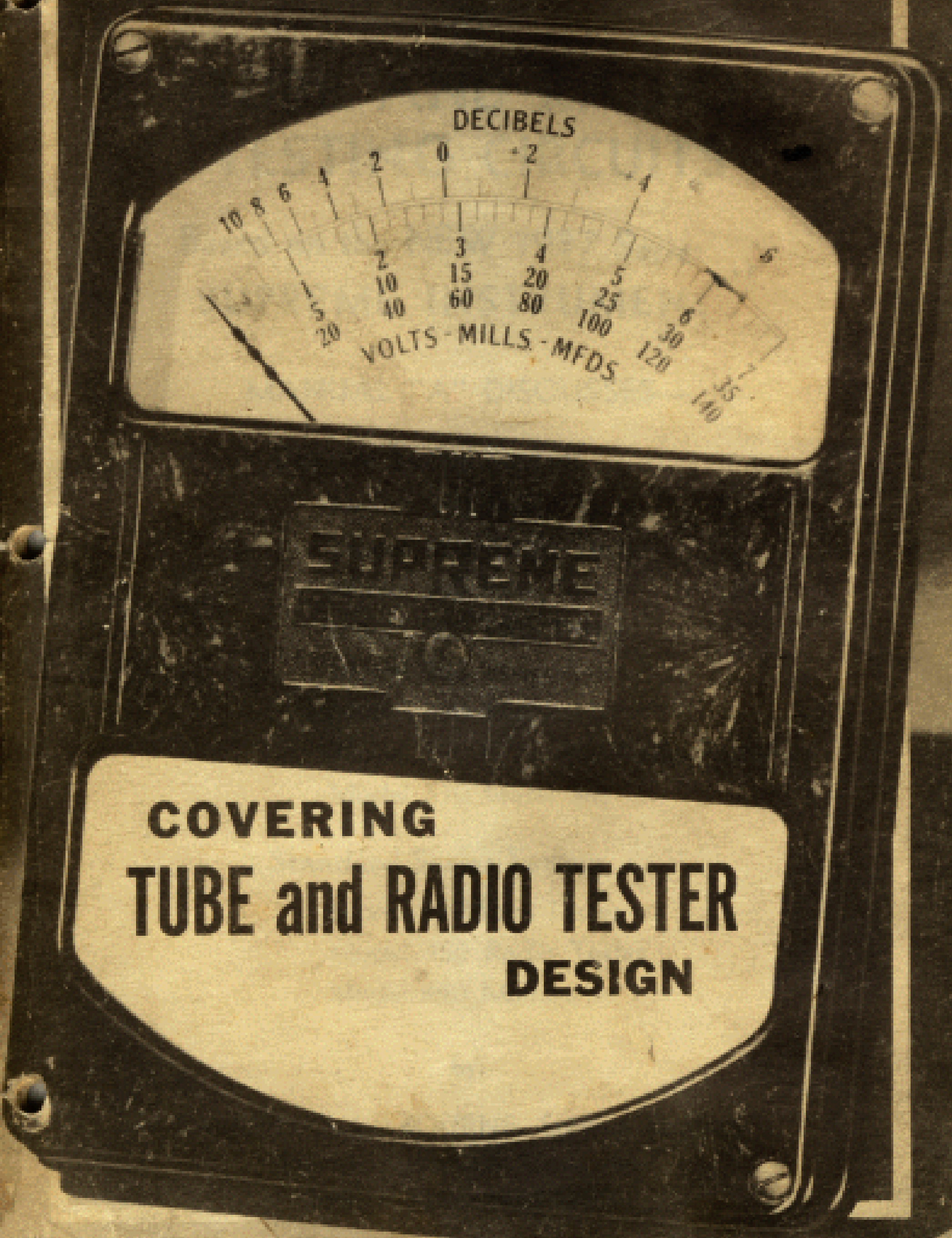
SUPREME

PRESENTS MANUAL "A"



COVERING
TUBE and RADIO TESTER
DESIGN

PRICE, FIFTEEN CENTS

Supreme Presents

A DESIGN MANUAL

OF

TUBE AND RADIO TESTING CIRCUITS

Based on the NEW 1937 Series of SUPREME INSTRUMENTS

MANUAL "A" DISCUSSES—

DeLuxe Series Testers

Model 540 Radio Tester
Model 550 Radio Tester
Model 505 Tube Tester
Model 500 Tube Tester
Model 585 Diagnometer
Model 590 Multimeter
Model 595 P. A. and Radio Tester
Model 510 Meter Kit

Standard Series Testers

Model 400 Tube Tester
Model 450 Radio Tester
Model 490 Multimeter

by

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Supreme Instruments Corporation
GREENWOOD, MISSISSIPPI

CHAPTER I. INTRODUCTION

1—THE MANUAL'S PURPOSE

The Supreme Instruments Corporation is fully cognizant of the growing interest displayed by servicemen, engineers, amateurs and experimenters in technical explanations of the internal and external functions, circuits and design procedure of tube and radio test instruments. We, therefore, offer this manual as probably the most complete discussion of these matters so far available to the technical fraternity.

