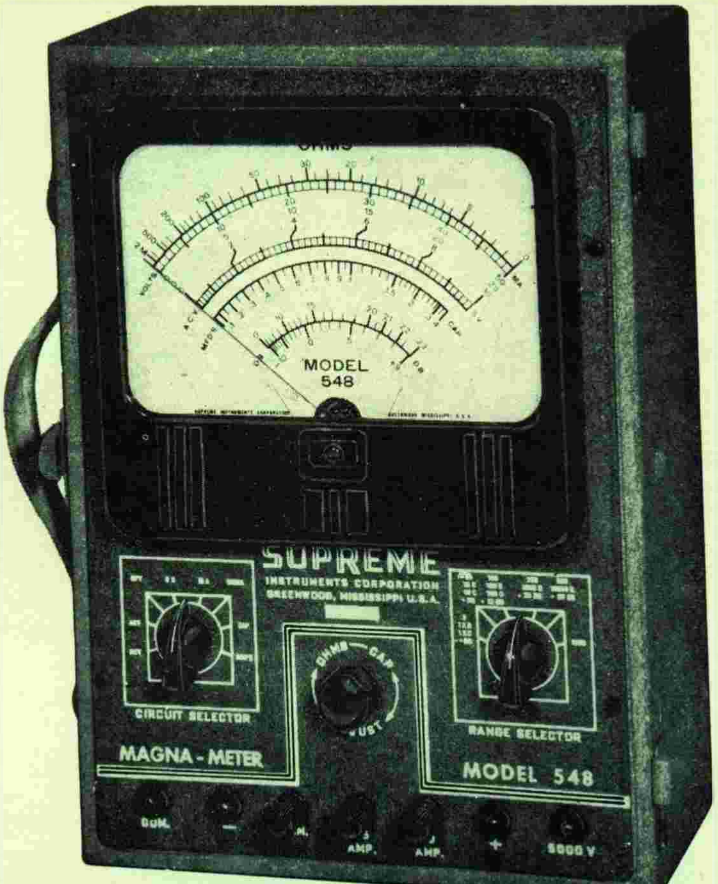

LESSON
52 RA

METHODS OF METERING RADIO AND TELEVISION CIRCUITS

RADIO-TELEVISION TRAINING SCHOOL, INC.
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Electric meters serve a very useful purpose in the analysis of a receiver that contains a defective unit or other troublesome condition, for if properly connected into the circuit system meters will readily reveal if the circuit is operative or not and what the voltage and current relations are. It is rather important, however, that the proper type of meter be selected in every case and that the scale range be suitable so that the meter indications can be accepted as being a correct revelation of the operating conditions in the circuit.

The range of the scale chosen is important from the angle that the indications of any meter are most accurate over the middle half of the scale, that is, the indications at the lower upper ends of the scale are not quite so reliable. For example, if the voltage in a 110 to 120-volt A. C. power line is to be measured, an A. C. meter having a range of 0 to 150 volts should be chosen. This is a common scale range readily available, and the operating value falls within the good operating range of the meter.

In the following paragraphs there will first be taken up a discussion of the rectifier type of A. C. meter and its applications in various kinds of test equipment, and this will be followed by a comprehensive discussion of the use of different kinds of electric meters for determining the electrical operating conditions in the various sections of radio and TV circuits.

RECTIFIER TYPE A. C. METERS

The rectifier type A. C. meter, as the name suggests, rectifies the alternating voltage or current to be measured and then sends the rectified current through a sensitive D. C. meter, as of the D'Arsonval moving-coil type. This arrangement makes it possible to employ the same highly sensitive meters for alternating current measurements as are used for direct current work.

The familiar movable iron type A. C. meter that is commonly used in radio service equipment, requires relatively large currents for full-scale deflection and hence draws considerable power from the lines into which it is connected. The meter current may in many cases be as great or even greater than the main current in the circuit under test, and it is readily evident how this can upset the electrical stability of the entire circuit system. If the signal output of a receiver were being measured with such a low sensitivity meter during a balancing or aligning process, the power consumed by this meter itself would be such a large proportion of the total output that the indications would be of little meaning or significance.

These disadvantages of the straight A. C. meters have been overcome to a great extent by adapting the more highly sensitive (low current consuming) D. C. moving-coil meters for A. C. measurements by equipping them with suitable rectifiers. Such rectifier equipped meters can be used for measuring all the low and high A. C. voltages that are operative in a radio receiver and at the same time the high sensitivity of the D. C. meters are retained. The current measuring range, however, is limited by the current capacity of the rectifier itself, and in the average meter rectifiers this seldom exceeds 15 to 25 milliamperes. Of course, shunts can also be employed with such rectifier meters to increase the current range.

On the other hand, however, the performance of rectifier type A. C. meters are readily influenced by a number of factors that impair the indicating accuracy, such as the wave form of the alternating voltage or current, the operating temperature, the frequency of the alternating current and the current density through the rectifier. Under normal operating conditions and at room temperatures when these sources of error do not have an undue influence, the indications of a rectifier type A. C. meter can be relied upon to within 5% of full scale value. Although this is not as good accuracy as is obtainable with a well built straight A. C. meter, still it is sufficiently close for all A. C. measurements made in radio service and repair work.

A certain amount of care, however, must be exercised in the use of rectifier type A. C. meters, for any appreciable overload will alter the rectifier characteristics and the balance of the associated circuits and cause the meter to give erroneous indications.

THE COPPER-OXIDE RECTIFIER

A rectifier is a one-way electrical gate or valve, that allows free passage to the flow of electric current in one direction but offers high resistance to the flow of current in the opposite direction. It can therefore be used for converting an alternating current to a uni-directional or direct current, and is used in this capacity in various forms in commercial practice.

The copper-oxide rectifier is commonly used with rectifier-type A. C. meters on account of its simple construction and special applicability for this class of service. Such a copper-oxide rectifier consists of a number of round copper discs that are oxidized on one side but left bright and clean on the other. These copper discs are assembled on an insulated shaft with a piece of lead or other inert metal between them for conducting the current to the oxidized surface. The entire assembly is then held pressed tightly together by a bolt passing through the shaft.

These copper discs have the peculiar property of permitting an electric current to pass freely from the copper-oxide surface to the pure copper but offering high resistance to flow in the opposite direction. In commercial units copper-oxide rectifiers are available as half-wave and full-wave rectifiers. The former, as the name suggests, permits only half of each alternating current wave to pass through and blocks out the other half, while the latter is arranged so that both halves of the current wave are made available.

OPERATION OF A FULL-WAVE COPPER-OXIDE RECTIFIER

In Fig. 1 are shown several different types of full-wave copper-oxide rectifiers. A full-wave copper-oxide rectifier employs four copper discs arranged in the form of the arms of a Wheatstone bridge as is shown in Fig. 2. The shaded area of the copper discs represents the oxidized surface and the clear area the free copper. Current can thus flow from the shaded area of each disc to the free area but not readily in the opposite direction.

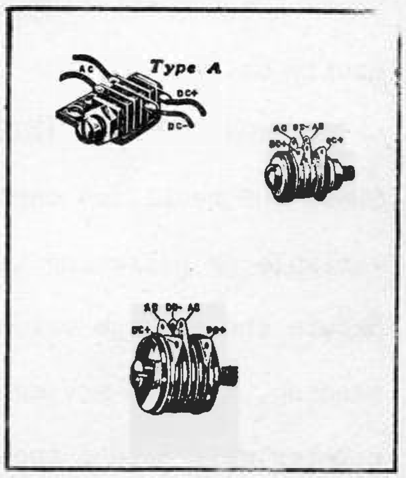

Fig. 1. Here are shown 3 type A full-wave copper-oxide rectifier units.

