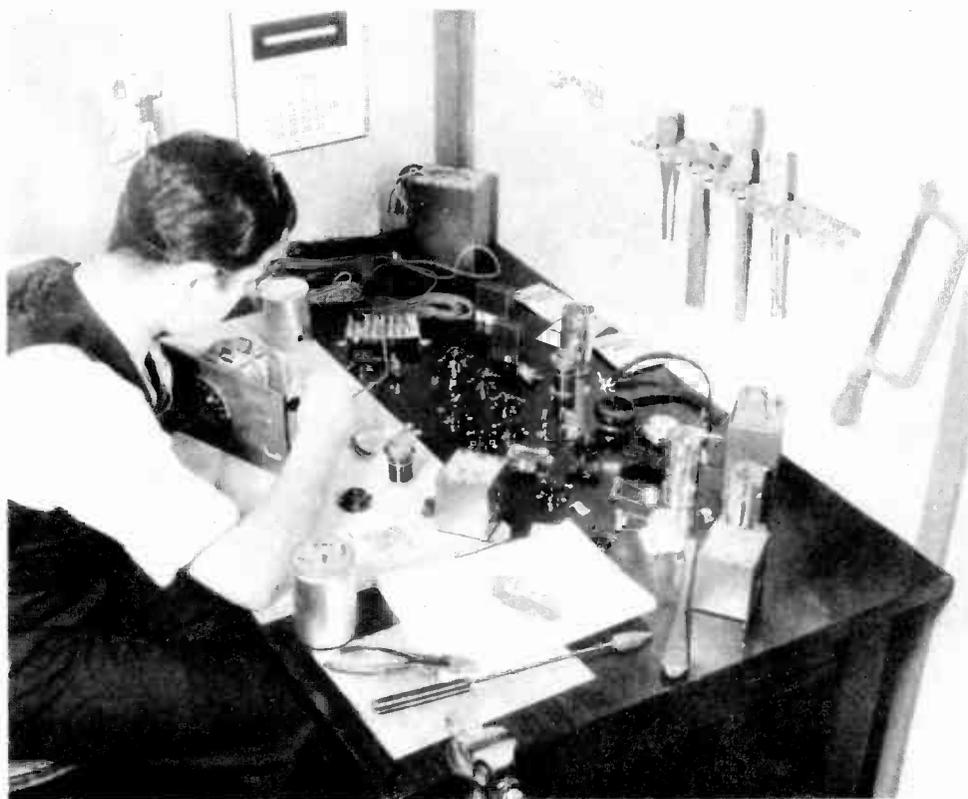


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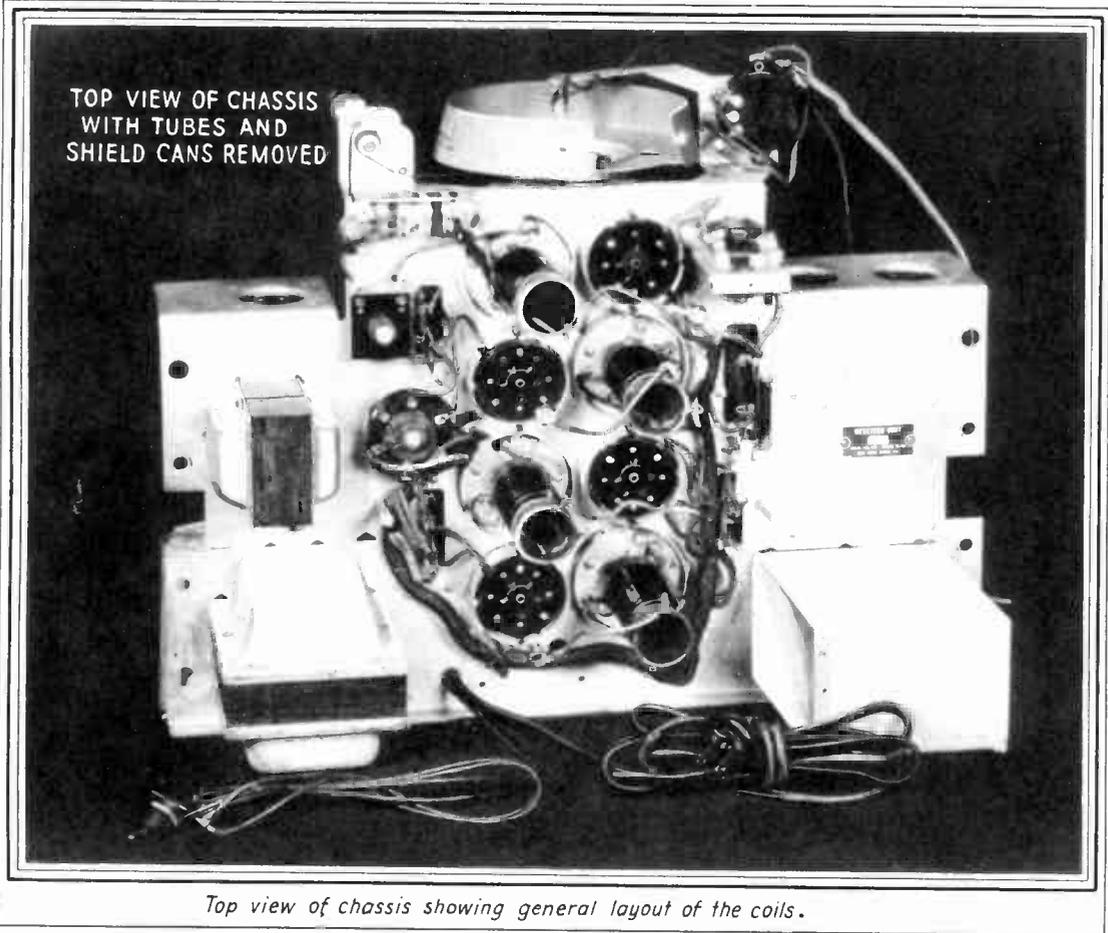


Assortment of parts used in a typical A.C. screen-grid receiver with pentode output.

General Review of Screen- Grid Pentode Receivers

VOL. 16, No. 12

Dewey Classification R161



TOP VIEW OF CHASSIS
WITH TUBES AND
SHIELD CANS REMOVED

Top view of chassis showing general layout of the coils.

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GENERAL REVIEW OF SCREEN-GRID PENTODE RECEIVERS.

The popularity achieved by electrically operated screen-grid receivers is a tribute to those who are responsible for the production of the a-c screen-grid vacuum tube and later the variable-mu and pentode tubes. When the wonderful characteristics of a screen-grid tube became known the interest of radio set manufacturers centered chiefly around the development of an electric set that could utilize one or more of these tubes and obtain from them every advantage to the fullest extent.

Although the screen-grid tube was originally designed to reduce inter-electrode capacity to a negligible amount and thus make it possible to build radio-frequency circuits without requiring the use of neutralizing devices of any kind, yet it was soon noticed that the tube had extraordinary amplifying qualities. To think that the amplification constant of an a-c screen-grid tube is 420 as compared to 9 for the three-electrode tube is nothing less than remarkable. With screen-grid tubes in the r-f circuit of a receiver weak signals or signals from distant stations are amplified many fold to be reproduced by the loudspeaker with ample volume, and the signals from nearby local stations usually come in with such large amounts of power that a volume control is required ahead of the detector so that the signal voltage applied to the detector grid may be lowered to a suitable value to prevent detector overloading. An overloaded detector produces distortion no matter what efforts are made to overcome this condition through careful designing of the audio amplifier circuits.

The extra high gain of signal level in a receiver using two stages of tuned radio-frequency amplification and a-c screen-grid tubes requires that some method of lowering this level be incorporated in the receiver. Thus, in certain types of receivers which do not have a volume control tube it is the general custom to employ a "LOCAL-DISTANT" switch. This switch is sometimes inserted in the antenna input circuit and is brought into operation under extreme conditions, that is, where a strong local signal would cause detector overloading. Although the use of the "LOCAL-DISTANT" switch and the volume control both have the same ultimate effect of controlling volume by permitting more or less signal energy to be applied to the detector grid, yet the principles upon which they operate are by no means identical as we will explain further in our lesson. While on this subject of screen-grid receivers attention should be called to the fact that

previous models of receivers employing three-electrode tubes (for instance, the 227 or 226 type) as radio-frequency amplifiers, and with the r-f stages properly neutralized, give results which compare favorably with those obtained from screen-grid sets. The set which does not use screen-grid tubes, however, will invariably be supplied with an additional radio-frequency tube thus permitting it to reach the higher degree of sensitivity. What we wish to point out is that the type of tube, or the number of stages of radio-frequency amplification incorporated in the design of a receiver is not a basis for estimating the performance of the set. We must realize that although the figures mentioned in the foregoing paragraph comparing the amplification constant of two different types of tubes are at such a wide variance these figures do not express in any sense the relative gain in radio-frequency amplification to be expected between the two tubes under consideration when operating in particular receiving circuits. The true gain in signal energy from any receiving circuit can be found only by measuring the performance under practical conditions and not by computing the gain from figures based on tube characteristics.

Whether one type of tube or another is more effective as an amplifier depends as much upon the circuit design and quality of the parts as upon the tube itself. Up to the present time not anything near the gain of which a screen-grid tube is theoretically capable has ever been fulfilled. For example, the advent of the screen-grid tube has brought about special considerations in the matter of coil design to reduce capacity effects and give the plate circuit a high impedance at resonance, and even with the best designing the impedance of the load circuit, due principally to the coils, is still far below the tube's plate impedance which is several hundred thousand ohms.

These and other factors which govern the maximum gain possible from screen-grid amplifiers (referred to usually as sensitivity) and also the degree of sharpness of tuning that permits a receiver to cut through a strong local station and pick up a distant station when both are working on closely adjoining frequencies (referred to as selectivity) are discussed in the following paragraphs.

Also, in the latter part of this lesson explanations are given which tell how the performance of a radio set is measured and shown by the use of curves called "performance" curves. The four important tests which indicate the merits of a particular radio set are sensitivity, selectivity, fidelity and power output.

The various important features in a-c screen-grid receivers with pentode output are, briefly:

1. High sensitivity with less tubes.
2. Selectivity greater than that obtainable from a similar number of tuned stages when tubes not of the screen-grid type are used.
3. Ease of control. Screen-grid tubes lend themselves to a very simple means of volume control and due to the fewer number of tuned r-f stages the gang condenser construction is greatly simplified.
4. Freedom from noise. The reduced number of tuned stages permits receivers of the screen-grid type to have a minimum signal to noise ratio.

5. Maximum gain of power. With 247 pentode tubes in the output feeble input signals are amplified to a greater extent than is possible with other types of power tubes.

