUITS

So far, tests have been made on the complete power unit up to the voltage divider. As progress is made, you eliminated the possibility of defects. You are now ready to check the condition of the individual tube circuits. As you make progress through the various

Screwdriver is utilized as simple instrument to test the magnetic pull of the speaker. Amateurs can use these methods effectively.

stages and add more tubes it will be necessary to increase the power rating of the test lamps (in the test circuit of Fig. 1A) because as more tubes are added to the circuit, more and more power is consumed.

At this point in the testing procedure it is not necessary to check each of the individual resistors making up the voltage divider unless you have conclusive evidence that one or more of these is at fault. By checking conditions at the tube sockets you will at the same time check the voltage divider. Another point to remember is that, as you get further and further away from the power unit and include more and more resistance in your test circuit, the shorting of a part to ground has less and less effect on the test lamps. This is because the *added resistance* further controls the amount of current that can flow and therefore the effect on the lamps is not so evident. Even so, by careful observation it is possible to go through an entire set and determine the condition of each part by direct and indirect tests.

The next step in testing procedure is made on the A.F. output stage—this stage may employ one or two tubes—in either case the same procedure is followed. Place a 25 to 50 watt lamp in your test circuit, and for Fig. 2, place the two 6F6G tubes in their respective sockets. Next turn on the receiver power switch. The test lamp normally should glow at about one-half brilliance. If the lamp is already to nearly full brilliance, use a lamp with a higher power rating in your test circuit. If, on the other hand, it too, lights up to full brilliance, then there is an overload in the output circuit and by the process of elimination you will be able to find the defect.

The object of this test is to determine the relative working condition of each part associated with the output stage. Fig. 4 shows the stage—the rest of the circuit being omitted.

First, you will want to know if plate voltage is applied to the plates of these tubes. To prove or disprove this, momentarily short each plate terminal to the metal chassis (ground) with a metal screwdriver. You should get a large spark when making this short, and the test lamp should increase in

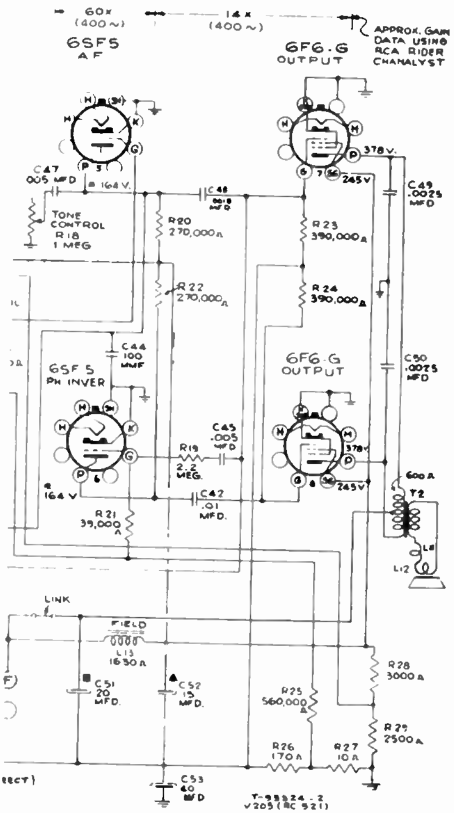
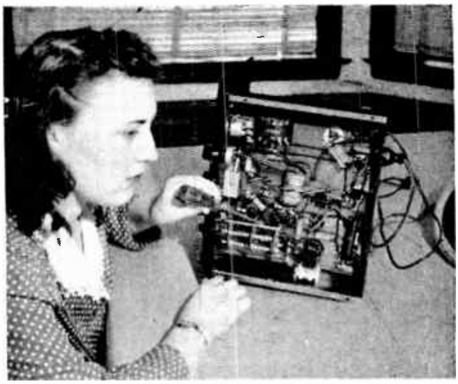


FIG. 4

brilliance.

Suppose you don't get this normal effect? With no spark and no increase in lamp brilliance, it means no voltage is reaching the plates of the tubes. Knowing the power unit is normal, it follows that the defect must be between the power unit output and the plates of the push-pull tubes. This circuit consists of the wires from the plates of the tubes to the speaker plug, through the speaker plug socket, through the primary of the output transformer and on to the power supply. It is not likely the circuit wires themselves will be open although the soldered joints may be poorly made. The next step then is to check the condition of these by visual inspection. The defect is more likely to be at the speaker plug, its socket or in the speaker output transformer. Therefore, you should see that the speaker plug makes firm contact to the speaker plug socket and that all soldered connections are in good electrical condition. If there is any doubt in your mind about the soldered connections, remelt the solder with a hot soldering iron (adding more solder if necessary). *Incidentally, this same observation applies to any other soldered connections in the receiver.* With the foregoing checks made, all that remains as a possible source of trouble is the primary of the output transformer. This may be *open,* preventing voltage from reaching the plates of the output tubes. It may be open in only one section—that is, in one or the other sections from the center tap—or it may be open in both sections. There are several ways to check this. The simplest way to do it is to unsolder all three connections from the output transformer and temporarily



Another screwdriver test: shorting from the plate of the tube to chassis to determine whether voltage is applied to plate of tube.

connect these three wires together. If, on doing this and shorting at the plate terminals of the output tubes to ground, you get a normal reaction (a spark on making the contact and an increase in the test lamp brilliance), it proves the primary of the output transformer is open, and therefore, needs replacing.

While you are checking the output stage you can also check the condition of the complete output transformer and the speaker voice coil circuit. To do this, you simply observe whether or not there is a loud click emitted by the speaker when you short from the plates of the output tubes to ground. Such a click indicates in a relative way that the primary and secondary of the output stage passes a signal and that the voice coil circuit is complete. If you have previously tested the power unit as directed, you will have already established that the speaker field itself is functioning properly.

Previously, it was mentioned in connection with testing C-52, that it was perfectly possible for a short to exist along the B+ circuit feeding the other tubes and that, if this short had little resistance, the effect might be to make it appear that C-52 was shorted. It was pointed out also that the way to check this was to disconnect the B+ feed line, check the condenser as directed and then from the effects exhibited, determine where the defect existed — either along the B+ circuit or in condenser C-52 itself. In regard to testing the B+ feed line *it is important for you to remember the general principles because these principles can be applied to any set and they will be conclusive.*

In any set the B+ feed line is from the output of the power unit through all elements to ground and back to "B" negative or to the center tap on the high voltage winding of the power transformer. Your tests must include all units between these extreme points (B+ and B−). On previous tests for plate voltage for the two 6F6G output tubes the tubes were supposed to be in their sockets. The purpose of this was to place a load on the power unit and to enable you to get a relative check on the speaker circuit. Normally this would be all right, but if it should happen that C-49 or C-50 in Fig. 2 (or any other similarly connected condenser) were shorted (a likely type of defect) or the B+ circuit was grounded in some other way, then the test by shorting from plate to ground at the tube sockets *would not be conclusive.* Thus, if you make a test like this and do not get the proper effects (a spark on making the short circuit and an increase in test lamp brilliance), a more complete isolation test must be made of the entire B+ feed line.

Refer to the first test described for C-52. By disconnecting the B+ feed line, you will remember it was possible to determine whether the defect was in the condenser or further along the B+ circuit. Suppose it was proven that with the B+ feed line disconnected, testing effects were normal for the power unit. It then follows that the defect *must be along the B+ circuit.* To find the exact location of the defect, remove all tubes from the receiver except the rectifier. Use a 10 to 25 watt lamp in your test circuit and reconnect the B+ feed line to the rectifier output.

HIGH VOLTAGE D.C. TESTS

In testing through the receiver it is much more convenient to carry tests up to and including the plate terminals of the tube sockets (the high voltage D.C. circuits). With this completed you can continue your tests from the cathode terminals of the tube sockets (the low voltage D.C. circuits) back to the center tap of the power transformer.