The alternating current lines, A and C, are connected to points 1 and 7, and the meter M to points 3 and 5. During the half cycle that the upper line A is positive, current flows in the direction indicated by the long thin arrows. It enters the rectifier at terminal 1, flows through disc 2 and out at terminal 3, through the meter 4 and enters again at terminal 5, flows through disc 6, and out at terminal 7 to the other side of the line C. During the next half cycle when line C is positive, current flows as indicated by the short heavy arrows. It enters the rectifier at terminal 7, flows through disc 8 and out at terminal 3, through the meter 4 and enters again at terminal 5, flows through disc 9 and out again at terminal 1 to the other side of the line A. Consequently, as the current in the line alternates, a correspondingly pulsating direct current flows through the meter. The use of the rectifier thus permits the measurement of alternating currents and voltages with a D. C. meter.

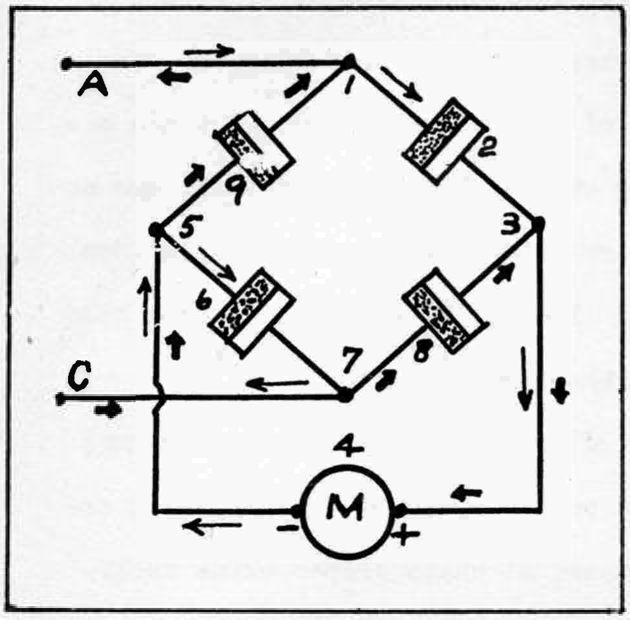

Fig. 2. This is a schematic diagram of a full-wave copper-oxide rectifier and meter.

In Fig. 3 is illustrated the arrangement of the four copper discs as they are assembled in a commercial rectifier unit. Four terminals are provided for the external connections, two for the A. C. line and two for the meter. The broken lines between the dixxx discs represent the thin pieces of lead that are used for making electrical contact. The terminal numbers shown correspond to those in Fig 3, and hence the current flow through the rectifier can easily be traced.

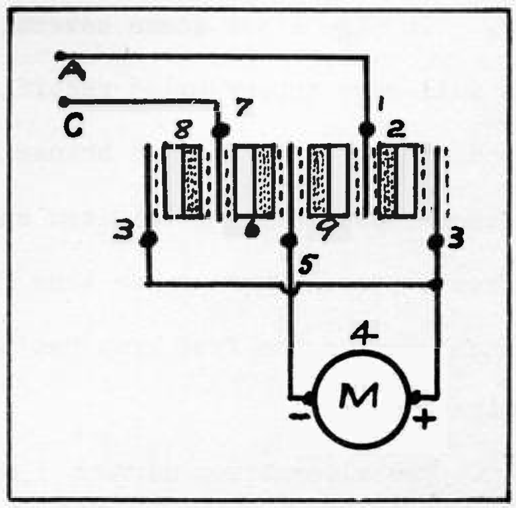

Fig. 3. This is another way of showing the pile of copper-oxide rectifier discs held in line schematically.

AVERAGE CURRENT VALUES ARE INDICATED BY THE METER

Since the rectified current through the meter is variable or pulsating in nature, the meter will indicate the average value or strength of current flowing, for the movement or swing of the meter pointer will depend upon the average magnetic pull on the movable coil.

This action of the meter will probably be understood more clearly by observing

Fig. 4. Here curve A represents the alternating current or voltage wave. Each cycle consists of two alternations in which the current increases from zero to the maximum value Im and then reduces to zero again, only to increase in the opposite direction to the same maximum value and then diminish to zero. In the next cycle the same action is repeated.

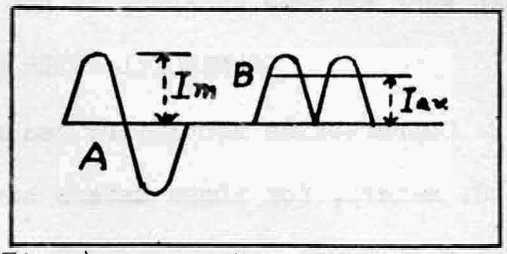

Fig. 4. At A is shown the A.C. current while at B is shown the output current of the full-wave copper-oxide rectifier.

Due to the action of the rectifier, the current during every alternate half cycle is reversed, so that the curve representing the current variations through the meter appears as is shown at B in Fig. 4. As the current increases in value, the magnetic pull on the movable coil of the meter increases; and as the current diminishes, the magnetic pull decreases. The resulting pull on the coil is then equivalent to a steady magnetic pull that is equal to the average of the different values exerted during each half cycle. This average magnetic pull, of course, is proportional to the average value of current flowing as represented by the horizontal line Iav. at B in Fig. 4.

Now it can be shown mathematically (although too lengthy a process to be taken up here) that the average value Iav. is equal to the maximum value Im X .635. But it is the effective value of an alternating current or voltage that is used in A. C. measurements, and all straight A. C. meters are calibrated to indicate directly the effective values. The effective value, it can also be shown, is equal to the maximum value Im X .707. In other words, to change the average value to the effective value it is necessary to multiply the average value by .707/.635 or 1.11.

Since it would be a rather tedious job to multiply the meter indications by 1.11 to get the effective value every time the meter is being read, all rectifier type A. C. meters are calibrated to read directly in effective values and no calculations or transpositions are necessary. Furthermore, as will be shown later on the scale calibrations on rectifier type A. C. meters are practically uniform through the whole scale length and not crowded together at the lower end as they are with A. C. meters of the movable iron type.

The fact that the scale calibrations on a rectifier type A. C. meter are practically uniform through the entire length, added to the feature that the operating sensitivity (ohms-per-volt) is very high (from 1,000 to 2,000 ohms per volt), makes this type of A. C. meter very desirable for radio service measurements in view of the fact that such extreme accuracy is not necessary in this class of work.

COMMERCIAL METER RECTIFIER RATINGS AND SPECIFICATIONS

Copper-oxide rectifiers can really be used only with D'Arsonval type movable coil D. C. meters, for these meters have a low current consumption and permit the design of high resistance voltmeters. Rectifier units designed for this purpose are quite compact in size and average from one-half to three-fourths inches in diameter and about three-fourths inch long.

Both half-wave and full-wave rectifiers are available. If higher voltages are to be rectified, a number of copper discs are arranged and connected in series; and if larger currents are to be rectified, a number of discs are connected in parallel. The current carrying capacity depends on the area of the contacting surfaces. Rectifiers designed for adapting D. C. meters to A. C. measurements generally have catalog ratings ranging from 5 to 20 milliamperes. Although 100 microampere meters are most commonly used, these rectifiers can be used with meters that require full-scale deflecting currents up to the current rating of the rectifier. An A. C. input rating of 10 volts is ample for such meter rectifiers.