Reference to the schematic diagram of any electric set will clearly show that the receiver is divided into two main sections, namely, the "receiver proper" and the "power unit," the latter often being called the "power pack" and "socket power unit." In turn we can subdivide these sections into their principal circuits according to the classified list below. These circuits can be easily identified by referring to the diagram in Figure 1 which shows a typical seven-tube a-c tuned r-f receiver employing three screen grid type RCA-224 tubes, one type 227, two type 245 power amplifiers and one type 280 full-wave rectifier. The latter part of our lesson is devoted to a general discussion of a similar type of receiving circuit with 247 pentode tubes operating in push-pull in the output stage and also explanations about the various curves used to indicate the performance of a radio receiver.

(A) The principal circuits of the receiver proper are -

1. Radio-frequency amplifier stages.
2. Detector.
3. Audio-amplifier stages.

(B) The principal circuits of the power pack are -

4. A-C input and power transformer.
5. Full-wave rectifier.
6. Filter, consisting of reactors (choke coils) and capacitors (condensers).
7. Voltage distribution system, consisting of several resistors.

It is suggested that you study this lesson with the idea of keeping the above seven principal circuits separated clearly in your mind.

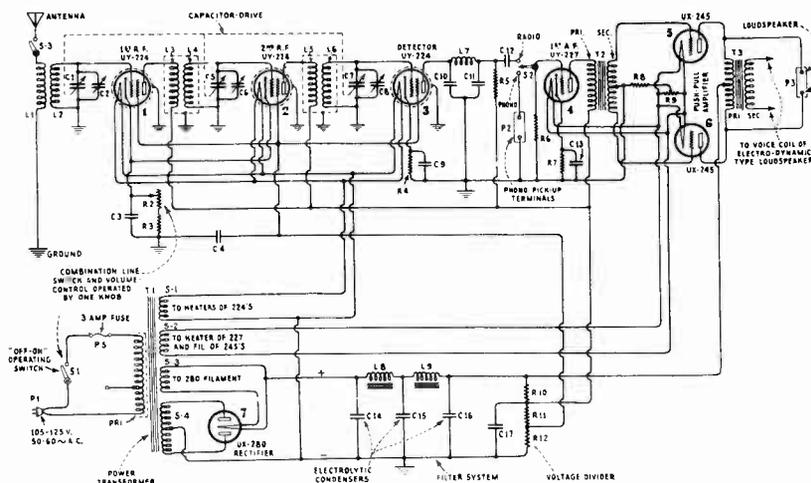


Figure 1

It is suggested that you study this lesson with the idea of keeping the above seven principal circuits separated clearly in your mind.

The schematic diagram in Figure 1 shows a typical tuned r-f receiver using a-c screen-grid tubes in the r-f and detector stages, an a-c three-electrode 227 in the first stage audio and two 245's in the push-pull output. The schematic in Figure 2 shows the use of variable-mu tubes in the r-f stages and by comparison with the diagram in Figure 1 it can be easily seen that only a slight alteration is necessary to provide for the use of pentode tubes in the audio output.

RADIO-FREQUENCY AMPLIFIER

The part of the radio receiver using screen-grid vacuum tubes that differs from the conventional type tuned r-f receiver is the radio-frequency amplifier. The r-f amplifier in Figure 1 employs two screen-grid tubes, and a tube of similar type is used for the power detector. This arrangement provides three tuned r-f circuits which requires a three-gang condenser. Each section of the gang condenser is provided with a small trimmer or balancing condenser built in the unit so that a trimmer is shunted across each tuning condenser as the diagram indicates. The stator plates of the tuning condensers connect respectively to the grids of the 1st and 2nd r-f amplifiers and detector, whereas, the rotor plates are mechanically and electrically connected together and are grounded. This arrangement permits the use of a single dial for simultaneously tuning the r-f circuits.

The three r-f transformer coils are wound to give them the best transformer characteristics, two being completely enclosed in aluminum cans which act as electrostatic shields to eliminate coupling effects between the coils themselves, or between the coils and other parts of the circuit.

From the diagram in Figure 1 each tuned circuit is seen to be a conventional one consisting of an r-f transformer, a variable tuning condenser and a trimmer condenser. The transformers are used as coupling devices to introduce the signal voltages to the input, or grids of the tubes in the case of the secondaries and to receive the output, or plate current in the case of the primaries. The primary of the first r-f transformer, of course, obtains its signal energy directly from the antenna to which it is connected.

The variable tuning condensers are used to resonate the r-f circuits to a particular station's frequency while the function of the trimmer condensers, which are easily adjusted, is to compensate for slight variations in the tuning circuits which may be caused by wiring or discrepancies in coils or condensers which is apt to occur when parts are manufactured in large quantities.

The "LOCAL-DISTANT" switch inserted in the antenna circuit should be used if strong local signals are picked up which would tend to cause detector overloading. By opening the switch according to the position shown in the diagram, the amount of signal energy transferred from the primary coil to the secondary is reduced and, thereafter, the desired signal level can be obtained by regulating the volume control. The next circuit to examine is the one that supplies positive voltage to the screen grids in Figure 1. This circuit operates

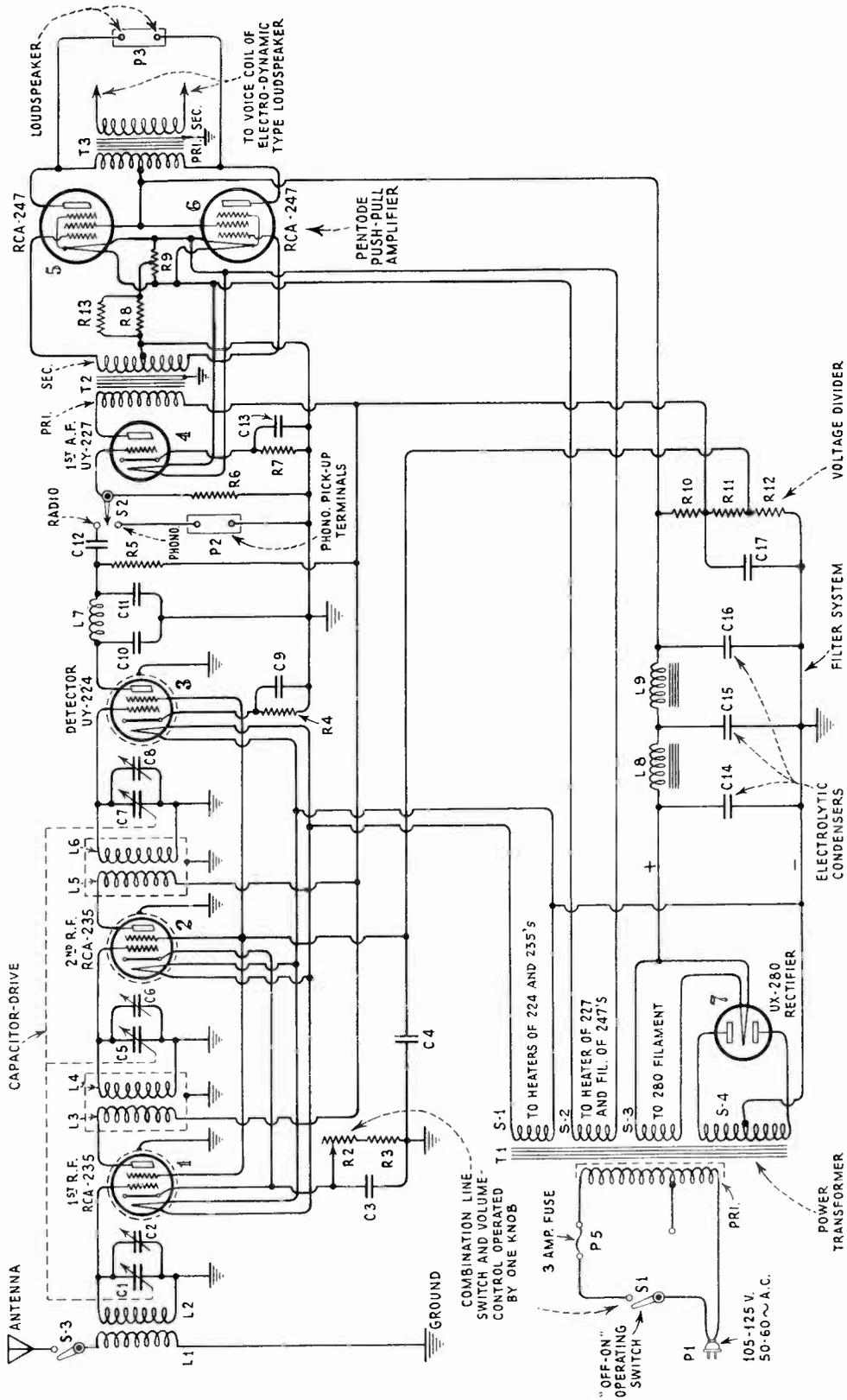


Figure 2

according to the principles as explained by Ohm's law which states that a certain relation exists between current, resistance and voltage as you already know. Observe how the resistors of the voltage divider are placed in series and in turn connected across the d-c power supply. Hence, the required voltage may be obtained from the resistor as determined by the amount of resistance included between the lower, or grounded end of the wire and the point where the screen grid wire is connected.

The purpose of the by-pass condensers shunted around the grid bias resistors is to furnish a path of low reactance which permits the r-f signal currents to pass through and thus prevent losses which would surely occur if this energy were forced to take a route through any resistor. The main purpose behind this design is to provide a radio-frequency circuit in which the signal current will circulate with highest efficiency to be impressed as an alternating voltage between the control grid and cathode of the tube. In Figure 2 the positive voltage for the screen grids of the 235 variable-mu tubes is obtained from a connection taken at one of the resistors comprising the voltage divider. Again we have another application of Ohm's law since the amount of this screen-grid voltage is determined by the voltage drop across the resistor which in turn is governed by the resistance value of the resistor and the intensity of the current flowing through it.

Points About Tubes Used in R-F Circuits, Types 235, 224, and 227. Reference should be made to Figures 3 and 4 which clearly show the general construction of a-c tubes of the three and four-element types. The 235 and 224 type tubes consist of four electrodes, namely, a plate, a control grid, a screen grid and the cathode with a heater, the four-electrode type being known as a "tetrode." The 227 type tube has only three electrodes, namely, a plate, a control grid and the cathode and heater unit, and is technically known as a "triode."

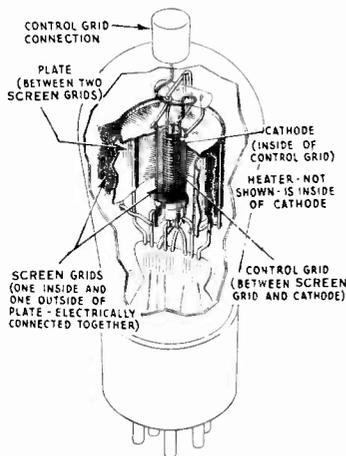


Figure 3

Both tubes have a cathode and heater which are quite similar physically, thus making it possible for a manufacturer to utilize certain parts interchangeably in the construction of their tubes. A small wire, called the heater, is imbedded inside of a special insulating material which is cylindrically shaped and around which is placed a metallic thimble, or sheath, previously covered with an oxide coating. It is this metal sheath of oxide, the cathode, which gives off electrons when the small heater wire is raised in temperature by the alternating current passing through it. The alternating current of proper voltage is obtained from one of the windings of the power transformer. Thus we see that the heater wire, which cannot be shown in the illustration because it is encased in the insulator,

serves only to conduct the current and indirectly heat the electron emitting oxide material, or cathode. Remember, the coated cathode around the insulator of a heater-cathode type tube is the source of

electron emission. It will be recalled that the source of electrons in tubes such as the 245 or 201-A type is the hot filament wire itself. The filament wire in the latter type tubes is treated with an oxide similar to the coating on the metal thimble in the heater type tube.