You have a justifiable right to a full explanation by the manufacturer of all instruments which you anticipate purchasing. No effort has been spared to bring you a complete sales and technical description of modern tube and radio testers as exemplified by Supreme's new 1937 test instrument line. Any further information you may desire can be obtained by addressing SUPREME INSTRUMENTS CORPORATION, Greenwood, Mississippi—Attention, Service Department.

Certain test equipment is absolutely necessary to the proper functioning of a modern service shop and such equipment should include nine vital general attributes as follows:

(1) Freedom-from early obsolescence.
(2) Simplicity of design.
(3) Ease, flexibility and speed of operation.
(4) Compactness without undue crowding.
(5) Professional appearance (customer eye appeal).
(6) Ruggedness to withstand normal usage.
(7) Accuracy within acceptable tolerances.
(8) Lowest cost without sacrifice of quality.
(9) Test equipment manufactured by a reliable and forward looking concern.

Point for point throughout this discussion, Supreme instruments are proven to be the very embodiment of these requirements which has resulted in Supreme instruments becoming the serviceman's "No. 1" preference and their ready acclamation as "Supreme-by-Comparison".

2—A FEW FUNDAMENTALS

In radio service, or maintainance work, the technician is interested in several groups of measurements. The first group involves the fall of potential across any circuit, being measured in volts, or in smaller or larger graduates such as milli-volts or kilo-volts, the last being very rarely used in present day actual service work. The second group depend upon the rate of flow of current through any given circuit, being measured in amperes or its equivalent larger or smaller graduates, such as microamperes, milliamperes, etc. The product of the fall of potential across the circuit and its flow of current result in the amount of power dissipated by the circuit which is measured in watts, certain other factors being taken into consideration in A. C. measurements. Other electrical measurements such as capacity, decibels, tube quality, etc. have circuits peculiarly adapted to their use. Inasmuch as we have no method whereby we can, through human senses, measure these quantities, it is necessary to fall back on external physical bodies actuated by mechanical or electrical forces to do our measuring for us. Thus we have the electrical meter which responds to the effect of electricity upon a given circuit. A meter may be calibrated in standard units of voltage, current, power, etc.

The whole basis of electricity and its off spring radio is governed by a very simple formula, Ohm's Law, familiar in name to all, but actually committed to memory (or of any practical worth) to an all too small group.

Ohm's Law states that the product of the current in amperes flowing through a circuit and the resistance of that circuit in ohms is equal to its fall of potential measued in volts. In other words, if a circuit has 10 ohms resistance and a current of 5 amperes flows through the circuit, an electromotion force of 50 volts is present across the circuit. Conversely, and by substitution, a circuit having across it, a 50 volt potential and a resistance of 5 ohms, will allow a current flow of 10 amperes. It is suggested that pride be placed to one side, a pencil and paper dusted off, and a few problems in Ohm's law be worked out before proceeding with the balance of this discussion inasmuch as much of its value will be lost unless the reader is fully familiar with the following three simple Ohm's law equations.

$$E = IR$$

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

E = Volts (Potential) I = Amperes (Current) R = Ohms (Resistance)

There is no substitute for actually working out the problems as presented in this discussion inasmuch as the reader would have to be a mathematical wizard to be able to compute the results mentally.

CHAPTER II. THE METER

3—THE GALVANOMETER

Most measuring devices in service work at present employ the magnetic effect of the current in combination with a permanent magnet but we will only discuss the moving coil or D'Arsonval type of "magnetic effect" instrument without delving into the "moveable-iron" type used in A. C. measurements.

The basic phenomena upon which all magnetic devices operate is that a current of electrons flowing through a circuit set up a magneto motive force, or field around the circuit, such M. M. F. being proportional to the rate of the circuit's electron flow measured in amperes.

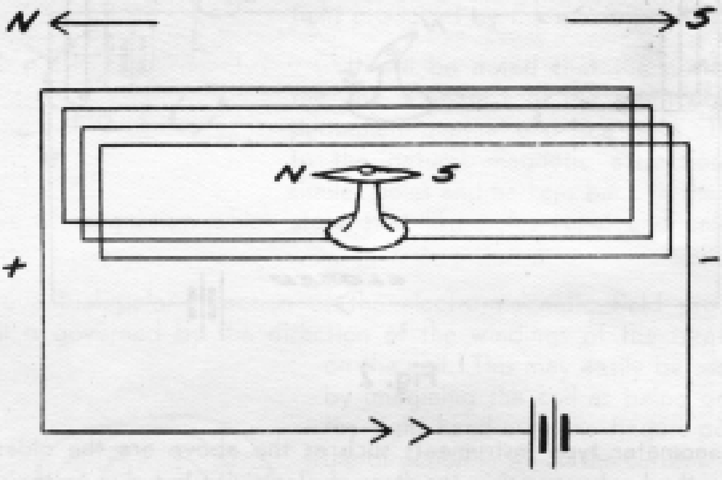


Fig. 1

This may be illustrated in Figures 1 and 2. A compass is placed within a coil of wire which is so located that the plane of its turns lie in a north and south direction. The coil of wire is connected in series with a source of D. C. supply and a switch which is thrown open in Figure 1. Inasmuch as there is no current flowing through the coil, the compass needle will take up a position parallel to the axis of the coil.