The points to consider, then, when purchasing such a copper-oxide meter rectifier are: 1. Does the circuit to be used call for full-wave or half-wave rectification? 2. What is the full scale deflection current required by the meter? 3. Does the rectifier offered have a current rating that is as large or larger than the full-scale current required by the meter? Only good quality rectifiers should be considered for cheaper and inferior rectifiers will cause erroneous and inconsistent meter indications, and in addition will have a rather short useful life.

Another catalog specification that often is found in the rating data of copper-oxide rectifiers is the A. C. input. Any rectifier having an A. C. input rating of 10 volts or more is satisfactory for such meter work.

Copper-oxide rectifiers are suitable for A. C. measurements at all commercial frequencies, even up to 5,000 cycles per second. They should not, however, be used for high frequency work, as the capacity effect of the copper discs then becomes too prominent and the meter readings would have little meaning. A copper-oxide rectifier should never be over-heated either through electrical overload or otherwise, for excessive heat is ruinous to any rectifier of this type.

CIRCUIT ARRANGEMENT OF A RECTIFIER TYPE A. C. VOLTMETER

The general circuit arrangement employed with a rectifier type A. C. voltmeter is illustrated in Fig. 5. The A. C. line is connected to the input side of the rectifier with a suitable multiplying resistor R in series. The output side of the rectifier is connected directly to the terminals on the meter, which, of course, is a D. C. moving-coil type meter, generally a 0 to 1 milliammeter. In some cases both the rectifier and multiplying resistor are mounted inside of the meter case, and with such meters only two terminals are brought out that are connected directly to the A. C. line.

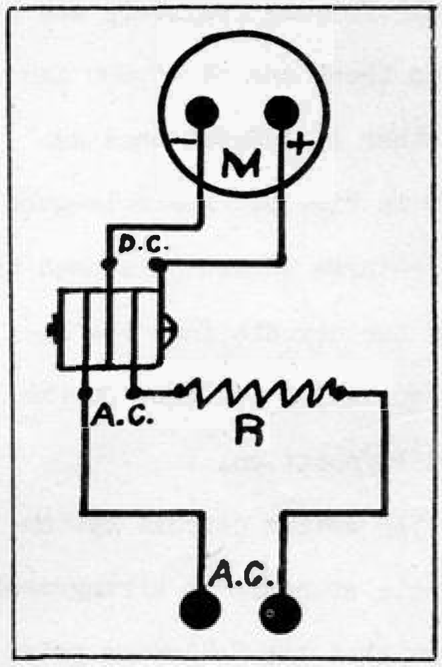

Fig. 5. This is the general circuit arrangement used with a rectifier type A. C. voltmeter.

Due to the arrangement of the copper-oxide discs in the rectifier, the alternating voltage is converted into a pulsating uni-directional voltage that in turn is passed on to the meter for measurement. The meter deflections are then proportional to the average value of the alternating current or voltage; but if the meter is initially designed for use with such a copper-oxide rectifier, the dial scale can be calibrated to read directly in effective values, so that no calculations or transpositions are necessary.

The meter multiplying resistors, it will be seen, are always connected in series with the A. C. input side of the rectifier. The values of these resistors are calculated just as they are for a D. C. meter, except as explained in the next section. If the meter is a 0 to 1-milliammeter, a resistance of 1,000 ohms is needed for every volt range the meter is to have. If it is to be a 150-volt A. C. voltmeter, the multiplying resistor must be 150,000 ohms. The resistance of the rectifier can be disregarded, for this is generally of negligible value compared to the high resistance of the multiplying resistor. An important point always to observe when using rectifier type A. C. meters is never to overload them seriously.

CONVERTING A D. C. METER TO A RECTIFIER TYPE A. C. METER

If the occasion arises that a D. C. meter is to be converted to a rectifier type A. C. meter, the circuit arrangement shown in Fig. 6 is employed. Let us suppose that the meter is a 0-15-150-volt D. C. voltmeter with a sensitivity of 1,000 ohms per volt, and that the A. C. meter is also to have a double range, 0 to 15 and 0 to 150 volts. Two multiplying resistors are needed then, one of 15,000 and the other of 150,000 ohms as shown in Fig. 6. A single-pole double-throw switch S is used to throw the circuit into the 15-volt operating position or the 150-volt position.

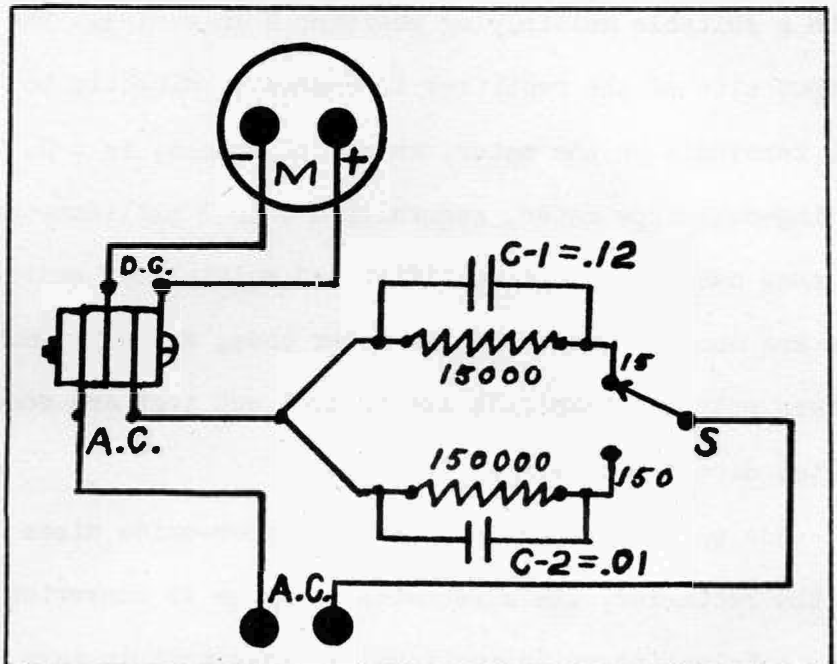

Fig. 6. Condensers are used to obtain the same reading when measuring D. C. and A. C. voltages.

The entire circuit system is quite standard in arrangement, except that the following point needs special consideration. If the same multiplying resistors are used for both the D. C. and A. C. ranges, a given alternating voltage will produce a lower reading than the same value of direct current voltage, due to the losses that occur during the rectification process and in overcoming the resistance in the rectifier. To obtain the same reading then, for equal values of direct and alternating current voltage, these losses must be compensated for.

One method of compensating for these rectifier losses is the condenser method illustrated in Fig. 6. Here that value of resistor is used as is properly needed for the D. C. meter. An alternating voltage is then applied equal to the full-scale D. C. reading. The meter indication, however, will now be less due to the losses in the rectifier. To make up for these losses a condenser is connected across the resistor. This condenser decreases the impedance of the circuit and hence permits sufficiently more current to flow to bring the meter indication up to full-scale value.

Condenser C-1 shunted across the 15,000-ohm resistor in Fig. 6 is such a compensating condenser. The value of this condenser is readily determined by experiment, that is different values of condensers are tried until the desired meter indication is obtained. The voltage rating of the condenser depends upon the potential drop across the resistor. A separate condenser is required across each voltage range, that is, each multiplying resistor must be shunted by a condenser so that an alternating voltage of a given value will give a corresponding meter indication on the D. C. scale.

A MULTI-RANGE A. C. - D. C. VOLTMETER AND MILLIAMMETER

In Fig. 7 is shown an interesting circuit arrangement by means of which a 0-1 D. C. milliammeter of the D'Arsonval moving-coil type and having an internal resistance of 50 ohms can be adapted for use as a multi-range D. C. voltmeter, a double-range D. C. milliammeter, and a multi-range A. C. voltmeter, both D. C. and A. C. voltmeter systems having a sensitivity of 1,000 ohms per volt. Later on it will be shown how an ohmmeter or resistance measuring arrangement can also be added to the network.