Both the 235 and 224 tubes are equipped with 5 pins in the base and a metal cap located on the top of the glass envelope to which the control grid clip may be connected. A point to be mentioned in regard to the sockets used with these tubes is that the heater terminals in some sockets are marked "H" and "H" and in others "FIL." The plate and cathode pins are in the same positions in the bases of the 227, 224 and 235, but the screen grid of either the 224 or 235 connects to the pin which in the 227 would make connection to the regular control grid.

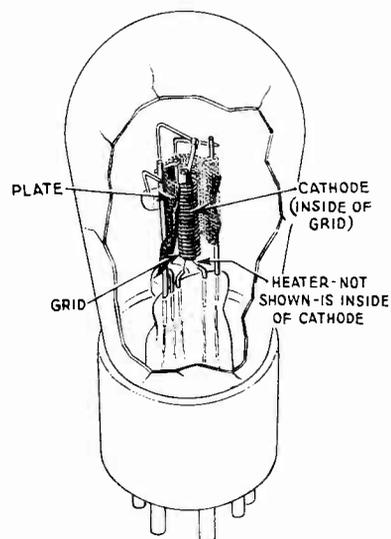


Figure 4

The screen grid is made up in two separate parts which are connected together electrically. One part of the screen, in the form of a spiral coil, is placed between the plate and the control grid, this being called the "inner screen." The other part, in the form of a metal screen of meshlike construction, is located outside of the plate, this part being known as the "outer screen." There is a thin metal cover mounted over the outer screen which acts as an electrostatic shield between the plate and the control grid lead which goes to the metal cap on the top of the tube. The principal difference between a 235 tube and a 224 screen-grid tube is that the control grid of the 235 is made with a non-uniform spacing of the mesh which gives it variable- μ characteristics as explained in a lesson on this subject titled - "Receiving Vacuum Tubes."

The internal capacity between grid (control grid) and plate of either a 235 or 224 is greatly reduced by the presence of the screen (screen grid) to a value which may be considered negligible. This arrangement effectively shields the control grid from effects caused by plate voltage variations through the inter-electrode capacity (grid to plate). If allowed to exist this capacity would permit troublesome feedback of r-f energy from the plate to grid circuits with the result that unwanted oscillations would be set up in the circuits. Due to the open spiral coil construction of the inner screen grid and the lower positive potential applied to it in comparison to the higher positive potential on the plate accounts for the fact that the electron stream is not obstructed as it passes through the vacuous space in the tube from cathode to plate. However, if an exceedingly high positive potential on the screen is permitted it would cause the screen to act like a miniature plate with the result that electrons would be prevented from going through the grid to plate. The latter situation must not prevail because it would reduce the effectiveness of the tube as an amplifier, as it would naturally lessen the current flow in the plate circuit.

The screen-grid tube fulfills two important functions: First, it practically eliminates inter-electrode capacity and thus makes the use of external neutralizing, or stabilizing devices unnecessary. Second, it provides an unusually high degree of radio amplification, or signal gain per stage. The high amplification makes it necessary to provide shielding between the r-f coils or in some assemblies shield cans are placed over coils and screen-grid tubes. In some cases further shielding on the control grid leads is required to prevent external capacitive coupling between the grid and plate circuits. Let us mention further that the screen grid, due to its high positive electric field, acts to speed up the movement of electrons toward the plate and thus the screen grid may be thought of as an accelerating device.

General Remarks About Amplification Factor, Mutual Conductance and So On. In the following paragraphs we have analyzed the comparative qualities of the three-element and four-element type tubes and other features pertaining to their use in r-f receiving circuits. To be specific let us consider the 224 and 227 types in our discussion.

The heater voltage of the 224 and 235 is the same as that of the 227 and, therefore, a common winding on the power transformer may be used to supply heater current for tubes of both types when used in the same receiver. This is a distinct advantage in simplifying transformer construction.

Since the plate voltage and current requirements of these tubes are moderate, the use of a 280 rectifier will prove ample for supplying all plate voltages.

The grid bias of the 224 and 235 is lower than that required for the 227. A low grid bias allows a tube to respond effectively to a low input voltage, hence, giving maximum output, but the disadvantage here is that a large grid swing may cause overloading.

In regard to the amplification factor of either a 224 or 235, it is considerably higher than for the 227. In practice it is impossible to get the full amplification constant from these tubes. However, the amplification obtainable from a 224, for instance, when used in a well-designed stage is several times greater than from the 227. A fair idea of the greater r-f gain possible from the screen-grid tube may be had by estimating that the average radio circuit employing a three-electrode tube, for instance, the 227 type, has a gain per stage of approximately 8, whereas, when a four-electrode or screen-grid tube is worked in a similar circuit, but designed expressly for the latter tube, the gain in signal level possible is from 30 to 40 per stage. So it is safe to assume that a 224 tube is about four or five times more effective as an amplifier. Placing the control grid close to the cathode and relatively far from the plate increases the amplification factor enormously while the insertion of the screen-grid increases the plate resistance. The advantages of high plate resistance are obtained from this tube without sacrificing the additional advantages of high mutual conductance. Since the distance between the grid and cathode is much less than the distance between plate and cathode then a positive potential impressed on the screen grid will cause a flow of plate current to be accelerated. In fact, the screen grid (because of its position in the tube) produces a greater acceleration of plate current than does the higher voltage

impressed on the plate. The mechanical construction of the screen does not permit it to collect many of the electrons which would ordinarily go to the plate, hence, the majority of electrons which constitute the tube current pass on through the screen grid to the plate; only a limited quantity flow in the screen-grid circuits as direct current.

The mutual conductance is slightly lower in the 227 than in either a 224 or 235. Mutual conductance is a direct function of amplification constant and plate resistance, and is a measure of a tube's general performance. However, the mutual conductance of an r-f amplifier does not assume the importance that it does in other stages. Inasmuch as the amplification constant of a screen grid tube is high, its mutual conductance is very high. The positive potential on the screen grid in relation to the cathode is necessary for operation as the mutual conductance of the tube is a direct function of the value of this voltage. Therefore, it follows that with a very low voltage the mutual conductance will be low and with maximum voltage the mutual conductance will be maximum. This action is utilized in some types of receivers since if we vary this voltage we can easily control the sensitivity of the r-f amplifier and this will act as a volume control for the receiver. In sets which use this method the screen-grid voltage is varied from 0 volts at minimum volume to about 40 volts positive, or more at maximum volume.

The plate resistance of a screen-grid tube is many times greater than that of a three-element tube. For the different broadcast frequencies that are used in operation it is known that the resistance of the load circuit into which the tube works should be as great, or greater than the impedance of the tube. On this account the 224 or 235 tube requires an output circuit different from that used with other tubes, such as the 227 for example. In practice the high resistance is gained by concentrated inductance in the coil windings.

Because of the fact that the self-capacity of a screen-grid tube is practically negligible the r-f circuits can be constructed without stabilizing or neutralizing devices of any kind providing, of course, all circuits external to this tube are properly shielded and, also, the tube itself is shielded where required, as previously mentioned. The low internal capacity of the tube is accomplished through the insertion of the screen grid between the control grid and the plate. The values in the vacuum tube characteristic tables show that grid-plate capacity is 0.01 mmfd. for the 224 and 3.3 mmfd. for the 227, thus indicating that self-capacity is lowered about 1/300th through the use of the screen grid. Again refer to Figure 3 which shows the screen-grid construction in the four-element tube and its absence in the three-element tube in Figure 4.

High amplification gain which a screen-grid tube provides is an advantage because it permits the use of resistance coupling between the detector and the 1st audio-amplifier stage which is usually followed by the final stage consisting of a transformer coupled amplifier using two power tubes in push-pull relation. It is generally agreed that resistance coupling in the intermediate a-f stage provides pleasing and satisfactory reproduction.

The 235 has a special characteristic which is advantageous when the tube is used as an r-f amplifier, but this makes it unsuitable for

use as a detector. This is called the variable-mu characteristic and is caused by the arrangements of the tube structure as explained in a lesson on vacuum tubes. Let us repeat that the amplification factor of a variable-mu tube changes for different values of potential on the control grid, and high negative potential is required on the grid before plate current reaches zero.

FACTORS WHICH GOVERN A SCREEN-GRID RADIO-FREQUENCY SYSTEM

Now let us continue our discussion concerning screen-grid r-f amplifier circuits. Although one or more of the items may have been mentioned earlier in the lesson they will bear repetition. Subjects such as grid swing of radio amplifiers and grid biases are explained in the following paragraphs.

Shielding is required in order to prevent oscillation due to plate to grid feedback of r-f energy through wiring, or coils. This shielding, which is in the form of aluminum or copper compartments or cans, should extend over the coils and tubes and in some cases the control grid leads are shielded. Shielding over the tuning condensers is not necessary as the radio-frequency field surrounding such parts is not particularly strong.

A power unit must provide suitable a-c voltages for the heaters of the 235, 224 or 227 tubes depending upon the type used in any particular receiver. This voltage is 2.5 volts with a current requirement of 1.75 amperes for each tube used. Also, direct current which has been properly filtered, or smoothed out, must be provided for supplying the control grid in certain sets with about 1.5 volts negative bias, and the screen grid with about 75 volts positive potential, and the plate with positive 180 volts. This power unit also supplies the detector and audio stages with operating voltages at specified values.

Due to the high sensitivity of the screen-grid circuits it is desirable to reduce the amount of signal energy when receiving strong local broadcast programs. In certain circuits this is accomplished by disconnecting the antenna from the input r-f coil by means of a switch, called a "LOCAL-DISTANT" switch as shown in Figure 1. In some receivers a small fixed condenser (for example, one with a capacitance of .00023 mmfd.) is automatically shunted across the antenna coil by the switch. Shunting the condenser around the transformer primary provides an oscillatory circuit on which the signal energy may be picked up. Then again, in other types of circuits we find such a switch so arranged that on the "LOCAL" position the antenna is connected to the ground through a small resistor, the value of the resistor being of the order of 15 ohms. The purpose of such a switch, as heretofore explained, is to prevent the strong carrier of a local station from overloading the detector, thereby causing distortion.

Radio-frequency by-pass condensers are placed in different circuits to act as a radio-frequency by-pass to ground, as otherwise oscillation will be set up and one of the most desirable properties of the screen-grid tubes would be lost.