To illustrate these high voltage D. C. tests as clearly as possible, the D.C. distributing circuits of Fig. 2 have been redrawn as in Fig. 5. All essential elements have been included except the plate loads for the various tubes. However, these will be automatically tested as tests are made. All other receivers can be reduced to these bare essentials. It will not be necessary for you to lay out the circuit of the receiver you are working on as in Fig. 5—all you will need is an original schematic diagram of the receiver, and even this is not necessary if you will remember the basic principles

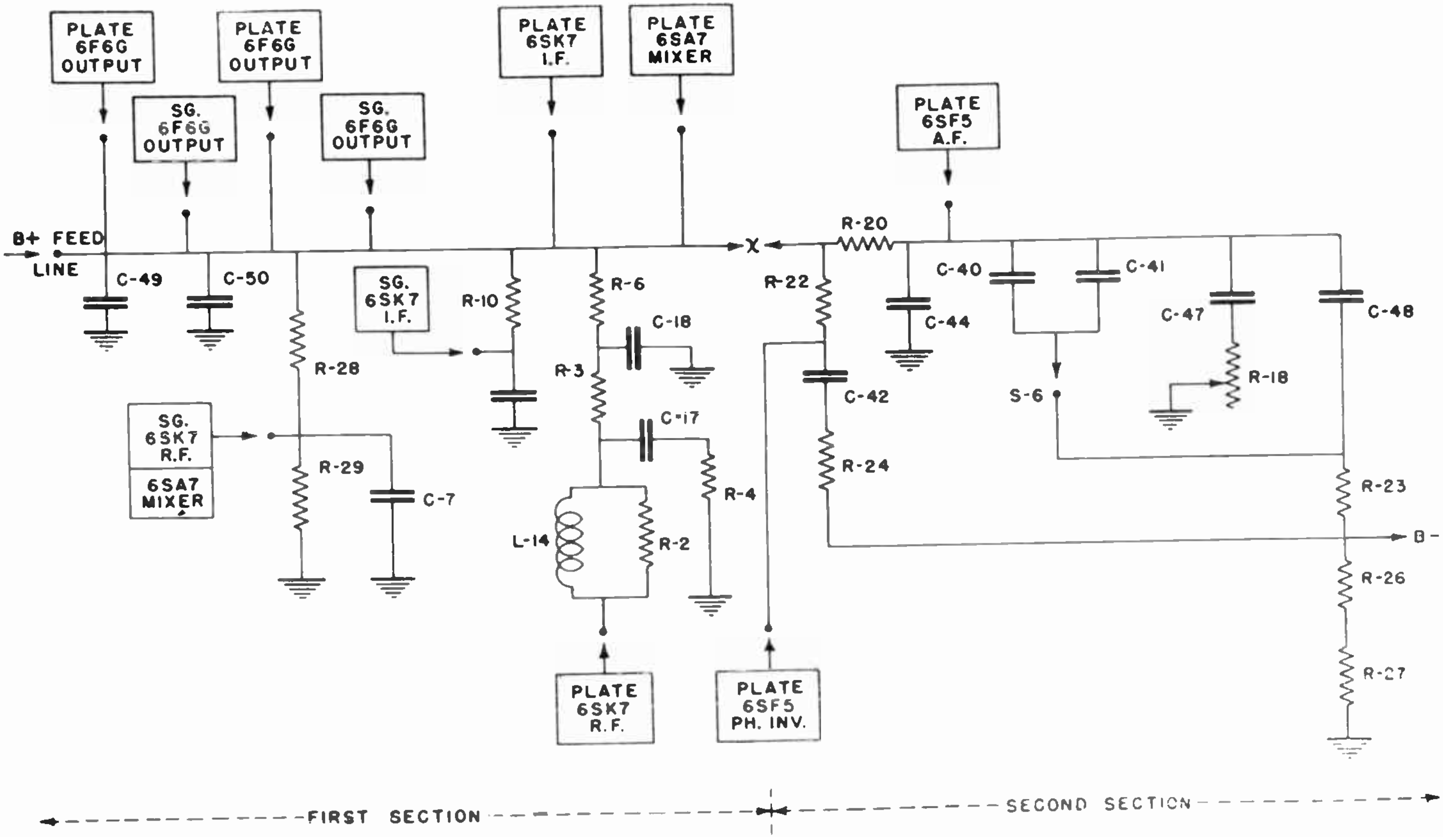
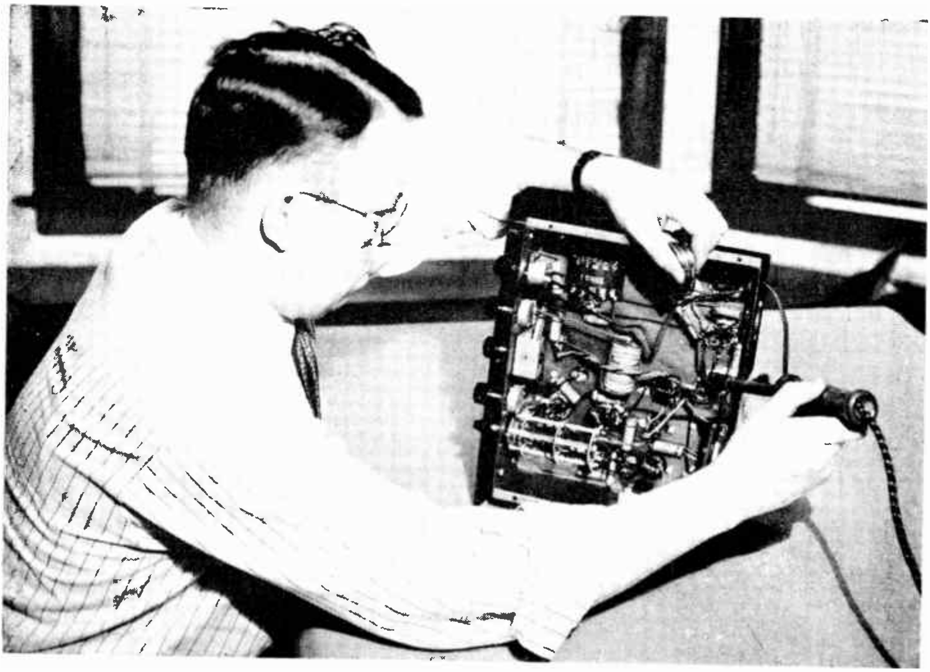


PLATE 6F6G OUTPUT
SG. 6F6G OUTPUT
PLATE 6F6G OUTPUT
SG. 6F6G OUTPUT
PLATE 6SK7 I.F.
PLATE 6SA7 MIXER
PLATE 6SF5 A.F.
B+ FEED LINE
X
R-20
C-49
C-50
SG. 6SK7 I.F.
R-10
R-6
R-22
C-40
C-41
C-44
C-47
C-48
C-18
R-28
R-3
C-42
S-6
R-18
SG. 6SK7 R.F.
6SA7 MIXER
C-17
R-29
C-7
R-4
R-24
R-23
L-14
R-2
B -
R-26
R-27
PLATE 6SK7 R.F.
PLATE 6SF5 PH. INV.
FIRST SECTION
SECOND SECTION

FIG. 5



Worn or loose connections are a frequent source of trouble in radios. All joints and contacts must be inspected and re-soldered where necessary, as illustrated above.

of this method of testing.

Study Fig. 5 in detail for a few minutes and compare it with the complete circuit of Fig. 2. Note carefully that although the appearance of Fig. 5 is different from that presented in Fig. 2 yet these two high voltage D.C. distributing circuits are in exact electrical agreement. Basically, you will see that Fig. 5 consists of resistors and condensers. You should immediately remember that for D.C., resistors will normally pass current — if they don't, they are open, and therefore, defective. For condensers, you have the opposite effect—normally they will not pass D.C., and if they do (normal current flow for electrolytics excepted), they are shorted and need replacing.