A 2-gang 5-point selector switch S-1 is used to select the different voltmeter ranges, while a double-pole double-throw (D.P.D.T.) toggle switch S-2 serves to shift the voltmeter operation to either the A. C. or D. C. side. The D. C. voltmeter terminals are shown at the right numbered 1 (pos) and 2 (neg). With switch S-2 in the D. C. position and switch S-1 in position b, the 15,000-ohm resistor is connected into the circuit and the meter operates as a D. C. voltmeter having a range of 0 to 15 volts at a sensitivity of 1,000 ohms per volt. With switch S-1 in position c the 15,000-ohm and 135,000-ohm resistors are connected in series into the circuit, making a total of 150,000 ohms, and the meter operates as a 0-150 volt D. C. voltmeter. When switch S-1 is in position d, the three resistors are connected in series with a total value of 300,000 ohms and the meter functions as a 0-300 volt voltmeter. If the switch is in position e, all four resistors are connected in series with a total value of 600,000 ohms and the meter operates as a D. C. voltmeter with a range of 0 to 600 volts. The meter can thus be used as a D. C. voltmeter with either one of four ranges, the range being selected by switch S-1.

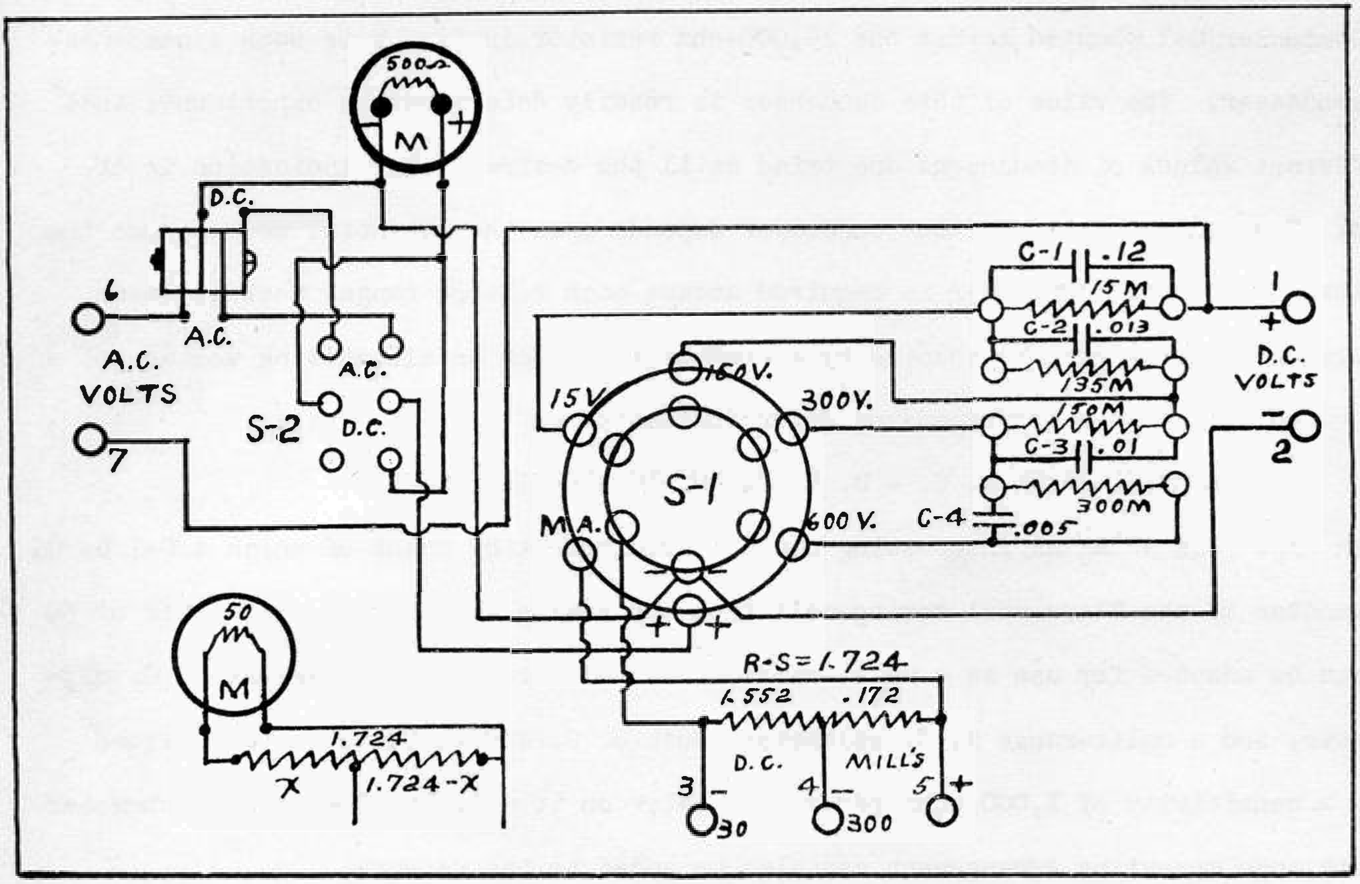

Fig. 7. Typical circuit diagram of a D. C. - A. C. multi-range voltmeter and milliammeter.

If terminals 6 and 7 on the left are used and switch S-2 is thrown into the A, C. position, the rectifier is cut in series with the meter circuit and the meter functions as an A. C. voltmeter, the range being determined by the position of the selector switch S-1, the same as when the meter was used as a D. C. voltmeter. However, when A. C. voltages are being measured, it is necessary to compensate for the losses that occur in the rectifier, and for that purpose small condensers are shunted across the multiplying resistors so as to decrease their A. C. impedance and permit sufficiently more current to flow to make up for the resistance losses in the rectifier. These condenser values depend upon the voltage range and the potential drop across each respective resistor, and the capacities required in each case are determined by experiment.

When switch S-2 is thrown into the D. C. position and the selector switch S-1 is in position a, the meter functions as a D. C. milliammeter with connections brought out to terminals 3, 4 and 5 and at the bottom of the sketch. The range as a milliammeter depends upon the value of shunt resistance Rs that is connected across the meter. If terminals 3 and 5 are used, the meter range is 0 to 30 milliamperes, and the value of shunt resistance is obtained by dividing 50 by 29, which gives a value of 1.724 ohm. If terminals 4 and 5 are used, the meter range is 0 to 300 milliamperes. For this purpose the shunt is tapped as shown, so that one section has a value of 1.552 ohms and the other 0.172 ohms, the combined value being equal to 1.724 ohms.

HOW TO CALCULATE THE VALUES OF SERIES SHUNTS FOR MILLIAMMETERS

The values of series shunts for milliammeters are calculated in much the same manner as ordinary single shunts are. To illustrate the process the shunt values used in Fig. 7 will be used as an example.

The resistance of the total shunt is first calculated for the lowest current range the instrument is to have as a milliammeter. In the present case the range is to be extended to 30 milliamperes, and to obtain the shunt resistance needed it is only necessary to divide the meter resistance by the multiplying ratio diminsihed by 1. In other words, 50 is divided by (30 minus 1) or 29, and the result is 1.724, which is the value the total shunt is to have.

The next step is to calculate the position of the tap and the values of the two sections of the shunt. For this purpose the circuit will be broken up so that it appears as shown in the lower left hand corner of the sketch. As a basis for starting the calculations one section of the shunt will be assumed to be X ohms (X stands for the unknown number whose value is being sought) and the other section will then be equal to 1.724 minus X.