A schematic diagram of one type of screen-grid amplifier using 224 tubes is pictured in Figure 5. In this circuit all of the d-c plate

current flows through the grid bias resistor. It also shows how the screen grids are made positive with respect to the negative cathode, and how the positive voltage on the screens can be regulated between the limits of 0 and about 40 volts by simply varying the amount of resistance on the volume control included between the sliding contact, or positive potential point, and the left-hand end, or negative potential point of this resistor. This is one way of regulating volume; another method by which control grid bias may be regulated is explained later.

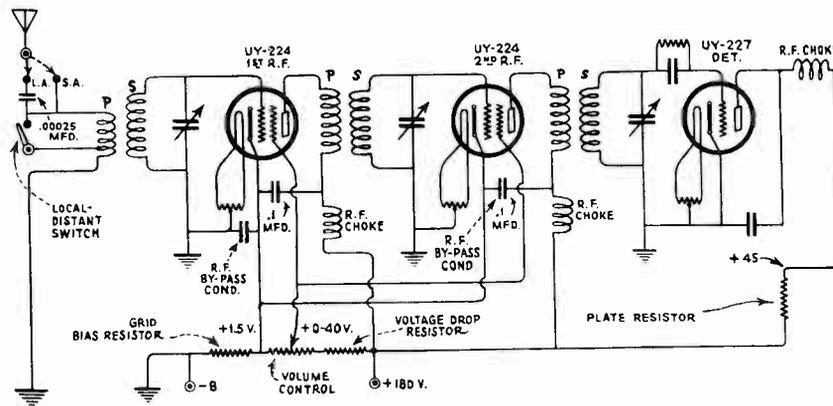


Figure 5

Next we will consider how the negative bias is obtained for the control grids of the 224 tubes in Figure 5. Referring to this diagram we notice that a resistor, marked "grid bias resistor," is connected in the circuit in such a manner that all of the plate current of both amplifier tubes must flow through it. The path of the plate current, considering only one tube and starting from the point marked +180 v. (this being the positive side of the d-c power supply) is through the r-f choke, through the primary of the r-f transformer to the plate of the tube, then to the cathode and down through the bias resistor and thence to the ground, (the ground being the negative side of the d-c supply). We know that there is a certain difference of potential (voltage drop) across such a resistor when current flows, the voltage depending upon the current strength and the number of ohms of resistance. Actually this resistor is connected in series between cathode and ground, and we also find that the grid return lead of the tube is connected to ground, the grid circuit being completed through the secondary of the r-f transformer. By this arrangement the flow of plate current through the grid bias resistor causes the cathode to become positive in potential with respect to the grid, or expressed the other way around and meaning exactly the same thing, the grid is made negative with respect to the cathode, which is the reference point of all potentials of the tube.

Let us now discuss the relation of positive grid swing from a signal voltage to the amount of permanent bias supplied to the control grids of the 224 tubes in Figure 5. If a radio set is located close to a broadcasting station the signal might come in so strong that the radio-frequency voltage applied to the control grid of the tube would cause the grid potential to actually swing over and become positive with respect to the cathode. You can well imagine from your previous

knowledge of the control action which the grid exercises over the stream of negative electrons in the tube what the resulting effect would be if the grid ever assumes a positive electric charge. Supposing that this happened, then the grid would naturally act in a manner similar to a miniature plate and, hence, attract electrons in great numbers. Since the flow of electrons between cathode and grid is nothing more than what is known as grid current then the presence of this grid current makes the intervening space between cathode and grid act as though a high resistance were connected between these electrodes. In actual effect this is like placing a high resistance across the tuned r-f circuit, inasmuch as this circuit is always connected across the grid and cathode of an amplifier tube.

Therefore, it should now be clear that if an r-f amplifier grid were not supplied with a permanent negative bias, or if the bias were so low as to be overpowered by strong positive impulses from a local signal, the space between these two elements would exhibit all of the characteristics of a high resistance shunted across the r-f tuned circuit. This condition is undesirable. What we would like to have is a grid which never becomes positive but is always working at greater or lesser negative values with respect to the cathode. The condition should be such that the grid to cathode path remains at all times practically like a small condenser, the electrodes acting as plates and the space as the dielectric. If this is fulfilled in practice the grid is left free to act efficiently as an electrically charged body whose potential is constantly varying in accordance with the characteristics of the signal wave, and the changing grid potential will cause a corresponding variation in plate current.

We know this to be the case because the control of the plate current is due to the effect which the electrically charged grid has over the electron stream as it moves through the vacuous path in the tube from cathode to plate.

What we have just said in regard to the radio-frequency grid swing has some bearing on the tuning qualities of the receiver referred to as "Broadness, or Sharpness" of tuning. The introduction of even a small amount of resistance in a circuit of this kind causes the resonance curve to become less sharp or less peaked, or to flatten out as it were. If this condition exists in a receiver it results in what is known as "broad tuning." In other words the receiver then cannot discriminate between broadcast frequencies when they are 10 kilocycles apart, but will respond with almost equal sensitiveness to the frequencies of more than one station, thus causing serious interference.

This extreme sensitivity of the control grid of either a 235 or 224 tube is responsible for the easy manner in which remote and distant stations are brought in on a modern screen-grid receiver. Moreover, it has the distinct advantage of permitting the use of shorter antennas than have heretofore been required to pick up signals from distant stations. An antenna not exceeding 50 feet in length often gives the best results.

PENTODE TUBES FOR R-F AND A-F CIRCUITS

We have discussed the use of three- and four-element tubes for r-f circuits and the use of three-element tubes for a-f amplification. Five-element tubes, called pentodes, are now available for use. They are of two types, the r-f pentode and the a-f pentode.

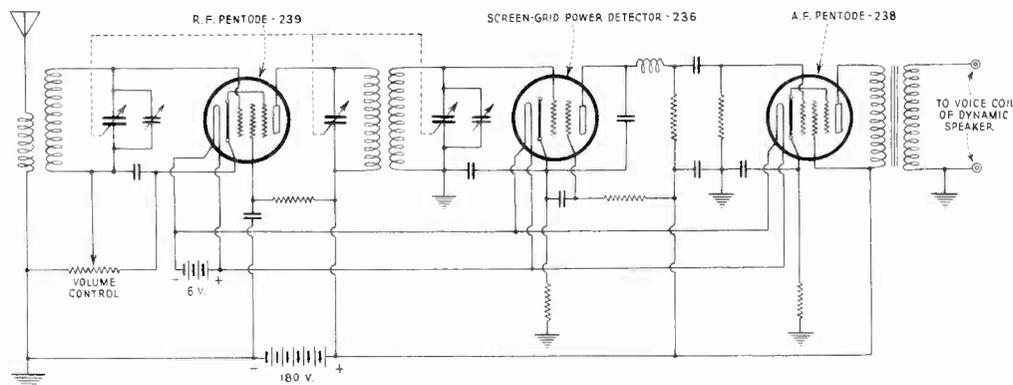


Figure 6

Like the screen-grid variable mu tube, or 235, the r-f pentode, or 239, is free from cross talk and gives high amplification. At present r-f pentodes are made with 6.3 volt filaments for automobile use only. A schematic diagram of a 239 r-f pentode, a 236 screen-grid detector and a 238 a-f pentode is shown in Figure 6. In the sketch in Figure 7-A the electrodes are identified as follows: F represents the filament; G1 is a conventional control grid; G2 is a grid or screen which is maintained at a high positive potential and serves to reduce the affects of "space charge" around the filament and increases the plate resistance of the tube; and G3 is a grid or screen which is usually connected internally to the filament or cathode of the tube and is therefore maintained at essentially ground

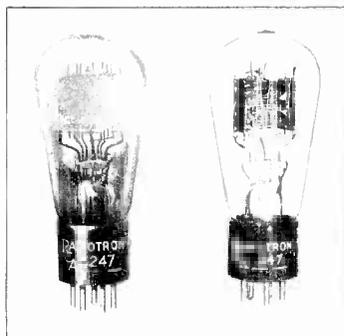


Figure 7

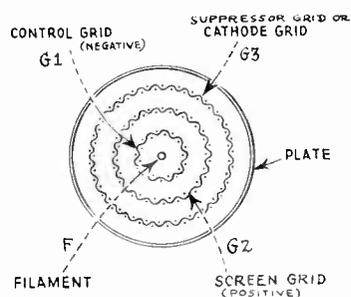


Figure 7-A

potential. The a-f pentode or 247 is shown in Figure 7. Two pentodes connected as push-pull amplifiers are shown in Figure 2. The first grid from the left is known as the control grid and it receives the energy from the previous stages. The next grid is known as the screen grid or high voltage grid. It corresponds to the screen grid of the 224 or 235 tubes. The third or suppressor grid connects to the midpoint of the filament and its function is to attract the space charge or loose electrons which gather around the plate. A comparison of 245 and 247 tubes as audio amplifiers is taken up under the heading "Final Audio Stage or Output".

DISCUSSION OF SCREEN-GRID RECEIVER CIRCUIT WITH PENTODE OUTPUT.

REFER TO FIGURE 2.

REQUIREMENTS. Present standards make it necessary for a receiving set to provide a high degree of sensitivity without sacrificing selectivity and also to provide a maximum of undistorted power which is free from any interfering noise such as hum for example. The receiver which is described in the following paragraphs was designed to meet present day conditions. The following general discussion should be studied with reference made to the schematic diagram in Figure 2 showing a typical a-c screen-grid receiver with a pentode output.

SELECTIVITY. An examination of the schematic diagram in Figure 2 shows that the antenna circuit includes a switch designated as S-3. When this switch is open only nearby stations may be heard because coil L-1 becomes the only interceptor of the electromagnetic waves radiated by the broadcasting station. This switch need be opened



Figure 8

only when the selectivity is poor, or the tuning is broad, which is another way of saying that a given station covers too many divisions on the tuning dial.

When tuning in the desired station by means of the single dial located on the panel there are actually three r-f circuits being resonated simultaneously through the variation in capacitance of the respective variable condensers in these circuits, that is, in the two radio-frequency and detector circuits. Vernier, or fine adjustments are provided on the outer rotary condenser plates by bending the

split plates to compensate for any difference in capacitance between the tuning condensers or slight discrepancy in the coils or wiring of these circuits. Additional adjustments can be made to bring the r-f circuits into proper resonance by turning a nut which moves the single plate of the midget condenser found on the top of each variable tuning condenser.

Figure 8 is a photograph taken in RCA Institutes' Laboratory showing how the r-f circuits are resonated using a pocket type insulated socket wrench made for this purpose. An ordinary metal tool cannot be used as it introduces hand capacity into the circuit. The instrument on the right is a modulated oscillator which provides a steady signal of uniform frequency.