With these general observations you are now ready to continue with testing. With all tubes removed except the rectifier, the only load on the power unit will be the bleeder current through the voltage divider and the small leakage current through the electrolytic condensers. This is not enough load to cause your test lamp to burn brightly. Therefore, under these conditions, if it does burn brightly, you may be sure it is due to a shorted filter or by-pass condenser or grounded B+ circuit. On the other hand, the dim test lamp might mean that one or more vital resistors in the power unit are open. Therefore, you cannot afford to assume or guess about conditions.

In testing such circuits as Fig. 5, it will be convenient to divide the circuit in sections. The logical place to do this in Fig. 5 is to open the circuit between R-6 and R-20, indicated by X in the diagram. The action of the test lamp will indicate in a general way what you will need to look for. If the test lamp burns brightly the chances are that the defect is due to a shorted condenser. To check on this, all you have to do is disconnect one condenser at a time, but you must keep in mind some basic principles. Suppose you have separated the B+ circuit in Fig. 5 at X. There are only two condensers in this section of the circuit (the left section in Fig. 5) which will produce the effects of a full short circuit. These are C-49 and C-50. In other words, there are no resistors in series with them and the B+ feed line. If either one of these or other similarly connected condensers in other receivers develop a short the effect is the same as shorting the output of the power unit. Under this condition, of course, the test lamp will glow to full, or almost full brilliance. However, when the suspected condenser is disconnected, the lamp will decrease in brilliance, proving the short.

All other condensers (C-7, C-55, C-17 and C-18) under test in this first section of the circuit have resistors between them and the B+ feed line. Thus, even though they do develop a full short circuit, current flow through them will be limited in direct ratio to the value of the resistance in series with the condensers. Therefore, depending on the value of the series resistance, the test lamp may not light up to full brilliance, even though the condenser is fully shorted. Furthermore, the fact that the condenser has shorted causes *excess* current to flow through the resistors, in series with the shorted condenser. This excess current may burn out the resistor or resistors. Thus, suppose C-7, in Fig. 2 or 5, a 16 mfd., electrolytic condenser develops a short. Excess current is then forced to flow through R-28 and in all probability will burn it out. Thus you must replace both C-7 and R-28 to get normal reception. *This is an important principle that you should always remember.*

Suppose the condition of a condenser connected like C-7 is unknown. To check it, you would ordinarily disconnect one of its leads. If the test lamp decreases in brilliance on doing this, assume the condenser is shorted. However, if R-28 happened to be open, the test would have no effect on C-7. Thus, whether C-7 was good or bad would make no difference. A better *preliminary* check is to disconnect C-7 and then short circuit from the junction of R-28 and R-29 to ground. If there is a small spark on doing this and the lamp increases slightly in brilliance it proves R-28 is not open. With this proved it becomes possible to make the foregoing test. To prove it, disconnect the condenser as previously described and then check on lamp brilliance.

R-29 in Figs. 2 and 5 is a bleeder resistor. About the only thing that could happen to it is an open or "burn out" as it is commonly called. In rare instances, such resistors as R-29 change in value, but it would require more than a 100% change in value here to materially affect the operation of the set. Furthermore, conditions which would cause a change in resistance value would also be conducive to burning out the resistance. Thus, for a resistance like R-29 you would be principally interested in whether or not it is open.

To prove whether or not a bleeder resistance like R-29 is open all you have to do is to disconnect its grounded end and then reconnect it several times in quick succession. If it is *not open*, there will be sparks each time you make and break the contact and the test lamp will increase and decrease in brilliance. This assumes of course, that you have already established that a condenser connected as C-7 is normal and that a resistor connected as R-28 is also normal. It is for this reason in testing by this method that you must begin testing at the rectifier output and establish the condition of parts as you go along. In other words, you begin testing at the highest point of potential and gradually work down to points of lowest potential — establishing the condition of all parts as you go along. After you get a little experience by this method you will quickly learn when and how to divide a circuit in sections as done at X in Fig. 5. The value of this is to limit your task to certain sections of the receiver and to reduce the number of parallel paths to ground. The fewer parallel paths of current you have to consider, the more conclusive your tests will be and the less chance of conditions in other circuits upsetting those of the circuit in which you are working.

In tests so far you will have established the condition of C-49, C-50, R-28, C-7 and R-29. These are the most vital parts in the voltage distributing circuit, and once it is established that these or others similarly connected in other receivers are not at fault, checking the condition of other parts is comparatively easy, as you will see from further study of this test method.

Now consider R-10 and C-55. R-10 reduces the B+ feed line voltage for the screen grid of the 6SK7 I.F. tube and C-55 filters it. In this and in all other similarly connected circuits, you can depend on the factor of "probability" to a great degree. Practice and experience has proven that such a circuit rarely develops trouble. R-10 carries relatively little current, and as long as C-55 does not short, such a circuit may never develop trouble. Therefore, in all probability, such a circuit will remain normal throughout the life of the receiver. Nevertheless, you will want to check to make sure. To do this, short from the screen grid terminal of the 6SK7 I.F. tube to ground. In this, you have to be careful. R-10 is 68,000 ohms, and a short from it to ground will not draw enough current to materially affect the test lamp brilliance. However, small sparks (darken the room you are in if necessary) should be seen on making and breaking the contact if both R-10 and C-55 are normal. If no small sparks are seen, disconnect one lead of C-55 and again make the short circuit test. If sparks are seen this time then C-55 is shorted. If no sparks are seen, then R-10 is open. The circuit of R-6, C-18, R-3, R-2, L-14, C-17 and R-4 is tested exactly like the circuit of R-10 and C-55. R-6 is 1,000 ohms and a short from the junction of R-6, R-3 and C-18 to ground will in this case produce a large spark and the test lamp will increase in brilliance, indicating normal conditions. If you do not get this effect, disconnect R-3 from the junction of C-18 and R-6 and short circuit from R-6 and C-18 to ground. If you now get normal effects the circuit leading through R-3 contains the defect. On the other hand, if you still do not get a normal test, then C-18 is shorted or R-6 is open. Disconnecting C-18 and R-6 and making the short circuit test at the lower end of R-6 will now prove whether R-6 is open or whether C-18 is shorted.

This leaves the condition of R-3, R-2, L-14, C-17 and R-4 to be determined. To get a *rough* test first short circuit from the plate of the 6SK7 R.F. tube to ground. This will include an effective D.C. circuit of about 2,500 ohms, consisting of R-6, R-3 and R-2 and L-14 in parallel. This is not too much of a limiting resistance, and for normal conditions the short circuit should produce a spark and an increase in test lamp brilliance. If you don't get this effect, you will have to break the circuit down into individual parts as was described for R-10 and C-55 also R-6 and C-18. In doing this, you would naturally disconnect C-17 and R-4, for these represent another parallel circuit. Likewise, since R-2 and L-14 are in parallel, to get a check on each of these one should be temporarily disconnected. As you include each one in the circuit, short from the plate of the R.F. tube socket to ground. A spark and increase in test lamp brilliance indicates normal conditions. Having determined the condition of both R-2 and L-14 reconnect them properly to the circuit.

C-17 and R-4 remain to be tested. If you will examine Fig. 2 again, you will note that C-17 is an R.F. coupling condenser. Thus C-17 and R-4 do not enter into the high voltage D.C. consideration unless C-17 should develop a short. If it should short, then a high positive bias is placed on the grid of the following 6SA7 tube. It follows, therefore, that D.C. flows through R-4 and that a voltage drop occurs across it. To get a check on this and similar circuits, *temporarily* connect a wire lead across R-6 and R-3 (short them out of the circuit). This will place the full value of the B+ voltage across C-17 and R-4. Next, separate C-17 and R-4 and connect or touch this free lead of C-17 to ground. If it is shorted, there will be large sparks and the test lamp will increase in brilliance. If it is not shorted, there will be less and less spark as you make and break contact, (charging action of the condenser) but the intensity of the test lamp will not change.