As the broken up diagram appears, the section of the resistor X can now be considered to be in series with the meter and the other part (1.724 minus X) in shunt with the meter and X. The total meter resistance is then (50 plus X); and since the milliammeter range is to be extended to 300 (the multiplying ratio being 300), the value of the shunt must be equal to (50 plus X) divided by 299. But this shunt it is known is also equal to 1.724 minus X. The problem then becomes to secure the value of X, and the solution of this problem involves a little algebra as is shown below.

The Meter Resistanceequals50 plus X and the Multiplying Ratio equals 300. Therefore, Shunt Resistance equals 50 plus X divided by 299 the Shunt Resistance equals 1.724 minus X. Therefore, 50 plus X divided by 299 equals 1.724 minus X. If this equation, as it is called, is cleared of fractions, it becomes:

$$50 + X = (1.724 - X) \times 299 = 515.476 - 299X$$

Upon transposing and collecting terms this becomes

$$X + 299X = 515.476 - 50 \text{ or } 300X = 465.476$$

By dividing both sides of the equation by 300, the value of X is found:

$$X = \frac{465.476}{300} \qquad \text{or } X = 1.552$$

And $1.724 - X = 1.724 - 1.552 = 0.172$

Consequently, to extend the range of the meter to 30 and 300 milliamperes through the use of a tapped shunt, the shunt must have a total value of 1.724, and this shunt must be tapped at such a point that one section is equal to 1.552 ohms and the other section to 0.172. It is across the latter section that the terminals are made for the 300 milliampere range of the meter.

The same principles are applied when a milliammeter shunt is used with two or more taps, as when a 3, 4 or 5 range milliammeter is desired.

HOW TO READ THE SCALE ON A MULTI-RANGE METER

When a meter is used with a number of different voltage and milliampere ranges as was described and discussed above and is illustrated in Fig. 7, it is hardly possible to imprint on the meter dial an individual scale calibrated for each range, for this would congest the dial too much and make it difficult to decipher the different scales. It is customary practice in such cases to divide the full scale length into a number of divisions that can be arranged into groups the major divisions of which correspond to integral portions of the lowest scale ranges. The higher scale ranges are then read by multiplying the markings on the lower scale by 10 or multiples of 10.

For example the meter used in the circuit arrangement shown in Fig. 7 can be equipped with a scale system such as is illustrated in Fig. 8. The lower scale calibrations are for measuring D. C. volts and D. C. milliamperes. The scale length is divided into 75 equal divisions arranged into groups of 5 each, the fifth line of each group being drawn somewhat longer and heavier to indicate a major marking. There are thus 15 of these major divisions with each consisting of 5 minor divisions. This arrangement permits the easy application of the various scale ranges used: 15, 30, 150, 300 and 600.

For the 15-volt range the major divisions are numbered consecutively from 1 to 15; but in order not to fill the dial with too many figures, only the 5th, 10th and 15th are numbered. Every major division then represents 1 volt, and since there are 5 minor divisions in each, the minor divisions represent .2 of a volt each. If, for instance, the meter pointer stands on the third minor division between the third and fourth major divisions, the meter reading is 3.6 volts. If the pointer stands on the second minor division between the eighth and ninth major divisions, the meter reading is 8.4 volts. Should the pointer stand midway between the second and third minor divisions following the twelfth major division, the meter reading would be 12.5 volts.

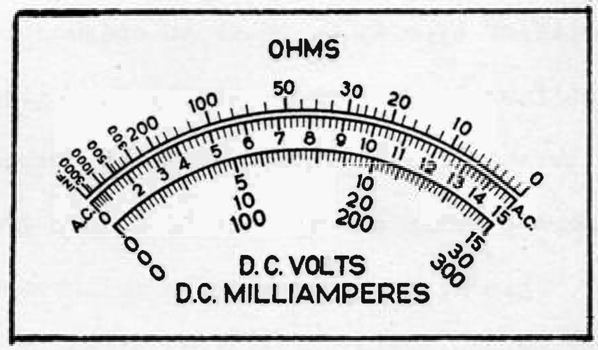

Fig. 8. Typical scale as used on universal A. C. - D. C. multi-range meter.

The same scale figures are used when the meter is set to operate on the 150-volt scale, but the readings as explained above are simply multiplied by 10. Thus, in the first instance illustrated above the meter reading would be 3.6 or 36 volts. In the second instance it would be 84 volts, and in the third 125 volts.

If the meter is set to operate on the 0-30-scale, then each of the major divisions counts 2 and each minor division .4. If the meter pointer stands on the second minor division, for instance, between the sixth and seventh major divisions, the meter reading is 12.8, and if the pointer stands midway between the second and third minor divisions following the twelfth major division, the meter reading is 25. If operation is on the 0-300-volt or milliampere scale, each major division counts 20 and each minor division 4. Thus, in the first instance cited in the preceding paragraph the meter would be 128 and in the second instance it would be 250. If the 0-600-scale is in use, the meter reading is taken on the 0-300-scale and multiplied by 2.

With the scale length graduated into 75 divisions that are grouped into 15 major units, the calibrations can be numbered so that the meter can be operated over any of the scale ranges mentioned above if the proper multiplying resistors or bypass shunts are used.

The middle scale shown on the dial in Fig. 8 is used when the meter operates as a rectifier type A. C. meter in conjunction with a copper-oxide rectifier. Due to the rectifier losses, etc., the A. C. calibrations are not in perfect step with the D. C. calibrations even though suitable compensating condensers are used, and consequently a separate scale is employed to insure greater accuracy.

This A. C. scale also is calibrated into 75 divisions grouped into 15 major units that are numbered consecutively from 1 to 15. If the meter is set for operation on the 15-volt range, the scale is read direct with each minor division valued at .2. If operation is on the 150-volt range, the scale readings are multiplied by 10. Similarly, if the meter is set for the 300-volt range, the scale readings are multiplied by 20, and for the 600-volt range the scale readings are multiplied by 40. If an additional range of 750 is desired, the scale readings need merely be multiplied by 50. All these multiplications can easily be done mentally, and the dial need not be cluttered up with excessive scale figures.

HOW TO USE ELECTRIC METERS IN RADIO CIRCUITS

Meters serve to give a visual indication of the electrical conditions that exist in a circuit, and to reveal these values correctly with respect to a given section or unit they must be properly connected into the circuit system.

Ammeters and milliammeters measure current flow, and must be connected "in series" into the line so that the entire current flows through the meter. Voltmeters, on the other hand, measure electromotive force or pressure difference and are connected "across" the two points between which the potential difference is to be determined. Whenever a meter with a number of ranges is to be connected into a circuit and it is not known even approximately what the voltage or current values may be, the highest range should be used at the start to ascertain within what limits the values lie. After this the range can be switched to a lower value, so that the meter indication falls near the center of the scale where the greatest accuracy is obtained.

HOW TO METER A VACUUM TUBE AND ITS ASSOCIATED CIRCUITS

In Fig. 9 is shown a typical vacuum tube circuit system as used in modern radio receivers. L-1 may be a tuned or untuned radio frequency or intermediate frequency transformer or the secondary of an audio transformer, etc; while L-2 is the primary of a similar type of transformer.