R-F AMPLIFIERS. The intensity of the received signal is controlled by means of the volume control R2 which is a variable resistance controlling the negative bias potential on the control grids of the two r-f tubes. This device is smooth and noiseless in its regulation of the amplification of the screen grid tubes. Due to their high amplification factor, or μ (μ), the 235 and 224 tubes make excellent r-f amplifiers and power detectors but since they distort when voltages in excess of 1.5 are applied to their grids they do not make good audio power amplifiers. The signal energy in the r-f and detector grid circuits is quite small but when the energy reaches the audio system it may be in excess of 1.5 volts so that 235 or 224 tubes cannot be used. The 227 does not distort until 9 volts are applied to the grid if the plate potential used is 135 volts. For this reason a 227 may be employed in the first audio stage where it is effective in amplifying the signal sufficiently to swing the grids of the two tubes in a push-pull amplifier regardless of whether they are 245 or 247 type tubes.

The r-f and detector coil secondaries which comprise the other parts of the tuning units are connected to their respective condensers. The second r-f and detector coils are shielded from capacity effects to other instruments and wires to prevent interaction between circuits which might cause oscillation. The shields are made of aluminum and are separated from the coil windings, or have a clearance of at least 3/4 of an inch on all sides, in order to reduce losses. It has been found experimentally that the first r-f coil need not be shielded as it does not have a tendency to oscillate as have the other circuits when the shields are removed from them. All shielding is connected to the ground.

IMPEDANCE MATCHING. In order to realize the maximum power transfer from one circuit to another the impedances of the two circuits must be identical. A water analogy will serve to illustrate this point. If we have a large pipe connected to a pipe of smaller diameter the flow of water from the large pipe to the smaller one will be impeded by the restriction of the smaller orifice. If, however, the large pipe is connected to one of like dimensions there will be no impedance to the flow of water due to this cause and the maximum transfer will be accomplished. Bearing this in mind this particular circuit was designed with a 500,000 ohm resistor coupling the high impedance detector plate circuit to the audio input or grid circuit.

PHONOGRAPH PICK-UP CIRCUIT. The audio-frequency amplifying system containing two stages of powerful amplification is capable of amplifying feeble voltages for loudspeaker reception. It is, therefore, a simple matter to introduce a phonograph pick-up into the grid circuit of the first audio stage where any variations in signal energy will be amplified. The phonograph connection is made through the tip jack P2, the switch S2 being used to disconnect the radio-frequency system from the audio and to introduce the phonograph connection at the same time. There are many types of phonograph pickups but in general the principle of operation is the same for each type.

Briefly, the operation is as follows: A voltage is induced in a coil by the cutting of lines of force by a magnet which is moved by means of its connection to a needle that travels in unison with the variations in the groove of the phonograph record. The lighter the pressure of the needle upon the record the less harm will be done to its groove and the more authentic will be the reproduction of the recorded sounds. Since the point of a needle has a very small area a weight of about one pound from the pickup may exert a pressure of several tons upon the record. To alleviate this condition of needle pressure as much as possible the most efficient types of pickups employ a finely balanced arm and are oil damped. The volume is controlled by means of a variable resistor provided with the pickup.

FINAL AUDIO STAGE OR OUTPUT. Modern practice requires that the final output of an audio amplifier must provide high undistorted output to the speaker. To obtain this result large tubes must be used which require adequate excitation from the preceding stages. As was previously mentioned the 227 in the first audio stage will swing the grids of at least two tubes of the 245 or 247 types. A maximum potential of 16.5 volts is required to swing the grid of the 247 tube whereas 50 volts is the maximum voltage allowed on the grid of the 245 assuming that 250 volts is applied to the plate of either tube. The undistorted power output of the 247 is 2.5 watts whereas for the 245 it is only 1.6 watts. Moreover, the 247 is more sensitive to small variations in grid voltage which means that it is more sensitive to weak signals than the 245. The 247 however will overload when voltages in excess of 16.5 are obtained from the signal input which will cause distortion. For very loud signals the volume control R2 should be kept at a medium position or the antenna switch S3 should be opened. For ordinary use the 247 will give excellent results and will amplify weak signals better than the 245.

The push-pull amplifier has strongly entrenched itself in present day receivers. Wherever the utmost fidelity of tone and the greatest undistorted power are desired a push-pull amplifier is used because objectional harmonic distortion is reduced and also the power output is greater than that of a single tube. Both the 245 and the 247 tubes give excellent results when used in the final stage of this receiver, and it requires only a few simple changes in wiring and sockets and bias voltage to interchange from one type of tube to the other.

When 247 tubes are used the cores of transformers T2 and T3 should be grounded to prevent oscillation.

Either magnetic or dynamic type speakers may be employed but as the average dynamic speaker voice coil has an impedance of about 16 ohms and as the impedance of a magnetic speaker is about 8,500 ohms at 60 cycles it is obvious that an output device designed for one will not be suitable for the other. As previously stated maximum transfer of power takes place when the impedance of the source and the impedance of the circuit to be energized are equal. In view of this fact the output transformer T3 was designed with a primary resistance of 8,500 and a secondary resistance of 16 ohms. By connecting a magnetic speaker to the tip jacks P3, a maximum transfer of power will take place from the tubes to the speaker. Likewise, connecting the secondary of P3 to the low impedance voice coil of a dynamic speaker will give maximum transfer of power.

Magnetic speakers are usually of a type not designed for handling a great deal of power and are generally used when the output is of the order of about 1.5 watts. If the plate current greatly exceeds 10 milliamperes the windings of most magnetic speakers are liable to be damaged. The primary of transformer T3 however is in parallel with the magnetic loudspeaker windings which divides the current so that the speaker is not unduly loaded. The direct current flowing through the windings of the average magnetic speaker connected in this manner to the receiver is usually less than one milliampere. The alternating current flow however will vary from zero to over 30 milliamperes. When peak signals are received voltages in excess of 150 are delivered to the speaker and 30 milliamperes of alternating current often flow through the speaker windings. The maximum undistorted power that can be obtained from two 247 tubes in push-pull is 5 watts, while the maximum from two 245's in push-pull is 3.2 watts. As the ear is only slightly sensitive to the 1.8 watt difference in power as far as volume is concerned it is immaterial which type is used. The choice of tubes should be governed somewhat by the requirements of the locality. If the set is far from most powerful stations the 247 tubes will give better results as the signal energy will have a better chance to excite the grids of these tubes. If the receiver is in an area which contains many powerful stations the 245 combination will be less apt to overload and distort the signal than the 247's. Both the 247 and 245 push-pull amplifiers will operate to best advantage when a dynamic speaker is used.

POWER SUPPLY. Transformer T1 which receives its energy from the 110 volt - 60 cycle alternating current line through plug P1 is the source of power for the entire receiver. The secondary contains three low voltage windings and one high potential winding. Winding S-1 delivers 2.5 volts of alternating current for the heaters of the 224 and the two 235 tubes. Winding S-2 supplies 2.5 volts for the heater of the 227 first audio stage tube and the filaments of the tubes in the push-pull second audio stage. The third winding S-3 delivers 5 volts to heat the filament of the 280 rectifier tube, the plates of this tube being supplied by the potential developed in winding S-4. Due to the fact that a vacuum tube conducts current only in one direction, that is, the electrons flow only from filament to plate, the 280 delivers a unidirectional pulsating direct current.

The insertion of chokes L-8 and L-9 in the positive lead and the connecting of capacitors C-14, C-15, and C-16 between the terminals of the chokes and the negative side of the line, filters or changes the pulsating current to a direct current. Capacitors C-14, C-15 and C-16 used for filters, may be of the paper or electrolytic types, either type being used in modern receivers. By means of the voltage divider the proper bias voltages for the grids and the proper voltages for the plates are obtained for all tubes.

PERFORMANCE CURVES OF BROADCAST RECEIVERS

How to interpret typical performance curves which are plotted from measurements taken in tests on broadcast receivers is explained in the following paragraphs. These curves are taken according to the specifications of the Institute of Radio Engineers which are fully outlined in the section following this explanation of typical curves. In general, it may be difficult to duplicate the absolute values given in the curves unless the same tubes and measuring apparatus are used. The curve form will be approximately the same in any case, however, for receivers of a given type.

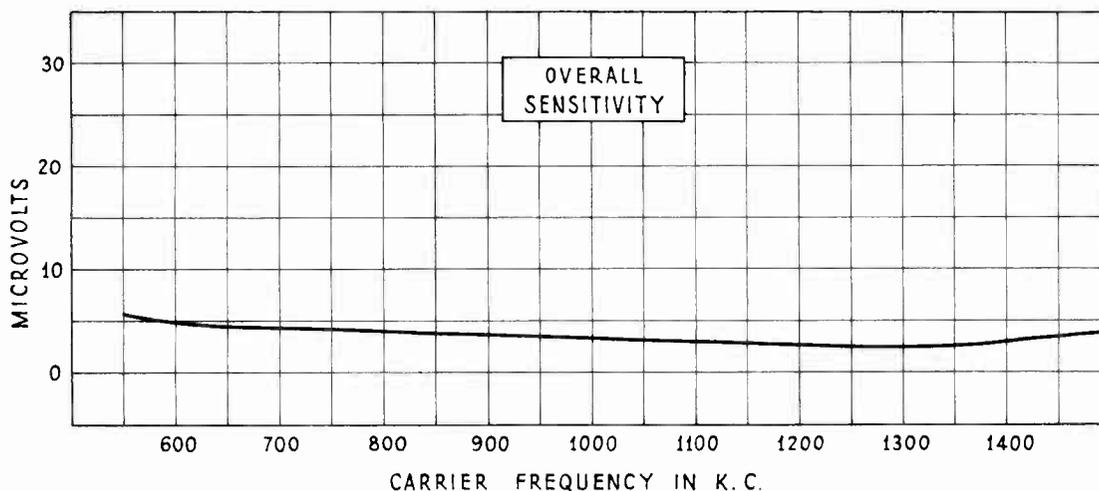


Figure 9

Sensitivity. The sensitivity of a receiver is the determination of how weak a signal the receiver will respond to, and is measured in terms of the amount of input voltage necessary to obtain a standard output. A typical sensitivity chart in which signals of various different frequencies corresponding to broadcasting stations are plotted against input voltages is shown in Figure 9. Looking at the graph we find that at a frequency of 550 kilocycles 5.5 microvolts are necessary to produce a given output whereas at 1300 kc. a potential of only 2.5 microvolts is needed to give the same output. Other points on the curve represent similar relationships. The normal output is taken as 0.05 watts, dissipated thru a load of 8000 ohms connected in parallel with the primary of the output transformer, with the voice coil of the speaker open circuited.