There are various ways to test a resistor like R-4 without meters. It has a resistance of 47,000 ohms, and therefore, limits current through it to a small value. You will be mainly interested in whether or not this resistance has continuity—if it does, the chances are that it is all right. It may not have continuity (a condition of being open) especially if C-17 has developed a short. Thus, in circuits like this, you may have to replace both C-17 and R-4 to get normal reception. One way to definitely establish that R-4 has continuity is to temporarily connect one end of it to the highest B+ point in the circuit and connect the other end of it to ground several times in succession. If it has continuity (not open), small sparks will be perceptible when you do this and the test lamp will change in brilliance to a degree depending on the resistance value. Another way to check for continuity of resistors like R-4 is to connect them across A.F. grid leaks in sets known to be in good condition. For instance, suppose you had a set like that in Fig. 2 in good working condition and wanted to know whether or not several resistors from another set had continuity. All you would have to do is to connect them across the terminals of the volume control (R-15 in Fig. 2). As you make and break contact you would hear a loud click from the speaker if the resistors had continuity. On the other hand, if the resistor was open (no continuity), there would only be a very faint click. The difference in the sound of the clicks from the speaker for an open resistor and for one with continuity is so distinct that there is no possibility for error under these conditions. Finally resistors connected similarly to R-4 or those having a high value can be tested for continuity by using a *neon bulb* continuity tester as will be described later on.

With the tests on C-17 and R-4 completed you can now go on to the second section of Fig. 5. However, before considering this section your attention is called to the various plate and screen grid terminals of the tube sockets of both sections of Fig. 5. In this figure the tube terminals are designated as small dots with blocks of printed matter and arrow heads pointing to them. If you want to establish whether or not voltage is applied to the various plate and screen grid terminals at the tube sockets, all you have to do is short the terminal in question to ground with a screwdriver blade. Unless there is a very high resistance in series with the circuit, shorting will produce sparks and an increase in test lamp brilliance. Should one or more plate or screen grid terminals have high resistances in series with them, temporarily connect a wire across the resistor or resistors so as to short them out of the circuit and proceed as usual. If you get no sparks and no increase in test lamp brilliance, check back over the circuit until you find an open resistor or shorted condenser as one or the other of these defects will probably be present.

To check the second section of Fig. 5, reconnect the circuit at X so as to complete the B+ circuit (remember this procedure is simply typical of the average receiver). It will be up to you to decide in other sets just where they should be divided into sections. Remember, too, you can divide a complete receiver circuit into as many sections as you wish to make for convenience in testing. Either resistor R-20 or R-22 may be tested first. To test R-22 short from the plate terminal of the 6SF5 phase inverter tube socket to ground. R-22 has a resistance of 270,000 ohms. Therefore, for normal conditions there should be a faint spark and only a slight increase in the test lamp brilliance. If there is any doubt in your mind about this or a similar resistance, test it for continuity as previously described. To finish this parallel circuit test C-42 and R-24 just as was described for C-17 and R-4 in the first section.

R-20 and C-44 should be tested next. A short from the plate terminal of the 6SF5 A.F. tube will determine the condition of both R-20 and C-44. A slight spark and slight increase in test lamp brilliance indicates normal conditions, without these it means R-20 is open or C-44 is shorted. To determine which is true separate these two units and test as described for R-28 and C-7 of the first section.

C-40, C-41, C-47, R-18, C-48 and R-23 remain to be tested. To test C-40 and C-41 temporarily ground S-6 and disconnect one end of both condensers one at a time. If either one is already shorted, the test lamp will be at about full brilliance. However, on disconnecting the shorted condenser, the test lamp will decrease in brilliance, thus proving that a short existed. C-47 and C-48 may be tested in the same way. To do this, connect one side of both condensers direct to ground. If either one is shorted, the test lamp will light up brightly and disconnecting the other side of each condenser, one at a time, will prove which one is shorted.

R-18 is a tone control. Rarely will it become defective unless a series condenser like C-47 becomes shorted. If your test should prove that a series condenser like it is shorted you can almost assume the tone control is also defective without testing it. However, if you do want to test it for continuity, test it just as described for R-4.

Resistor R-23 has a resistance of 390,000 ohms and is a grid leak. Any of the forms of continuity testing as was described for R-4 will also work for a resistor like R-23. Resistors R-26 and R-27 are not strictly a part of the high voltage D.C. supply. Therefore, they will be considered under testing for the low voltage supply—cathode circuits, etc.

IMPORTANT NOTE: In the foregoing tests we have gone into detail in testing or determining the condition of each part. In any given defective receiver this long procedure *will not be necessary*. The reason for this is obvious—not all the parts will be defective. Usually the trouble will be just one defective part, and with it found and replaced, the receiver will probably operate normally. It will usually be possible for you to short the tube socket terminals to the chassis and from effects exhibited you will get a general idea of the type of trouble. Then if you use the principles set forth herewith you ought to be able to go right to the direct cause of the trouble. After a little experience with this test method you will soon gain speed and be able to do a good and quick repair job.

HOW TO TEST THE LOW VOLTAGE D.C. CIRCUITS

You are now ready to test the low voltage D.C. circuits and those in which the signal voltage only is involved. Here you must employ a different testing technique because little D.C. power is involved in these circuits. Shorting parts, etc., as was done for the high voltage D.C. circuits will not therefore be as conclusive as in the former case. This does not mean, however, that such circuits as these cannot be tested—it merely means that you must go about the job in a different manner. The easiest way to check the low voltage circuits is to make use of a *continuity tester* and perform a static test—that is, a test with no operating voltages applied to the set under test. The "continuity tester" may take one of several forms, but because of high value resistances to be tested it will be necessary to use an indicator of high sensitivity, at least when high resistances are involved.

A simple device of this type and one easily obtained is the *neon bulb*. A high voltage D.C. supply in series with the neon bulb is also required. This D.C. voltage is most easily obtained from the power supply of another radio set, although any other high voltage D.C. supply will be satisfactory. Before going into this, consider a "continuity tester" in more detail. Such a tester may be any electrical device as long as it will indicate the electrical completeness, or lack of it in a circuit. Such testers are known as low and high sensitivity continuity testers. One requiring relatively high current for its operation is a low sensitivity tester. Examples of this type are the low voltage radio pilot or dial lamps, buzzer, 110 volt house lighting lamps, flashlight bulbs, etc. Examples of the high sensitivity type are the microammeter type of ohmmeter, headphones, neon bulb, etc. In other words, *the less current an indicating device needs for its operation when used in testing high resistances the better continuity tester it makes for radio circuits*. It is for this reason we recommend the neon bulb type of tester (in lieu of a meter) although there are special

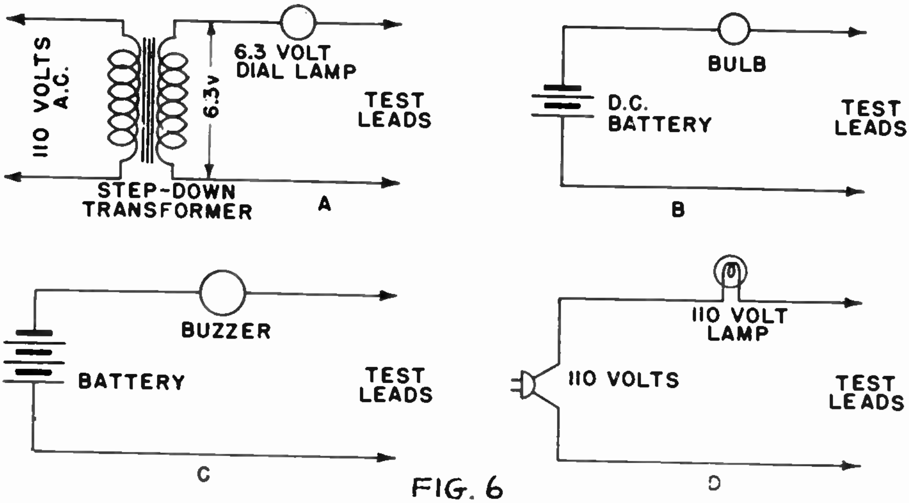


FIG. 6

cases where a low sensitivity tester is desired (when it is desired that a circuit carry high values of current).