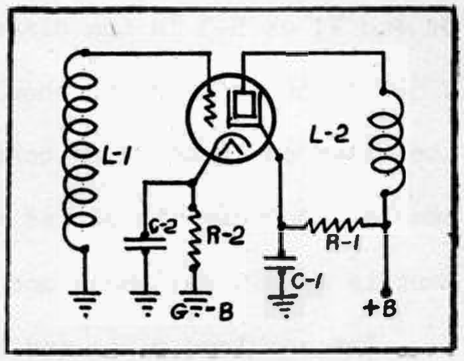

Fig. 9. A typical RF amplifier circuit system.

The plate is supplied with a high D. C. voltage through terminal B, and resistor R-1 serves to drop the potential to a suitable value for the screen grid. In the case of a triode no screen grid is present and consequently this resistor will be absent. C-1 bypasses the screen resistor to ground. R-2 is the cathode biasing resistor for providing the necessary negative potential on the control grid with respect to the cathode. The resistor is bypassed by condenser C-2, which in R.F. and I.F. stages generally has a capacity of about .1 mfd. and in audio stages values up to 10 mfds.

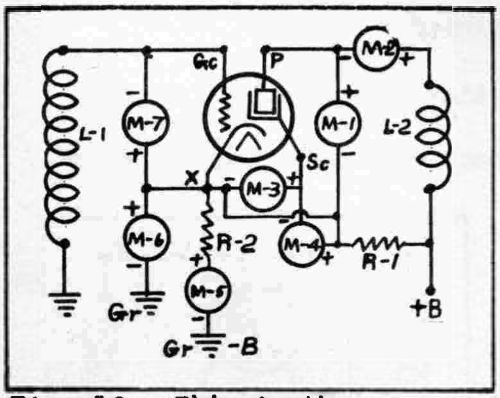

Fig. 10. This is the same circuit as shown in Fig. 9 but with meters inserted to indicate circuit conditions.

Fig. 10 shows how meters are connected into the various branches of this circuit to measure the voltages and currents at the different socket terminals. The cathode or filament, it will be remembered, is the starting point from which all electrical potentials are measured, and the meters all return to this point marked X in the diagram.

Plate voltage is measured with a D. C. voltmeter M-1 connected between points P and X. Seldom are potentials above 300 volts employed here, but for safety purposes it is best to start with a 500 or 600 volt range on the meter. To measure the plate current the line feeding the plate terminal is opened and the meter connected in series with this line, as M-2 in the diagram. A D. C. milliammeter is used here, and to start with a 100 or 150 mill. range is employed. From this initial indication it can then be determined what lower range is suitable for a more accurate reading.

Screen grid voltage is also measured with a D. C. voltmeter connected between points Sc and X, as M-3 in the diagram. Since a rather high potential is also always used here, a 500 or 600-volt range should be used initially; and if a lower range is permissible, the meter can then be switched to it. Screen current is measured with a D. C. milliammeter connected in series with the screen line as M-4 in the diagram. The screen current is relatively small and a low meter range can be used, 0 to 10 or 0 to 15 mills.

The combined plate and screen current can be measured with a D. C. milliammeter connected into the cathode return line as M-5 in the illustration. The range to be employed, of course, will depend upon the values of the plate and screen currents as explained above. The cathode bias created by resistor R-2 is measured with a D. C. voltmeter connected across resistor R-2 or between point X and the ground Gr or chassis. These bias values are generally below 10 volts, except in the case of power output tubes where values up to 65 volts will be encountered. With output tubes, then, a 0-100 or 0-150 voltmeter range should be used, while for other tubes a 0 to 15 volt range will be satisfactory.

HOW THE GRID VOLTAGE READING MAY BE MISLEADING

According to the methods explained in the previous section the potential on the control grid Gc is measured with a D. C. voltmeter M-7 connected between points Gc and X. As long as all component parts in the circuit system are in good working order, this arrangement is quite satisfactory, for the meter is virtually connected across the cathode resistor R-2 with coil L-1 in series.

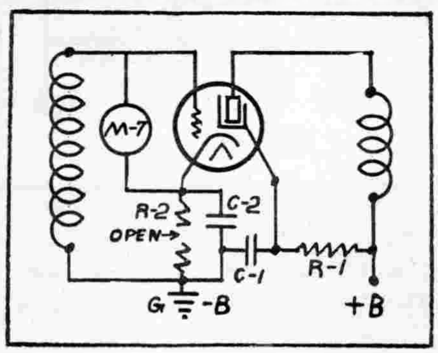

Fig. 11. One way of measuring control grid voltage.

However, in case resistor R-2 is open as shown in Fig. 11, no plate current will flow and the plate voltmeter connected as shown in Fig. 10 also will indicate 0. But as shown in Fig. 11 the meter itself takes the place of the open bias resistor and permits a small current to flow. This current causes part of the available B-supply voltage to be dissipated across the internal resistance of the tube and the remainder across the meter resistance itself. It is this drop across the meter that will be registered and appear as an abnormally high grid voltage, whereas the actual grid bias is zero.

Another condition that may cause a misleading indication is an open input coil L-1 as shown in Fig. 12. No negative bias is on the grid, but a charge of electrons tends to accumulate on the grid and this leaks off through the meter and causes the pointer to swing over the scale. This action, however, is very erratic, and at the same time causes similar erratic fluctuations in the plate current flow.

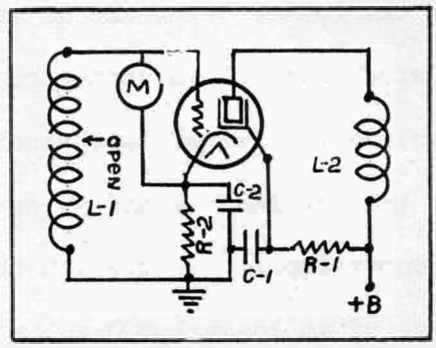

Fig. 12. One way of finding an open circuit in the coil L-1.

In any of these cases it is necessary to analyze the situation, and when any question arises test out the circuit to ascertain if the meters tell a true story.

HOW TO METER AN ELECTRIC POWER SUPPLY SYSTEM

A typical electric power supply system as employed in modern A. C. operated receivers is shown in Fig. 13. The diagram also shows how electric meters are connected into the various branches of the circuit system to measure the different voltages and currents that are supplied to the receiver proper.

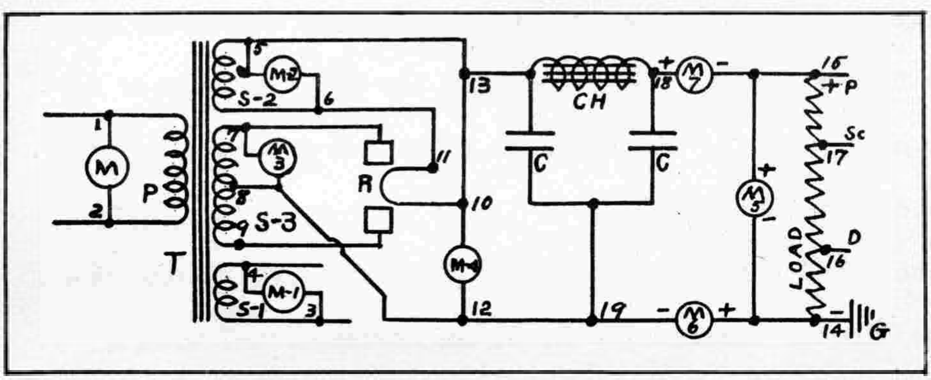

Fig. 13. The connection of meters in a typical electric power supply system.

To measure the voltage supplied to the primary winding P of the power input transformer T an A. C. voltmeter M is used connected across terminals 1 and 2. For a 110 to 125 volt line a 150-volt meter range is recommended, and for a 220 to 250 volt line a 300-volt range. There are three secondary windings, the first of which S-1 supplies the heater or filament current to the tubes in the set. To measure the voltage output of this winding a low range A. C. voltmeter as M-1 is connected across terminals 3 and 4 of this winding.