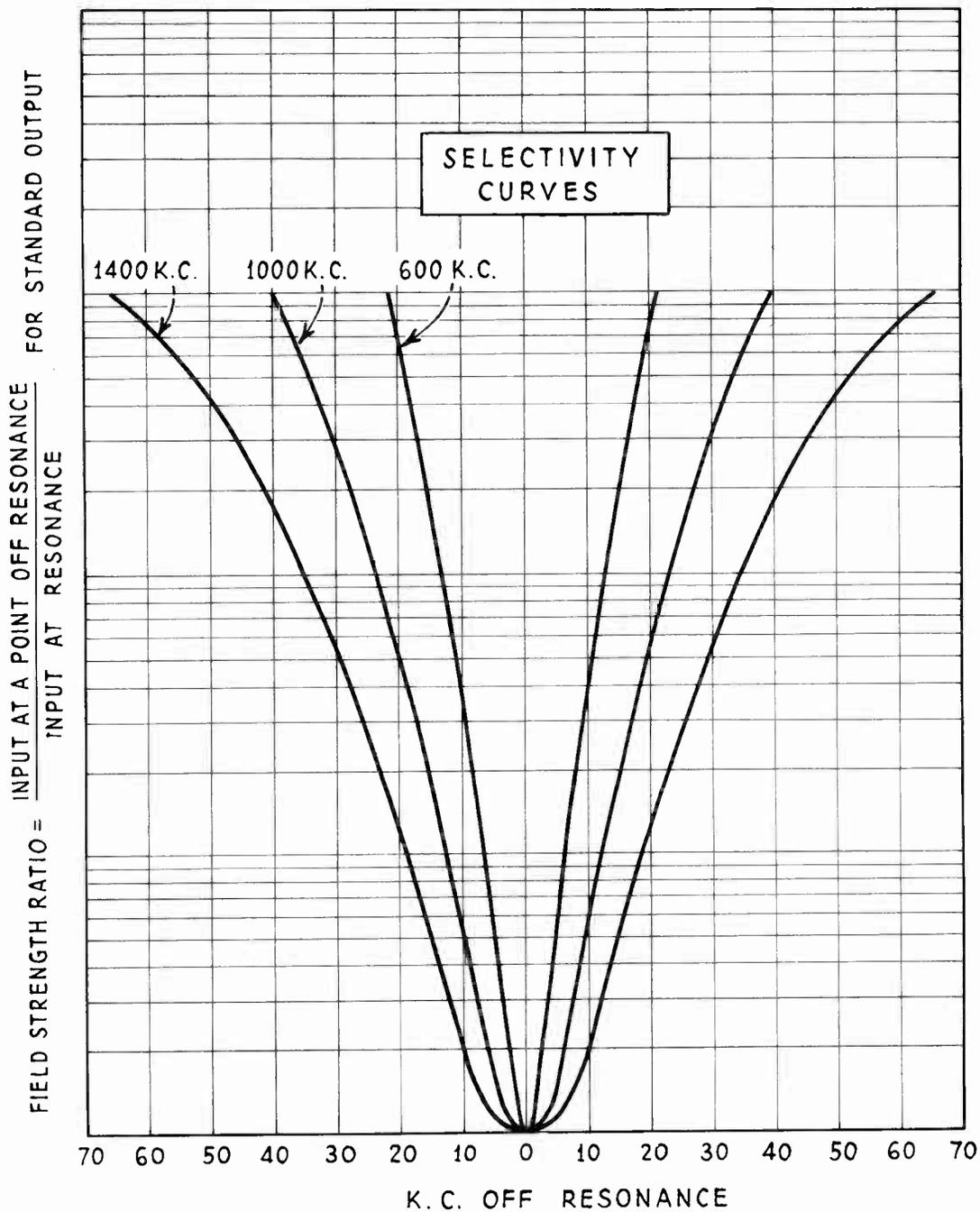


Figure 10

Selectivity. The ability of a receiver to select a single station and exclude all others is its selectivity. In Figure 10 the straight vertical line or zero axis midway between the two curves represents the exact location of the received signal, or the point of resonance. The width of the band of frequencies to which the receiver responds is indicated by the distance between the two curved lines. The lines join each other at zero field strength but as the received energy increases the curves diverge, the higher frequency curves being further removed from the zero axis than the lower frequency curves because the r-f resistance increases with the frequency. As the signal energy of the broadcast transmitter is reduced by the use of the volume control the signal seldom covers more than 30 kc. in modern broadcast receivers.

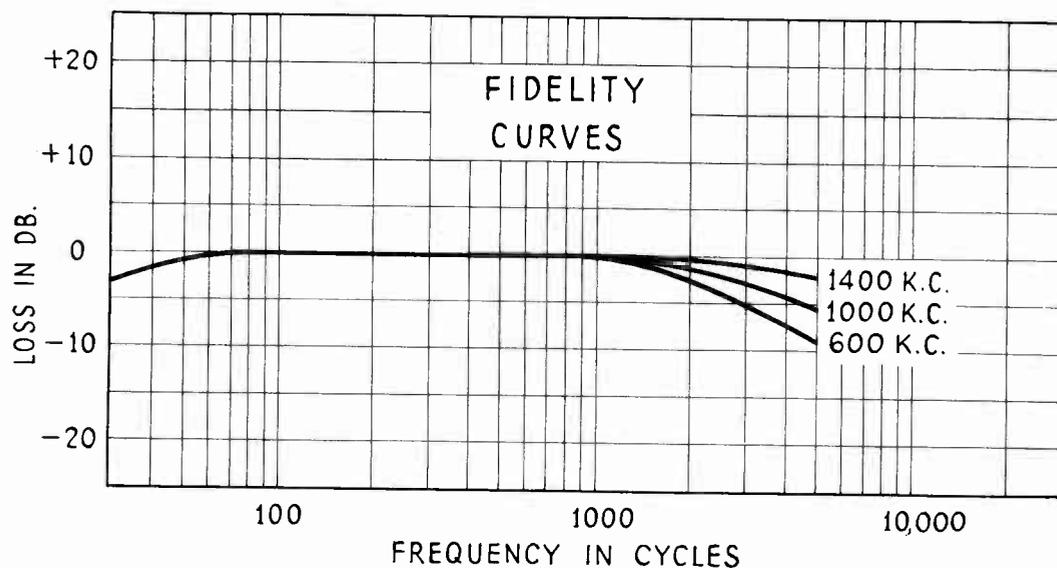


Figure 11

Fidelity. The degree to which a receiver accurately reproduces the modulated wave of the broadcasting station is its fidelity. An ideal receiver would be one which would have a flat horizontal line from the lowest to the highest frequency of sound or roughly from 16 to 10,000 cycles. Figure 11 shows a typical fidelity curve where sound frequencies are plotted against various power outputs measured in decibels. Looking at the curve marked 600 kc. we find that its gain of power output at a frequency of about 16 cycles, or the lower limit of sound, is -3 db. whereas at the audible frequency of 1000 cycles the gain of power is 0 db. The loss increases greatly as the frequency increases above 1000 cycles.

Power Output. Figure 12 shows the relation between input voltage and output power, the abscissae representing the input potential and the ordinate showing the power output. All potentials over 100 microvolts are seen to give a power output of about 7 watts.

An ideal composite curve is shown in Figure 13. It is given to enable one to make comparisons between curves taken under test con-

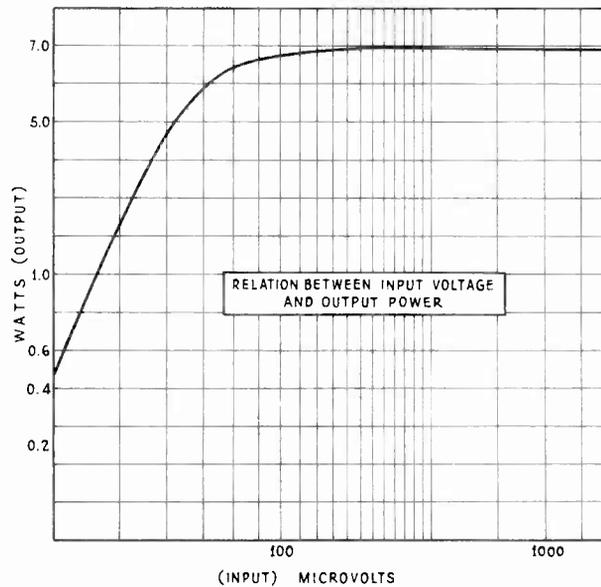


Figure 12

ditions and the ideal condition. As shown on the graph in Figure 13, an ideal fidelity curve is represented by the almost flat horizontal line which covers a frequency band between 60 and 5000 cycles. It is to be understood that this band is an arbitrary one and the frequency range may extend to either side of these limits. In the case of an ideal condition of sensitivity of a receiver a curve which indicates this particular quality would fall between the two horizontal lines ranging from 10 to 5 microvolts as also shown on the graph. The third curve, drawn on the graph paper, whose two sides are vertical practically all the way up and 10 kilocycles apart shows the best condition possible for selectivity.

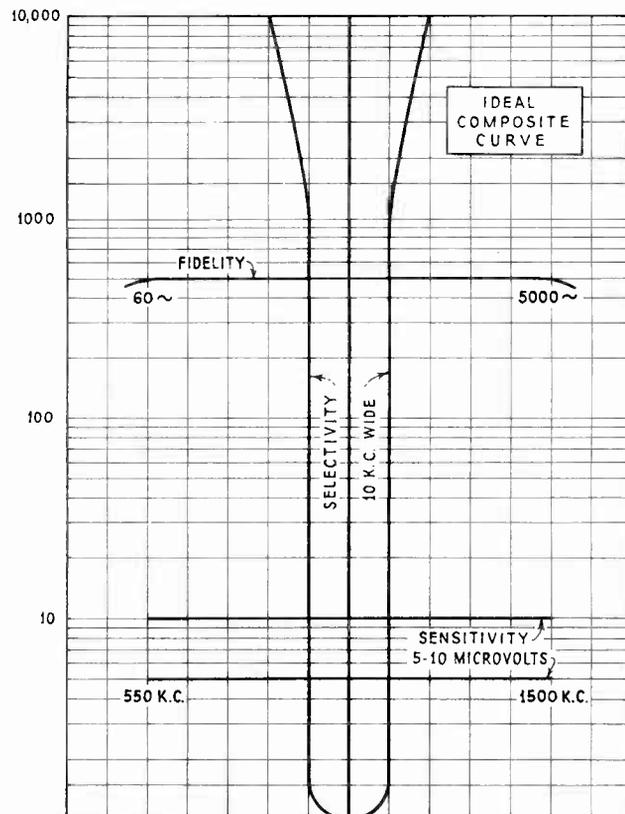


Figure 13

SELECTIVITY, SENSITIVITY AND FIDELITY MEASUREMENTS

The standard tests by which the performance of a broadcast receiver is determined are performed according to specifications proposed by the Institute of Radio Engineers. They are given in the following pages through the courtesy of this engineering society.

I. GENERAL

The purpose of the standard tests here proposed is to provide by general agreement a basis upon which the complete normal performance of any broadcast radio receiver may be reasonably predicted. It is believed that no simple "figure of merit" can properly be derived that will by itself give an index of complete performance. This follows from the varying weights that may be applied at different times and in different services, to the fundamental properties of sensitivity, selectivity, and fidelity. Consequently it is believed to be essential to define and to provide for the separate measurement of each of these fundamental properties. Such information is of somewhat too highly technical a nature to appeal directly to the average user of broadcast radio receivers, but is thought to be useful to radio distributors and dealers in guiding their selection of apparatus for specific service conditions, and to engineers and manufacturers in aiding the comparison and improvement of their products.