Figure 6 shows four examples of the low sensitivity type of continuity tester. At A, is an ordinary step-down transformer such as a 6.3 volt filament transformer. The secondary of this is in series with a 6.3 volt radio dial lamp. At B, a flashlight bulb is in series with a flashlight battery. A similar circuit is used at C with a suitable battery in series with a buzzer, such as the door bell type. At D, is an ordinary house lighting bulb in series with the 110 volt power line. This is the least desirable circuit among those of Fig. 6 because it is more dangerous since it is operated by the power line.

Figure 7 shows three high sensitivity types of continuity testers. At A, is the usual meter in series with a voltage source—this is commonly called an ohmmeter because its scale is graduated in values of resistance. At B, a pair of headphones is in series with a battery and at C, a neon bulb and a 150,000 ohm resistor is in series with a high D.C. voltage source. This will indicate through resistances of between 30 and 50 megohms.

Note particularly that all the circuits of Fig. 6 and 7 have three things in common, (1) a source of operating voltage, (2) an indicating device and (3) a pair of test leads. The test leads may be of the ordinary commercial type such as is usually obtainable from any radio parts jobber. However, you may use a pair of ordinary insulated wires (but bare at the ends) if commercial test leads are not available. Regardless of the type of indicator used, make sure that its operating voltage source does not exceed the safe voltage limits of the indicating device. For instance, in Fig. 6B do not use a 6 volt battery in series with a 3 volt flashlight bulb, etc. The reason for this is that with little or no resistance across the test leads, the full force of the operating power is applied to the indicating device. Thus, with excess operating voltage, your indicator is likely to be damaged.

A continuity tester operates on the principle that with the test leads shorted (touched together) the indicator will denote a flow of current. But remember, this flow of current is from the power source which operates the indicator of the continuity tester. It does not indicate a current flow from the power source in the radio set you are working on. When using the continuity tester of the types described in Figs. 6 and 7, the radio set must be disconnected from its power source and all tubes of the receiver should preferably be removed from their sockets.

The type of continuity tester you use will of course determine what you are to observe to indicate continuity. For instance, in Figs. 6A, B and D, the lamps or bulbs will light when the test leads are touched together. In Fig. 6C the buzzer will emit sound when the test circuit is completed. In Fig. 7A with the test leads touched together, the meter needle will move. In Fig. 7B, the headphones will click (sound) and in Fig. 7C the neon bulb will light.

The indicators in these various test circuits will produce evidence (light, sound, etc.) of a complete circuit when the test leads are shorted. When one test lead is placed at one point in a radio circuit under test and the other test lead at another point in the same circuit, the continuity tester will show whether or not a circuit is complete. This is a most important principle and one which can be made very useful. However, in making use of this principle, the radio man must be careful to take into consideration the resistance of the circuit under test and the type of radio parts connected to the circuit.

In general, with a circuit consisting of wire connections only, any of the continuity testers shown in Figs. 6 and 7 may be used satisfactorily. However, as more and more resistance is included in the test circuit, the current from the tester circuit will become less and less with the result that when a certain resistance value is reached

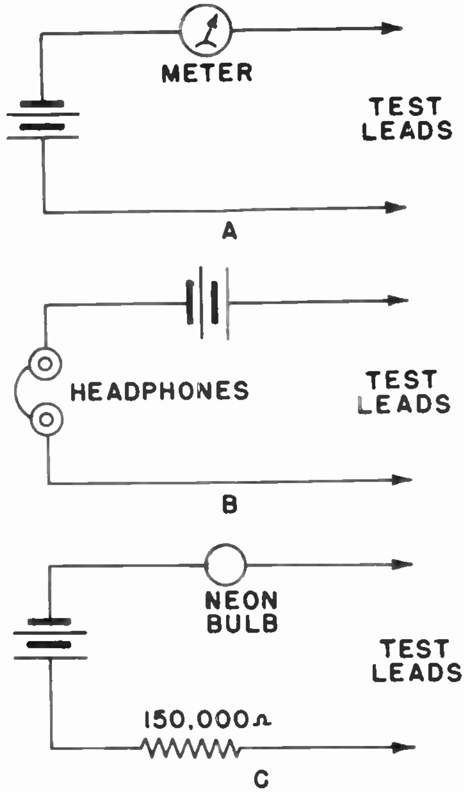


FIG. 7

the tester will no longer indicate. When this happens the tester is no longer useful and you must resort to a tester with a higher sensitivity. Thus, you might as well use a high sensitivity tester to begin with, for then you can take care of all circuits with one unit. The circuit of Fig. 7C is therefore recommended.

Any high voltage D.C. (200-500 volts) may be used in place of the battery shown in Fig. 7C. If you want to use your work bench radio set for this purpose, the circuit of Fig. 8 may be used, or its equivalent. This circuit should be set up in permanent form. Two insulated tip jacks should be mounted on the receiver chassis of the type which will accommodate the tips on your test leads. Use a red jack for positive and a black one for negative. Connect the neon bulb and 150,000 ohm resistor in series between the plus tip jack and the positive terminal of the second filter condenser, or to an equivalent point along the B+ circuit. The neon bulb may be of the 1/8 or 1/4 watt type (or larger size) as the size is not critical. It may be mounted in a socket or not just as you wish. Sockets for these may not be available in some cases. If you prefer, the neon bulb may be held in place with its own wiring although an insulated socket mounted on the receiver chassis makes a neat permanent job. The important point of course is to place the neon bulb where you can see it light or glow. The black tip jack may be connected to any convenient ground terminal on the receiver chassis (the receiver from

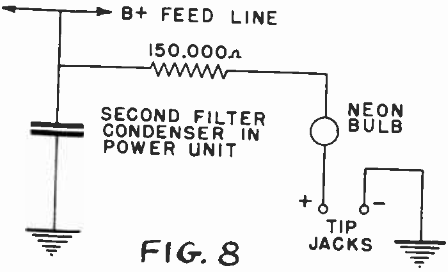


FIG. 8

whence you get operating power for the neon bulb). With the addition of Fig. 8 or its electrical equivalent, to your radio set, all you need to do to use it as a continuity tester is to turn on the receiver power switch and plug two test leads into the tip jacks. Then when the other end of the test leads are shorted the neon bulb will light. You now have the finest kind of high sensitivity continuity tester. Incidentally, the fact you have added a test circuit like Fig. 8 to your radio set will not interfere with its operation for any other purpose. The neon bulb load on the set is so small that it may be neglected entirely.

Now consider the low voltage circuits of Fig. 1. These low voltage circuits have been redrawn in Fig. 9 so that the test method may be followed by you more easily without having to consider the complete circuit. However, you should study both Figs. 1 and 9 carefully to make sure you understand the electrical relations between the two—electrically both circuits are alike.

When testing the high voltage circuits you will remember the factor of probability — that is, where trouble would be most likely to appear. Obviously, in Fig. 9 or in a similar circuit, the most likely defect which may occur is the opening of a resistor, a shorted condenser, or varying degrees of these. Of course, there may be poorly soldered joints, open circuits (connecting wires), etc. Even so, a routine test will establish where the trouble exists.

Also, there is the question of *when* it is necessary to test the low voltage circuits. This you decide by making the foregoing described tests on the high voltage circuits. If you don't find the trouble in that section of the receiver, then of course the next logical step is to continue on with the low voltage circuits as will now be described.

If you have made the high voltage tests without finding the trouble then your next tests should include any resistors and condensers associated with the most negative end of the voltage divider. For the receiver under consideration, this would include R-26, C-53 and R-27 in Figs. 1 or 9. Assuming you have set up the neon test circuit of Fig. 8, touch your test leads across R-26. If the neon bulb glows, the resistor is not open, and otherwise, is probably in good condition. If the bulb does not glow, the resistor is open and must be replaced. Next, do the same thing for R-27, making the same observation. However, if it should happen that a condenser, as for instance one like C-53, is connected across a resistor like R-26 or R-27, to be sure of your test, disconnect the condenser to remove a possible parallel circuit across the resistor in case the condenser is shorted. Then make a separate test on the condenser before reconnecting it.