The other two secondary windings supply the rectifier tube. S-2 supplies the heater current, and to measure its voltage output a low range A. C. voltmeter M-2 is connected across terminals 5 and 6. This voltage can also be measured by connecting meter M-2 across the heater terminals 10 and 11. The third secondary winding S-3 is the high voltage winding which is connected to the plates of the rectifier tube for reotification. The voltage output of this winding is generally between 700 and 750 volts across the outer two terminals 7 and 9, or from 350 to 375 volts between either outer terminal and the center tap 8. To measure the voltage output of this winding an A. C. voltmeter with a range of at least 1,000 volts should be used if connections are made to the outer terminals 7 and 9. If an A. C. meter with a range of only 500 or 600 volts is available, the meter M-3 can be connected between either outer terminal and the center tap 8. When these measurements are being made, good care should be exercised so that the hands will not come in contact with any bare part of the circuit or a severe shock may be received.

To measure the total rectifier output voltage ahead of the filter a D. C. voltmeter M-4 with a range of 500 or 600 volts is connected across terminals 12 and 13, that is, between the rectifier heater terminal and the center tap on the high voltage winding. If the same meter is connected across terminals 14 and 15, the output at the voltage divider is obtained. This will be less than the previous reading by an amount equal to the voltage drop or loss in the filter system. By connecting the D. C. voltmeter across points 14 and 16, 14 and 17, or 16 and 17, the voltages operative across the different sections of the voltage divider are obtained.

If it is desired to measure the total current supplied by the rectifier to the receiver circuit system including the bleeder currents, a D. C. milliammeter M-7 with a range of at least 150 milliamperes is connected in series with the positive side of the line between points 15 and 18, or in series with the negative return line between points 14 and 19.

HOW TO INTERPRET SOCKET VOLTAGE TABLES FOR COMMERCIAL RECEIVERS

To aid the Radio Service Man in determining whether every stage of a radio receiver is functioning properly by measuring the voltages at the various socket terminals, the manufacturer of a set generally issues with the circuit diagram a table of voltage values that should be found within reasonable limits at these different terminals providing the entire circuit system is operating normally. If upon making a socket terminal analysis it is found that some of the voltages differ widely from those listed or that the voltage in some cases is missing entirely, it is evident that something is wrong with those branches of the circuit that are associated with these particular socket terminals, and the service man at once has a clue as to where to begin looking for the source of trouble.

Formerly these socket voltages were always given with respect to the point of zero potential at each socket, such as the cathode or the center tap on the filament. However, after the all-metal chassis came into common use, and the chassis itself began to be employed as the negative return, it was found more convenient to list these socket voltages with respect to ground or chassis. In those cases in which the cathode or filament center tap is grounded directly to the chassis the two listings are alike, but where the cathodes are above ground potential through the use of a biasing resistor, the values are different. Therefore, when such a voltage table is used for reference, it is always necessary to observe whether the voltages are given with respect to ground or otherwise.

When the voltages are given with respect to ground or chassis, one side of the meter is connected to the socket terminal in question and the other side to the chassis at any convenient point. With the aid of a pair of test prods attached to a pair of flexible wire leads that in turn are connected to the indicating meter. It is a simple matter to go from socket to socket and make these voltage tests.

The Zenith Chassis No. 5619 is built around a 6-tube superheterodyne circuit that employs the new all-metal tubes. As shown in the circuit diagram in Fig. 14, the first stage is a compositive 1st detector-oscillator with a type 6A8 tube, which is similar to the 6A7 in the glass models. This is followed by an intermediate frequency amplifier stage tuned to 252.5 kilocycles and employs a type 6K7 tube, the latter being similar to the familiar No. 78 tube. In the 2nd detector stage which also develops the automatic volume control potential, a type 6H6 tube is used. This tube is merely a double-diode rectifier and corresponds to the diode section of the type 75 tube in glass. In the 1st audio stage another type 6K7 tube is used, and in the output stage is a type 6F6

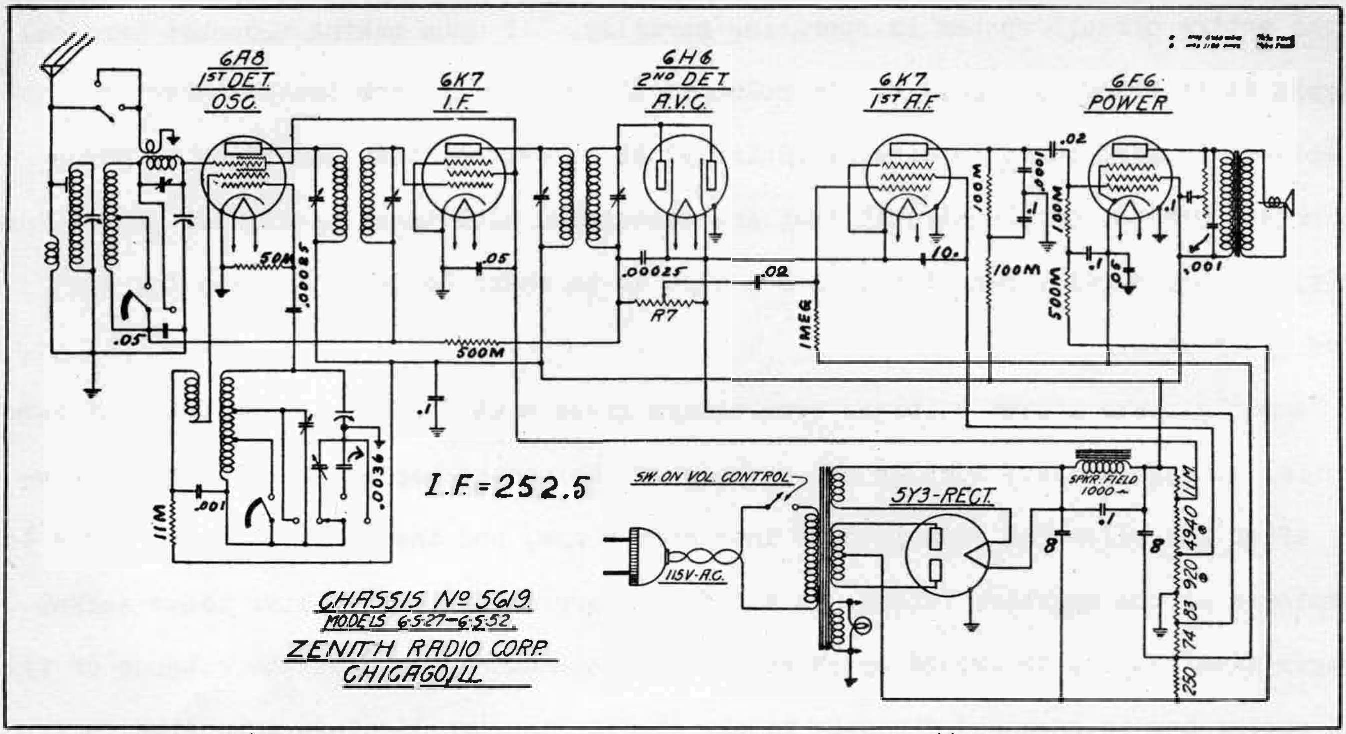

Fig. 14. Circuit diagram of Zenith Chassis No. 5619 as used in their receiver models 6-S-27 and 6-S-52.

power pentode that corresponds to the No. 42 in glass. A type 5Y3 rectifier is used in the power stage which is of standard design and arrangement.