It is recognized that the tests do not comprehend the entire range of service conditions that may be met in practice, and that peculiarities of design not reflected in the test data may in special cases affect the deductions to be made properly from the test results. It is also recognized that the three basic properties of sensitivity, selectivity, and fidelity are in some radio receivers dependent upon adjustments that will change the relative prominence of each, and consequently the three factors should be invariably measured at the same settings of the radio receiver adjustments. Nevertheless, it is thought that acceptance of the procedure outlined, together with proper interpretation and correlation of the results obtained by the tests, will serve to permit a standard comparison of normal radio receiver performance.

II. DEFINITION OF TERMS

(A) Sensitivity. Sensitivity of a radio receiver is that characteristic of the radio receiver which determines to how weak a signal it is capable of responding. It is measured quantitatively in terms of the input voltage required to give a standard output.

(B) Selectivity. The selectivity of a radio receiver is the degree to which the radio receiver is capable of differentiating between the desired signal and signals of other carrier frequencies. This characteristic is not expressible by a single numerical value, but requires one or more graphs for its expression.

(C) Band Width. As applied to selectivity, the band width of a radio receiver is the total width of a selectivity curve at a specified point on the scale of ordinates. The specified points are usually two, ten, and successive powers of ten.

(D) Fidelity. The fidelity of a radio receiver is the degree to which the radio receiver accurately reproduces at its output the form of the signal which is impressed upon it. The fidelity of a radio receiver is measured by the accuracy of reproduction, at the output terminals, of the modulation of the received wave.

(E) Normal Test Output. As applied to the testing of a broadcast radio receiver, the term represents an audio-frequency power of 0.05 watt in a noninductive resistor arranged to carry alternating current only and connected across the output terminals of the radio receiver (usually the loud speaker terminals), the resistance of the resistor having been adjusted to that value recommended by the tube manufacturers to give maximum undistorted output power for the type of vacuum tube intended to be used in the output of the radio receiver, with normal adjustments of this vacuum tube. If the radio receiver is not arranged to filter out direct current from its output circuit, then an external filter system shall be employed, of such character as to introduce negligible resistance to direct current, to have negligible loss and to have negligible shunt admittance and negligible series impedance relative to the output resistor.

(F) Normal Radio Input Voltage. As applied to the testing of a broadcast radio receiver, this term represents the root-mean-square voltage of a received signal, modulated 30 per cent at 400 cycles per second, which results in normal test output at resonance. If the radio receiver does not include a self-contained antenna, then the signal is to be impressed on a real or artificial standard antenna.

The method of measuring the percentage modulation involves calculation of the percentage modulation from measured values of the peak voltage of the radio-frequency oscillator output under modulated and unmodulated conditions. The voltage measurements are made with a vacuum tube peak voltmeter.

(G) Standard Antenna (Real or Artificial). As applied to the testing of a broadcast radio receiver not having a self-contained antenna, this term represents an antenna having in series a capacity of 200 micromicrofarads, a self-inductance of 20 microhenries, and a resistance of 25 ohms.

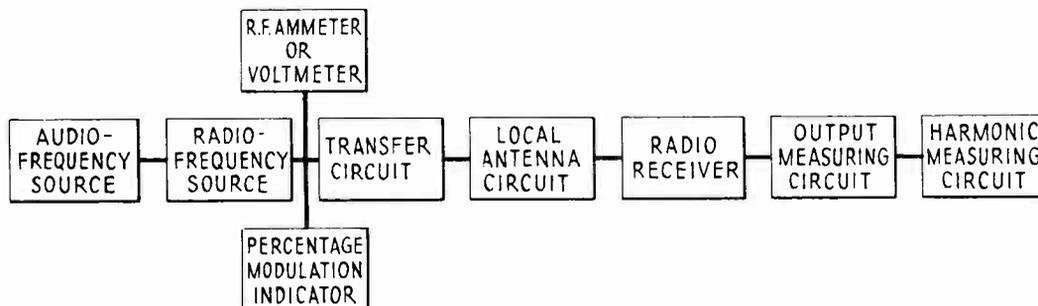


Figure 14

(H) Standard Test Frequencies. In the testing of a broadcasting radio receiver, the five standard carrier frequencies are 600, 800, 1000, 1200, and 1400 kilocycles per second. When tests are required at only three carrier frequencies, the values 600, 1000, and 1400 kilocycles per second are recommended.

III. REQUIREMENTS AND CHARACTERISTICS OF TESTING APPARATUS.

The apparatus employed in testing radio receivers should be as simple as is consistent with accurate performance of the necessary functions. As far as possible, the same apparatus should be used in the different tests. The values of the electrical quantities and calibrations should not change with time, or if some change is unavoidable, means for checking should be provided.

The required apparatus for tests of sensitivity, selectivity, and fidelity, is indicated in block diagram form in Figure 14. Both frequency sources should be calibrated so that a separate measurement of frequency is not needed. The requirements of the separate elements are stated in the following paragraphs.

(A) Audio-Frequency Source. For sensitivity and selectivity tests this may be a mechanical oscillator of fixed frequency (400 cycles per second), but a vacuum tube oscillator having a frequency range at least from 40 to 10,000 cycles per second is preferred and for the fidelity test is necessary. The total harmonic content in the output of this oscillator should not exceed five per cent. The audio-frequency oscillator is arranged to modulate the radio-frequency oscillator by a known amount and preferably should furnish the same degree of modulation without readjustment at all carrier frequencies and all modulation frequencies. Means should be provided for adjusting the degree of modulation for at least the normal value of 30 per cent.

(B) Radio-Frequency Source. This consists of a vacuum tube oscillator supplied preferably from batteries, either fully shielded in itself or so shielded from the radio receiver under test that there is no direct radiation to the receiver. If the power supply is external to the shielding system which encloses the oscillator all ungrounded leads to the oscillator should pass through shielded low-pass filters. The frequency should be adjustable by an external control to any desired value between 500 and 1500 kilocycles per second, and the frequency should not be affected by changes in output power. Means should be provided for varying the frequency in small steps immediately on each side of any specified frequency. A second external control should be provided for varying the modulated radio-frequency output supplied to the transfer circuit, and an instrument should be provided which indicates the effective value of this output. The oscillator in conjunction with the transfer system used (see "Transfer Circuit") should be capable of supplying in series with the receiving antenna system at least 200,000 microvolts at all carrier frequencies.

(C) Transfer Circuit. The radio receiver under test is provided with a local antenna circuit consisting of either a loop antenna (which may be self-contained) or an artificial antenna. In determining the significant characteristics, as outlined in the preceding sections, modulated radio-frequency voltages of known value are impressed in the local antenna circuit through the transfer circuit which should assume one of two forms as follows:

1. A coupling coil fed from the radio source and mounted in inductive relation with the loop antenna or with the 20-microhenry coil.

2. A calibrated attenuator of the resistance type terminating in a low impedance of known value (usually a resistance of about one ohm) which may be inserted in series with the artificial or loop antenna. This attenuator should be so constructed that all attenuation ratios are substantially independent of frequency within the broadcast band. It is preferably made variable in steps with additional provision for continuous variation between the steps. As an alternative to continuous variation with the attenuation network, provision may be made for continuously varying the measured current or voltage supplied from the source to the attenuator over a sufficient range to cover all values of receiver input voltage which lie between the steps of the attenuator. Design details of attenuators fulfilling these requirements are available in the literature. The combined range of ratios on the attenuator and variable currents from the source should be such as to allow a range of voltage across the terminal unit which feeds the receiving set of one microvolt to 200,000 microvolts.

(D) Output Measuring Circuit. The components of the output measuring circuit should be as follows:

1. A noninductive load resistor adjustable to any desired value between one and 20,000 ohms and capable of dissipating 10 watts at any setting.

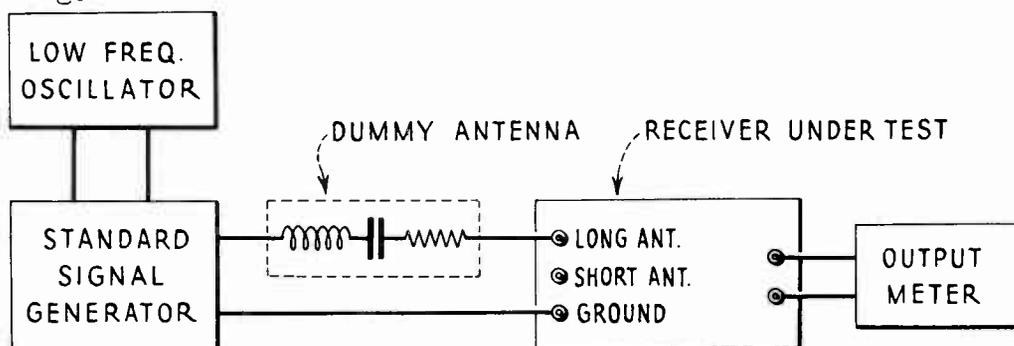


Figure 15

2. An output filter to be used with radio receivers normally having direct current in their outputs. This filter should fulfill the requirements given under definition D, section II, and a recommended form consists of an inductance of not less than 100 henries (with 50 milliamperes direct current in the winding) and a capacitance of not less than eight microfarads.

3. A vacuum tube voltmeter or an equivalent device which will accurately measure the root-mean-square values of output voltage. At normal test output the voltage is of the order from 10 to 20 volts for ordinary output vacuum tubes. For the sensitivity and selectivity tests the output meter need be calibrated only at these values. For the fidelity test continuous calibration is required, and for the overload level test calibration for much higher values is needed.

IV TEST PROCEDURES.

(F) Sensitivity and Tuning Range Tests.

1. The sensitivity test is as follows: The sensitivity is determined by impressing a radio-frequency voltage, with 400 cycles, 30 per cent modulation, in series with a standard antenna (definition G, Section II),

or by inducing a known radio-frequency voltage in the self-contained antenna, if the radio receiver is so provided, and adjusting the intensity of the input voltage until normal output is had under conditions stated in E and F, section II, for carrier frequencies between 550 and 1500 kilocycles per second. See Figure 15.

A graph is plotted with normal radio input voltage as ordinates and carrier frequency as abscissas. A uniform scale should be used for the abscissas and either a uniform or logarithmic scale may be used for ordinates.

2. The Tuning Range Test is as follows: In conjunction with the sensitivity test it is convenient to make a test of the tuning range of the radio receiver. Using the same test conditions as for the sensitivity test, the radio receiver tuning adjustment should be set for the lowest carrier frequency it is capable of receiving under normal operation. The radio-frequency oscillator is then adjusted in frequency until it is at that frequency which gives maximum output in the output meter. The output signal used should be approximately normal test output, to avoid inaccuracies due to overloading. The radio-frequency setting of the oscillator is then recorded as the lower frequency limit of the tuning range. If the radio-frequency oscillator is incapable of reaching the low-frequency limit of the receiver, the oscillator should be set at its minimum frequency and the receiver tuned to it. The dial scale reading of the radio receiver is then recorded for that frequency. The process is then repeated at the high-frequency limit of the range. The maximum and minimum frequency settings of the tuning control will generally correspond to the maximum and minimum dial scale markings. If they do not, the dial settings corresponding to the limit frequency settings should be recorded.