At this point it is necessary to remember some fundamental effects when testing condensers with a neon bulb in series with a high voltage D.C. source, such as that in Fig. 8. A solid type of condenser dielectric such as used in ordinary paper and mica type condensers will if in *normal condition*, cause the neon bulb to flash on and off at a rate, depending on the capacity value. When the condenser is first connected to the test circuit there will be an initial flash (flash of light then cutting off) of the neon bulb. The bulb will then continue to flash at a regular rate as long as the condenser is left connected in the test circuit. The larger the capacity value (.5 mfd. to 10 mfd.), the less frequent will be the bulb flash. On the other hand, from .5 mfd. to very small values (up to .0005 mfd. or smaller), the bulb flashes will increase in frequency until the higher limit is reached where the bulb will appear to be continuously lighted. *All this refers, of course, to a normal condenser.*

An open condenser *will not* show an initial charging flash, nor will the bulb light at any time (it may show a very faint glow but this will be due to leakage across the condenser terminals). An intermittent condenser may or may not show an initial charging flash, or again the bulb will glow infrequently and will eventually (if left connected in the test circuit long enough—usually 5 to 10 minutes) go out altogether. Such a condenser should be replaced. A full shorted condenser or one with an internal high resistance short will cause the bulb to light continuously, but at a reduced glow in intensity if there is a high resistance short. Condensers showing this effect should be discarded and replaced.

For electrolytic condensers, the neon bulb will light continuously at slightly less than full brilliance. (Be sure to observe polarity when testing electrolytics.) This applies to both the high and low voltage types (it does no harm to test low voltage electrolytics by this method when the condenser is only connected in the test circuit for a moment). To test an electrolytic condenser, connect it to the test circuit just as you would any other condenser, but while it is connected and still under test, short the condenser terminals with a metal screw-driver blade. This should produce sparks and the neon bulb should increase in brilliance. If there are no sparks and if the neon light does not increase at the instant the short circuit is made, then the condenser is shorted and should be replaced. If there is no initial charging flash and if the neon bulb does not act as described for a normal condenser, then the condenser is open and should be replaced.

When testing very small value condensers, the neon bulb will appear to be lighted continuously because the flashes will be so frequent. The light, however, will be at less intensity than when the test leads are simply shorted. Thus, from this you can judge if the condenser is all right. On the other hand, if the bulb does not light, the condenser is open, and if it lights to full brilliance, the condenser is shorted.

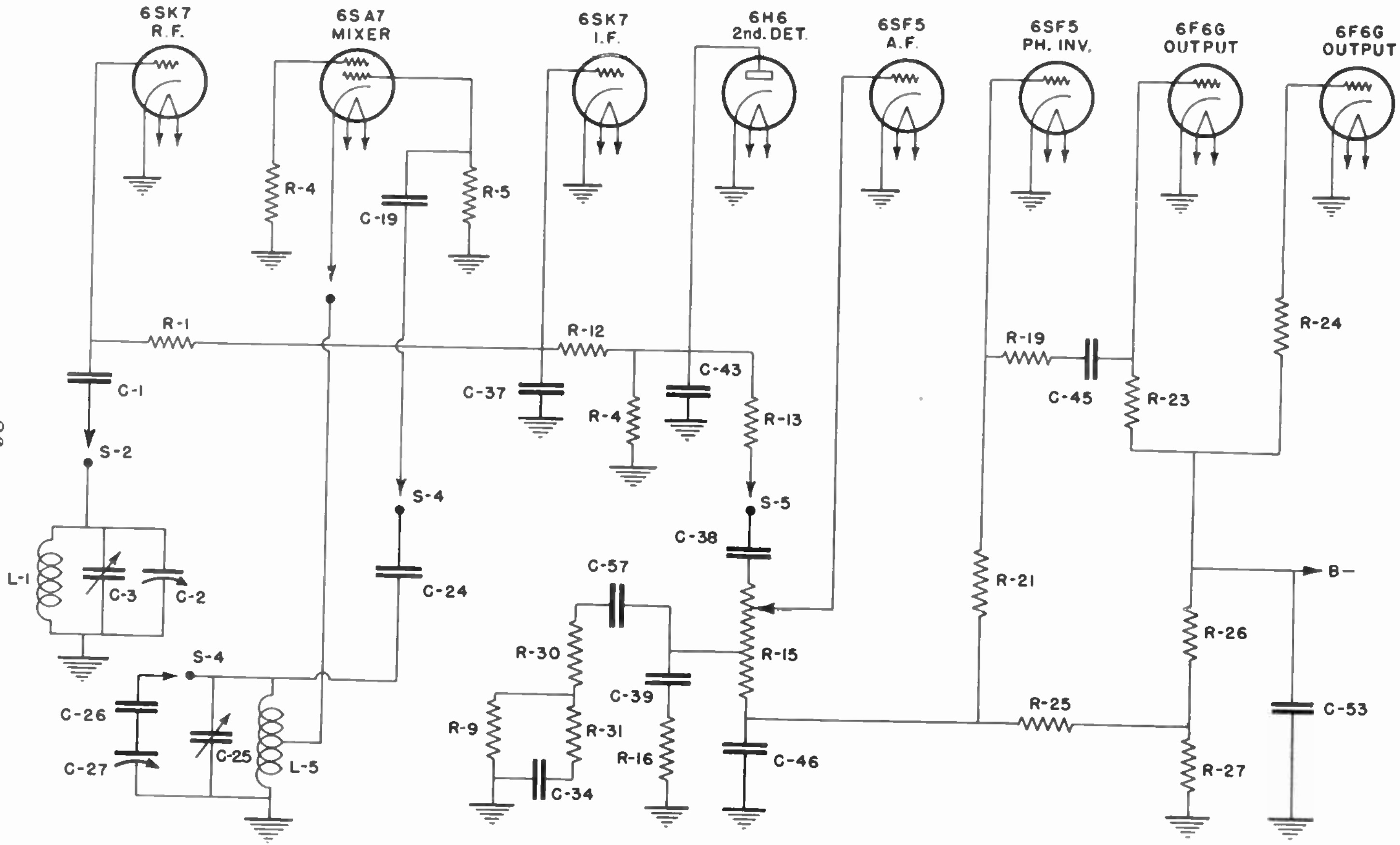

6SK7
R.F.
6SA7
MIXER
6SK7
I.F.
6H6
2nd. DET.
6SF5
A.F.
6SF5
PH. INV.
6F6G
OUTPUT
6F6G
OUTPUT
R-4
R-5
C-19
R-1
R-12
R-24
R-19
C-1
C-37
C-43
R-4
R-13
C-45
R-23
S-2
S-4
S-5
C-38
C-57
L-1
C-3
C-2
C-24
R-21
B-
R-30
R-15
R-26
S-4
C-39
C-26
R-9
R-31
R-25
C-53
C-25
R-16
C-27
L-5
C-46
R-27
C-34

FIG. 9

Refer to Fig. 9 and the further testing of the low voltage parts. Condenser C-53 or any other one similarly connected should now be tested according to the foregoing test described for condensers.

Just where to test next in a circuit similar to Fig. 9 is largely a matter of choice plus the symptoms which the set exhibits. To make the testing systematic, it would be a good idea in any set to check the bias resistors first, then disconnect any condensers associated with them and give each an individual test. Check the grid return circuits next. In Fig. 9, this would include R-23 and R-24 for the output stage. R-21 and R-25 for the phase inverter stage. R-15 through R-25 for the 6SF5 A.F. tube.