In the accompanying table are given the socket terminal voltages supplied by the manufacturer. These voltage values will be found to exist at the various socket terminals if the receiver as specified is operated from a 110-volt A. C. line and the antenna and ground are disconnected. It is generally assumed that a 1,000-ohms-per-volt D. C. voltmeter is used for making these measurements, except the filament voltages that are measured with a low range A. C. voltmeter, and the high A. C. voltage that is applied to the plates of the rectifier tube. For the latter a high range (0 to 600 volts) A. C. voltmeter is needed.

SOCKET TERMINAL VOLTAGES

Zenith No. 5619 Chassis — Line Voltage - 110 Volts

Tube	Position	1	2	3	4	5	6	7	8
6A8	Det. Oscil.	0	5	225	70	-1.	180	0	0
6K7	I.F. Amp.	0	5	225	70	0.	—	0	0
6H6	2nd Det.	0	5	-1	-2.5	-1.	—	0	-2.5
6K7	1st Aud.	0	5	60	14	-2.5	—	0	-2.5
6F6	Power	0	5	220	225	-2.5	—	0	-2.5
5Y3	Rectifier	0	300	—	305	—	305	—	300

The first column gives the type number of the tube, and the second column the stage of the circuit in which the tube is used. In the next eight columns are given the voltages that should be found at each of the sockets, the numbers at the tops of the columns being the numbers of the socket terminals.

The easiest method of taking these socket voltages is with a pair of test leads that are connected at one end to the indicating meter and that at the other end have test prods mounted in insulating handles. The chassis is turned upside down, and one test prod is touched to the socket terminal at which the voltage is to be measured and the other prod to any convenient point on the chassis. Since in the plate and screen circuits quite high voltages are operative, a severe shock can be received if the work is carried on in a careless manner.

If any of the voltages vary widely from those given in the table or are absent entirely, it is evident that there must be something wrong in that branch or branches of the circuit system that supply these socket terminals. Knowing in what section of the circuit the trouble appears to lie, it is then an easy matter to analyze the circuit further and locate the source of the trouble that is upsetting normal voltage relations.

CARE AND MAINTENANCE OF ELECTRIC METERS

The electric meters used in radio testing equipment are sensitive pieces of apparatus; and to obtain accurate and reliable service from them for an extended period of time, they should receive proper care and attention and not be subjected to any needless abuses. If the following suggestions are observed, a long useful life can be expected from them, providing, of course, that they are built of materials that will not wear out readily.

The various faults or troubles that occur in electric meters and cause them to indicate incorrectly are generally due to some form of mistreatment that it might be anticipated would be harmful to them. Such abuses in the order of their importance are: overloading, mechanical jolts and jars, penetration of moisture into the movement or resistors, and admission of dirt, chips or fuzz into the movement.

Overloads of considerable magnitude are often imposed on electric meters in routine work, even with exercise of the greatest care. The effect of such overloads depends upon the nature of the meter, whether A. C. or D. C., or of the rectifier or thermocouple type. Also, whether it is a single or multiscale meter and which scale was in operation when the over-load occurred.

Excessive overloads will generally cause the meter to burn out completely, while smaller overloads may cause a partial breakdown of the armature on resistor and result in unstable and erratic action. Although well built meters are designed to withstand abnormal strains to some extent, heavy overloads will exceed this limit and cause serious displacement of the moving parts or twist them out of alignment. If the pointer is bent, this will throw it off balance; and even though it is reset to zero, the meter indications will be inaccurate until proper repairs are made.

In the case of alternating current meters the overload may be sufficient to change the position of the moving vane with respect to the pointer. This will change the meter characteristics and result in wrong readings. A heavy overload on a rectifier type of meter will affect the characteristics of the copper-oxide rectifier and seriously throw off the calibration of the meter. Only one serious mishap is sufficient to render a meter unfit for reliable service. Rectifier type meters should therefore be guarded very carefully against any appreciable overloads.

Heavy overloads have a tendancy to expand the moving coil due to the heat generated in it. This frequently results in dulling the pivot point. Also, if one bears in mind that the normal pressure on a pivot point may be as high as 400 lbs. per square inch, a severe expansion of the moving coil may completely ruin the pivot or bearing jewel or both. In view of the damaging effects that are likely to result from a heavy overload, it is advisable to have a meter checked if it does happen, for some of the above faults may occur and not be noticed from a casual inspection.

Jolts and jars may also seriously affect the proper performance of a meter by causing the pivot to scratch the bearing. The pointer may stick or be sluggish in action. The same condition is evidenced by the meter changing its reading if the case is tapped not too severely. It can also be identified by measuring a steady current a number of times. In a normal meter the readings will be the same each time, whereas with a sluggish movement the readings will vary.

A severe jolt or jar may crack the glass on the meter and permit dust and dirt to enter the movement. With the clearance in the air gap between the pole pieces and the outside turns of the moving coil often being only .01 inch, it is evident that only a few particles of foreign material can readily interfere with the free action of the meter. Carelessly setting a testing instrument on the floor or dropping it into a car is bad practice, for the jolt is likely to sufficiently impair the meter in its performance so as to render its indications completely worthless. When carrying a test set in a car, it should be placed on a cushioned seat and whenever possible with the meter face up.

Testing equipment containing delicate meters should never be kept in damp places, for moisture is readily absorbed that will harm the meter in at least two ways. It will cause corrosion of the polished metal surfaces, and leakage and probably complete breakdown in the resistors used on the higher range scales. Changes in resistor values will throw the readings off accordingly and practically render the tester useless.

Sometimes a meter case is opened and the movement removed to satisfy the owner's curiousity as to what the inside looks like. This is very bad practice, for generally the screwdriver or wrenches have been used for other purposes and have not been cleaned. The metallic dust that may cling to these tools is then drawn to the densest part of the field magnet which, of course, is in the air gap, and obstructions get in that will cause the meter action to be unreliable and erratic. Similarly, if thin chips of glass get into the air gap, they will retard or block the free movement of the meter.

In view of the various troubles described above that can beset an electric meter, it is not only necessary to give a meter proper care and attention while it is in use; but when purchasing a meter, thought should be given to the various features in its construction that will reduce to a minimum the possibility of any of these troubles setting in. For example, the case should be inspected carefully to see that it is fitted tight enough to be absolutely dust proof and as nearly moisture proof as possible. Also, the scale pointer should not be too close to the glass so that a slight mechanical displacement will not at once render the meter inoperative.

In regard to the internal construction and the quality of the materials used, the reputation and reliability of the manufacturer should receive first consideration. Probably the most important elements are the jewel bearings, these should be genuine natural rather than synthetic sapphires. And the polish on them should be of the highest degree. Evidence of roughness in the jewel is given when the meter is held in a vertical position, as on a switchboard, and the pointer action is a sluggish due to friction. While a new meter may swing properly and freely in both the horizontal and vertical positions, exposure to the atmosphere will gradually cause a thin film to form over the pivot or jewel or both and produce a sluggish action unless the jewel or pivot have had a high enough polish.

Permanency of calibration is a very important factor that must not be overlooked in considering the purchase of a meter. Such permanency depends primarily upon the magnetic structure within the meter, both the physical shape of the magnetic parts and the composition of the steel. The method of treating and aging the magnet during the manufacturing process is also significant, for it determines how the magnetic structure will retain its magnetism. These qualities of a meter of retaining its calibration accuracy can be determined only over a period of time, and it is the reputation and reliability of the meter manufacturer, therefore, that must be relied upon when the question of permanency of calibration is considered.

-END OF LESSON-

EXAMINATION QUESTIONS ON NEXT PAGE