If a calibration of dial setting versus carrier frequency is desired, it can be obtained by adding to the limit values, a set of readings of the dial settings for each of the standard test frequencies used in the sensitivity test. The dial calibration is plotted in the form of a graph with carrier frequency as abscissas and dial setting as ordinates, both to a linear scale.

(G) Selectivity Test. The selectivity is determined by tuning the radio receiver to each standard test frequency (definition H, section II) in succession, with the receiver in the same condition as in the sensitivity test, and measuring the radio-frequency input voltage necessary to give normal test output at a series of carrier frequencies in steps not greater than 10 kilocycles per second at least up to 100 kilocycles per second on either side of resonance, or until the radio input voltage has increased to at least 1000 times its value at resonance (and preferably 10,000 times or more if the measuring equipment permits).

The conditions of modulation of the radio-frequency oscillator are to be the same as given under the definition for normal radio input voltage (definition F, section II). For each standard test frequency a graph is plotted with carrier frequency as abscissas and the ratio of input off resonance to the input at resonance, as ordinates. The scale of ordinates should be logarithmic and the most accurate representation is secured by plotting the graphs for selectivity with separate enlarged frequency scales, which should be uniform and alike.

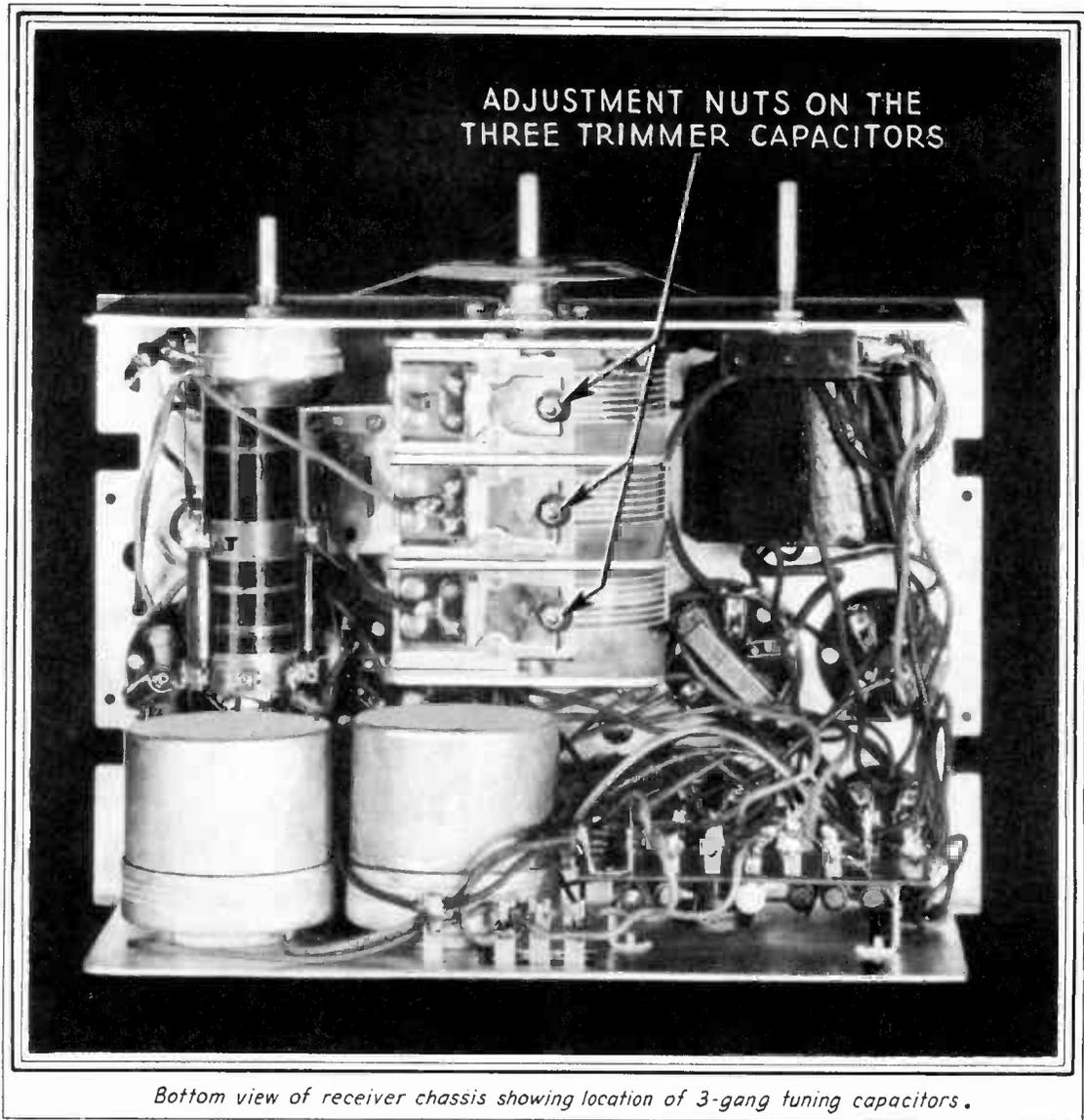
On some receivers the volume control setting has an effect on the selectivity, and this fact should be considered when making this test.

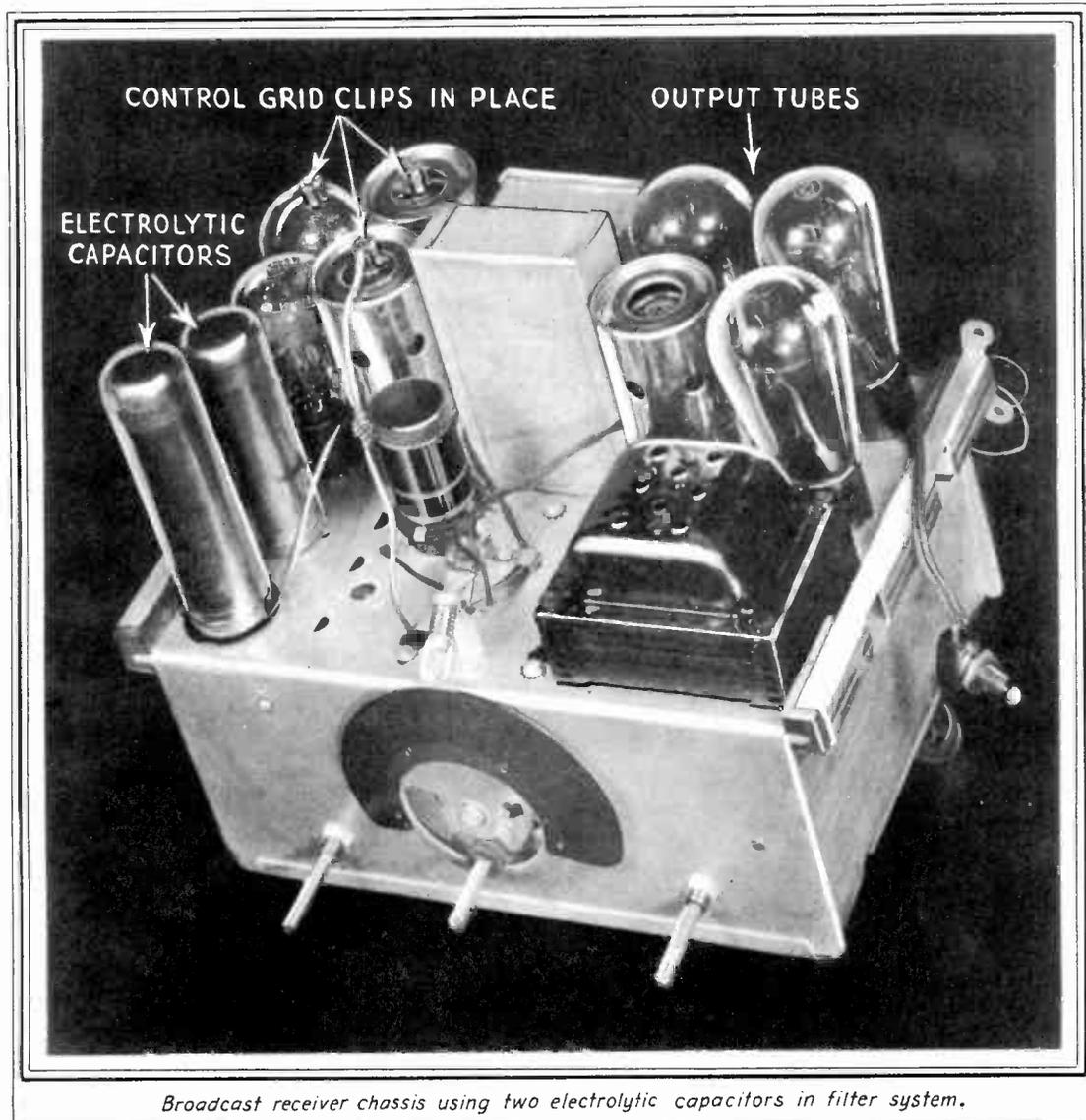
(H) Fidelity Test. This is determined by tuning the radio receiver to each standard test frequency (definition H, section II) in succession, with the receiver in the same condition as in the sensitivity and selectivity tests, adjusting the impressed voltage to the normal radio input voltage, (definition F, section II) and then varying the modulation frequency from 40 to 10,000 cycles per second at 30 per cent modulation and constant radio-frequency input voltage throughout, taking readings of relative output voltage at convenient modulation frequencies. For each standard test frequency, a graph is plotted with modulation frequency as abscissa, and as ordinate, the ratio of the output voltage at the modulation frequency of measurement to the output voltage at the modulation frequency of 400 cycles per second. A logarithmic scale should be used for the abscissas and either a uniform or logarithmic scale for the ordinates.

It is often useful to make fidelity tests at output levels higher than normal test output. The output levels to be used are left to the discretion of the test engineer and should be stated in the results. Certain types of volume controls have an effect upon the fidelity of the receiver and this fact should be considered when making this test.

EXAMINATION QUESTIONS

1. Describe some of the characteristics of screen-grid receivers that differ from those employing other type tubes.
2. Why are there no neutralizing condensers or stabilizing devices required in screen-grid receivers?
3. How is the grid bias obtained for the 224 tubes in the receiver shown in Figure 1?
4. What is the result of impressing a signal voltage higher than the biasing voltage on a tube?
5. How may the signal voltage be reduced?
6. When is maximum power transferred from one circuit to another?
7. Upon what principle does a magnetic phonograph pick-up work?
8. (a) Define sensitivity, selectivity, and fidelity. (b) Why is each of these qualities important in a receiver?
9. (a) Give two advantages of the 247 tube over the 245 tube. (b) When is the 245 more desirable?
10. Why is shielding necessary in screen-grid receivers? What units must be shielded?





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