The grid or plate load for the 6H6 diode tube is not shown in Fig. 9. However, it would be tested like any other resistor or inductance for continuity. Merely place one test lead on the plate of the diode tube and the other one at some point on the A.V.C. feed line. If there is a complete circuit the neon tube will light. Fig. 1 shows that C-36 is connected across the diode load winding. If you suspect it, disconnect the condenser and check it just as previously described for any other condenser. The grid circuit of the I.F. tube is checked in the same way. Check R-4 in Fig. 9 for continuity just as you would any other resistor. Both Figs. 1 and 9 show R-4 to be the grid load for the 6SA7 tube. The 6SK7 R.F. tube has no grid load other than R-1 and it should be tested for continuity.

The oscillator grid circuit includes R-5, C-19, S-4, C-24, L-5, C-25, C-26 and C-27. To check R-5 for continuity, connect your test leads across it. Such a resistor very often has a condenser across it. When this happens disconnect the condenser and give both the resistor and condenser a separate check. This removes the possibility of parallel paths through possible short circuits and enables you to get a positive check on each unit.

L-5 in the oscillator circuit would be checked for an open and short just as you would check a resistor. You can get a separate check on each of the condensers in the circuit by disconnecting them and testing as described. Where switches are involved, as S-4 in Figs. 1 and 9 make sure they are turned to the right position when you are checking for continuity through them. Note in Fig. 9 that the 6SA7 oscillator-first detector tube has two grid circuits to be checked. This will require the testing of both R-4 and R-5. A similar situation would exist in other sets using this type of tube.

It so happens that condenser C-1 interrupts the D.C. continuity in the grid circuit of the R.F. tube in Figs. 1 and 9. Ordinarily this would not be true for most sets and the control grid circuit would include a coil such as L-1 which would return to ground or to the A.V.C. feed line. Since C-1 is included in this circuit, a separate check should be performed on it, observing principles previously outlined. A continuity test may then be made through S-2 and L-1 by connecting one test lead to the proper terminal at S-2 and the other one to ground. Similarly condensers C-2 and C-3 may be tested by disconnecting one lead of each and performing a separate check on each one of them. This completes the checking of the grid return circuits with the exception of the A.V.C. feed line, portions of which have already been tested.

In general for any receiver, the A.V.C. feed line can be checked for continuity by connecting one of your test leads to the diode or second detector plate or grid (depending on the arrangement of the circuit) and connecting the other test lead to the control grid of the tube in the antenna stage. Then to check the intermediate stages in between the antenna stage and the second detector for A.V.C. feed line continuity, all you have to do is touch one test lead in turn to the oscillator-first detector control grid, (provided its circuit returns to the A. V. C. feed line) and also to the control grid of all I.F. tubes leaving the other test lead connected to the second detector stage. In Fig. 9 this check would include the circuit from the 6H6 diode plate to the control grid of the 6SK7 R.F. tube and then move the test lead from the R.F. control grid to the I.F. control grid. No light in the neon bulb would indicate one or more open resistors such as R-12 and R-1 or it may mean an open grid circuit, as for instance, in a coil. An individual continuity test across each resistor or coil will show which one is at fault.

Note in Fig. 9 that with one test lead connected at the switch end of R-13 and the other test lead at the 6SK7 R.F. control grid, you would check the continuity of the circuit from S-5 all the way to the control grid of the R.F. tube. Such a test will often save time, and for this reason, you should develop the technique of testing as much of the circuit at one time as is possible.

Once you establish the continuity of all grid returns and the A.V.C. feed line, the next thing to do is to check any condensers associated with these circuits, particularly those across the A.V.C. feed line to ground. In Fig. 9, these would be C-43, C-37 and C-1. Other circuits would have similar condensers and a separate check should be made on each one. To do this, merely disconnect one lead of each condenser to separate it from its circuit and then perform the condenser test with neon bulb as previously described.

Next is the A.F. section, and the logical point to begin is from the plate of the 6H6 diode, checking through R-13, S-5, C-38, R-15 and C-46. Although tests have been described for R-13 you might not, for some reason, have made this test up to now. Regardless of this, it is a good idea to begin testing at the source of a circuit and continue on through to its end. Thus, for this circuit one test lead would be placed on the diode plate and the other one at S-5 so as to include its contacts—this provides a test on both R-13 and the contacts of S-5. C-38 is next in the series circuit and it should now be tested separately. Then check R-15 and C-46. Remember, too, you can check one or more resistors at one time, whereas only one condenser should be tested at a time. Thus, in the A.F. network of Fig. 9, separate tests would be required for C-38, C-46, C-39, C-57 and C-34.

Resistors, however, as in Fig. 9, R-30 and R-31 can be tested at one time and so can R-30 and R-9. This is because R-30 and R-9 form another series circuit involving nothing more than resistance. You should take advantage of such connections when they exist. Another place where this situation exists in Fig. 9 is from ground to the C-45 condenser side of R-19. Thus, one test lead at ground and one at R-19 will complete a circuit through R-27, R-25, R-21 and R-19. A light of the neon bulb in this case establishes that all of these resistors have continuity, and therefore, the circuit is complete. Likewise, a test from ground to the control grids of the output tubes will establish whether resistors R-27, R-26 and

R-23 are complete and moving one test lead over to the control grid of the other output tube will establish the condition of R-24. If it should happen that the neon bulb does not light when making such a test, then retrace the circuit and test each individual resistor. One or more of them will be found to be open. and of course should be replaced.

The circuit of Fig. 9 does not include all of the units relating to the phonograph record reproducing system as shown in Fig. 1. However, these parts would be tested just as described for the others. For instance, R-7 and R-8 can be tested for continuity by testing from one terminal of the pick-up unit to termnial 2 of S-5 for R-7 and to terminal 1 of S-5 for R-8. The crystal pick-up from a D.C. viewpoint can be considered as a condenser and would, therefore, be tested just like any other condenser.

The A.C. motor for the turntable (M-1 of Fig. 1) can also be tested for continuity just as you would test any other wire winding. For instance, you may test from S-8 (switch should be open) to one terminal of the power plug (the one not connected to S-7). This will establish continuity through the motor windings. But since two sections of the motor winding are in parallel, to get an accurate check on each section, the windings should be disconnected from each other and a separate test made on each. The same thing applies to C-56. Disconnect it and make a separate test as for any other condenser.

Continuity testing such as described here is not, of course, limited to the low voltage circuits. For instance, the R.F. coil windings which includes the oscillator and I.F. windings can easily be checked for continuity with the neon bulb. Simply select the two terminals of the coil which should show continuity and test across them. If the coils should happen to be shunted with a condenser, disconnect the condenser and make a separate test on both the coil and condenser. If there are no defects, reconnect the circuit and continue on with your routine check until you do locate the trouble for which you are searching.

As you can see, the entire set may be tested by the continuity testing method alone or you may test the high voltage circuits with the 110 volt lamp in series with the power line, or as very often may be the case, you will probably want to combine the two test methods. You will have to determine these things to fit the particular circumstances. In any event, a little practice and close attention to details will enable you to service or repair practically any set without the aid of meters.

TESTING TUBES

This is no problem for a man that has a good tube tester. The man who does not have one has one or two other methods open to him. First he may take all the tubes he suspects of being defective to his local radio parts jobber or to a friend for testing. If that is not possible then he will have to make tube substitutions.

This requires that he have on hand or can get a complete set of new tubes for the radio set under repair. An alternative is to take similar tubes from a radio set known to be in good condition and substitute them for tubes in the set under suspicion.

The substitution method is simple to follow. All you have to do is to substitute tubes *one at a time* and notice the effect on the reproduction of the set.

OUTLINE OF TRAINING UNIT NO. 5
AND HOW TO ANSWER THE LESSON QUESTIONS

Your fifth Training unit represents a distinct division in your progress with Sprayberry Training. Essentially, the division is between theoretical and practical studies. With lesson ND-34 and 35 completed, the remainder of your studies will be concerned almost wholly with practical work. By this time, you will have completed all of your theoretical studies and will begin to explore practical work. Thus, you will notice in this Training Unit, some of the lessons have the prefix "TV". This, by the way, has no connection with television—it is merely a convenient division separating the theorectical from the practical studies. However, it should be thoroughly understood that practically everything described in the "TV" lessons may also be applied to television receivers. From an Electronic viewpoint, the testing of component parts of a circuit is the same whether the particular circuit happens to be employed in radio, television or some other branch of electronics. In fact, the testing procedures set forth in the "TV" lessons, while describing specifically radio and television circuits, apply equally as well to transmitters, audio amplifiers or other specialized circuits having similar component parts.

It is in this Training Unit that you complete your work with the multitester, and it is suggested that you take this up just as soon as you finish with lessons ND-34 and 35.

We want to particularly called to your attention the Reference Lesson 1R1, which has a very definite place in elementary and basic testing of circuits. In fact, if you care to do so, you set up the test circuits of 1R1, making tests and getting experience in testing and analyzing circuits before attempting to use your meter, which is a more delicate and fragile device than the basic simple elementary testers described for Lesson 1R1.

Some of our other students will receive Lesson DX-3 in this Training Unit, which you will not be concerned with, if you have previously received the "R" series of lessons. In order to have the Study Hints complete for this series, we are therefore, including Lesson DX-3 for those of our students who do get this particular lesson at this point in their training.

As in other Training Units, we, again, include our usual Business Builders, service Bulletins and Service Manual 3. All of these represent useful and time proven reference material, which you should be able to put to good use. Thus, you have a most interesting series of lessons and practical work in this training unit to add to your store of knowledge and experience. We shall be glad to give you any additional help you might need upon request from you.

HOW TO ANSWER QUESTIONS

Lesson ND-34: Two lessons on the general subject of Photo-Electronics concludes your studies of general theory, applying to radio and television. Photo-Electronics is important in both fields, and we think you should have in your background the general knowledge that these two lessons present. For question 1, it is 'no'. Photocells also respond to frequencies not detectable by the human eye. For 2, convex lens and parabolic reflector. For 3, time lag response and fatigue. For 4, two—a cathode and an anode. For 5, by the amount of light falling on the cathode. For 6, a photo-voltaic type. For 7, proportional to the light intensity. For 8, the difference is in the applied current. The sensitive type operates on minimum current, while the power type requires much more current. For 9, the gas filled photocell. For 10, AC necessary to unlock the relay. This brings about a reduction of plate current with each cycle.

Lesson ND-35: For question 1, they are direct coupled and impulse type of amplifiers. For 2, relay operates at certain fixed current or voltage values. Color light is not uniform enough to be accurate and a meter is used instead. For 3, vacuum tube memory circuit or meter type counter. For 4, 'yes', a double interlocking photocell is used. For 5, an angular light beam is used, insuring door clearance. For 6, reflect the light beam to cover all entrances. For 7, use sensitive relay to control a power relay. For 8, use of photo-meter and color measurements. For 9, 'yes' many direct applications. For 10, use of a light filter sensitive to infra-red rays.

Lesson R-5: For question 1, the off position. For 2, change operating conditions of a circuit, calibrate meters or other instruments and resistor substitution. For 3, 'no'. For 4, parallel. For 5, to obtain zero adjustment for ohmmeter. For 6, to avoid parallel effect of other parts. For 7, static tests made without applied operating power. Dynamic tests require circuits to be operating. For 8, connect test leads across filament pins. For 9, it blocks

DC but allows effect of AC to be measured. For 10, make sure to use current range higher than current value to be measured.

Lesson DX-3: For question 1, to change AC to pulsating DC. For 2, AC continually reverses direction of flow. DC flows in one direction only. For 3, flows in one direction but increases and decreases in intensity or amplitude. For 4, condensers- coils-resistors arranged to smooth or even AC or pulsating DC, resulting in practically unvarying DC. For 5, it accepts or bypasses current variations. Associated with the rectifier, it increases the output filter voltage. For 6, refers to arbitrary voltage charges, commonly called positive or negative. For 7, three different tests are: use of neon bulb, a DC meter or by electrolysis. For 8, disconnect and test with ohmmeter or other continuity tester. For 9, make continuity test on all parts from grid to cathode. For 10, special meters or test circuits may always be used. In this lesson, the simple tests make use of neon bulb, incandescent lamp, etc. Such tests are relative—the degree of light or brilliancy being indicating factors. For condensers, a relaxation oscillator may also be used.

Lesson TV-1: This series of lessons begins a description of practical testing. The first lesson deals with the work bench. For question 1, test leads with phone plug tips and alligator clips. For 2, storage batteries with trickle charger. For 3, voltage regulated, use of series lamp and connection direct to power line. For 4, 0-10 DC voltmeter and 0-30 DC ammeter. For 5, fuses. For 6, to indicate open circuits, low power; to indicate short circuits, high power and to show general overall conditions. For 7, for protection, for testing and for controlling current. For 8, for condenser substitution to show opens, shorts and excessive leakage and hum tests for filter circuits. For 9, determine resistor values, prove a resistor open and to restore a circuit to normal operation. For 10, necessary when speaker is missing or when there are possible defects in speaker, field coil or output transformer.

Lesson TV-2: For question 1, permits opening of circuit to measure current flow. For 2, 'no', the same point in a circuit may be positive or negative in relation to some other point. For 3, 'yes', bleeder current still flows. For 4, 'no', defects may be in other circuits. For 5 because cathode current is the sum of plate and screen currents. For 6, polarity, proper meter range and certainity only DC is involved. For 7, connect negative meter terminal to ground instead of to cathode. For 8, refer to

Fig. 28—connect voltmeter across coil. If meter reads high value, choke is open; low value, indicates voltage drop and normal current flow through choke. For 9, if voltage drop occurs across primary winding, it is not open, hence plate current must flow through it. For 10, connect negative of meter to grid and positive to ground, thereby measuring voltage drops across R15 and R16.

Lesson TV-3: For question 1, ohmeter, headphones or neon bulb suitably connected in series with a voltage source. For 2, establishes if a circuit or part will or will not conduct current. For 3, examples for continuity are: resistors, coils, wire circuits, tube filaments, volume controls, tone controls, etc. Examples for no continuity are: condensers (except electrolytics), pick-up units, open switches, elements of tubes, etc. For 4, to eliminate effects of parallel circuits. For 5, approximately 550,000 ohms. For 6, with B + disconnected, approximately 15,000 ohms. For 7, observe polarity of test leads. For 8, ohmmeter will first show low resistance and gradually increase as charge is built up. For 9, all sizes may be tested. For 10, no reading—otherwise condenser would have excessive leakage.

Lesson TV-4: For question 1, 6,666 ohms per volt, resulting in 3% accuracy. For 2, Class A. For 3, see Figs 8 and 9—zero bias obtained by use of bridge circuit. For 4, when voltage to be measured does not exceed normal grid voltage of the VTVM tube. For 5, increases the grid voltage range, improves the Eg-Ip characteristics and the circuit is less critical to the particular tube used. For 6, high impedance rectifier. For 7, increases sensitivity of the VTVM, resulting in high input impedance. For 8, 'yes'. 9, 'no'. For 10, at the 6K7 plate or at diode D1 of the 6H6 tube.

These study hints include all lessons in the fifth training unit. It is suggested you read over each section dealing with the lesson you are studying and **then write out the answers in your own words.** It is hoped you find this extra material of great help in better understanding of your lessons.

Your Radio-Television Friend,
F. L. Sprayberry, President

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To SPRAYBERRY ACADEMY OF RADIO
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This sheet to be used for ANSWERS to lessons ONLY. If you have questions to ask, USE A SEPARATE SHEET OF PAPER. Mail in your answers to EACH LESSON . . . . . Put the correct postage on each set of answers. Number your answers to correspond to the questions. USE ONE SIDE OF PAPER ONLY.

Name .... Date ....

Address .... Lesson No. ....

City .... State .... Student No. ....

Write the above plainly.

Do Not Write in Space Below

Grade

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