In Figure 2, we depress the switch and a current flows through the coil, causing a magneto motive force to be set up around the coil. With the coil plane pointing north and south, the magnetic lines passing through the coil will tend to swing the compass needle from its north-south position inasmuch as these lines of force are at right angles to the compass needle.

By varying the amount of current through the coil, thereby varying the strength of the magnetic field set up as a result of its flow, or alternately, by increasing or decreasing the number of turns in the coil, the needle may be caused to deflect a proportionate amount of degrees from a position parallel to the earth's magnetic field, up to a 90 degree declination. If an alternating current were passed through the coil, it would tend to set up a magnetic field in one direction and then when the polarity of the current flow was reversed, set up a magnetic field in the opposite direction; the two forces tending to buck each other and unless the compass needle were to have no weight and its pivots were to have no friction whatsoever, would result in the needle remaining stationary or vibrating slightly about its north-south position. Therefore, this type of measuring instrument cannot be used for alternating current measurements unless the alternating current is first rectified as explained later.

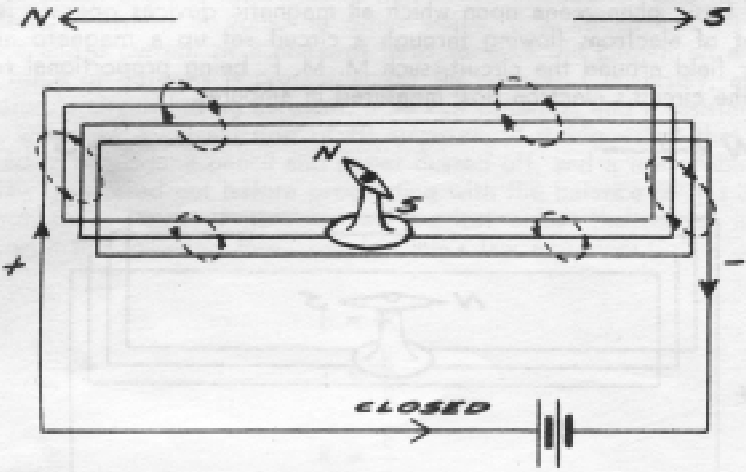


Fig. 2

Galvanometer type instruments such as the above are the oldest and simplest methods of measuring the flow of electricity but due to their many disadvantages resulted in the search for a more satisfactory commercial model. This form of galvanometer due to its construction must of necessity be used only in a level position and must also be placed so that the coil plane is in a north-south direction. Due to the long air path it is not sensitive enough for measurements of small currents and is easily effected by stray external magentic fields which might be set up locally. If no "damping" is employed, the needle will swing back and forth through the "at rest" position and will thereby be relatively slow in use. Due to its dependence upon the earth's terrestrial magnetism it is also effected by any change due to "sun spots" and magnetic storms. Its construction is rather bulky, and it is not very adaptable to portability.

4—THE D'ARSONVAL TYPE METER

As a result of D'Arsonval's experiment, we have what is known today as the D'Arsonval galvanometer. In this instrument, the earth's magnetic field is replaced by a permanent horseshoe magnet which is placed in a stationary position and the coil made moveable.

By referring to Figure 3, we see a small coil suspended between the poles of a permanent horseshoe magnet, the turns of the coil being in a parallel plane to the magnet's magnetic field. If the coil is connected in series with a source of D. C. supply, a current will flow through the coil, setting up lines of force around the coil which will be at right angles to the lines of force of the permanent magnet's poles. This will result in the coil revolving about its axis $(x\text{-}x_1)$ until the direction of the permanent magnet's field is parallel with that of the magnetic field produced by the moving coil. (Figure 4.)

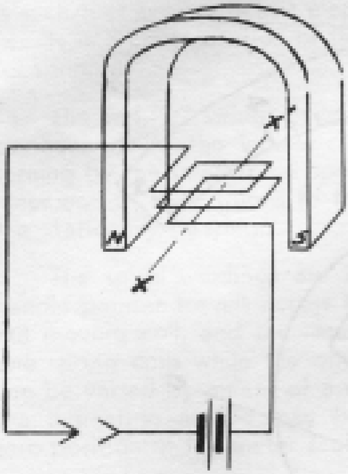


Fig. 3

It will be noted that the north pole of the coil is nearest to the south pole of the permanent magnet and vice versa. This is due to the natural magnetic attraction of dissimilar poles and harkens back to the elementary laws of magnetism which state that like poles repel and unlike poles attract.

The actual polar direction of the electro-magnetic field produced in the coil is governed by the direction of the windings of the turns of wire on the coil. This may easily be ascertained by imagining the coil as being grasped in the right hand with the fingers pointing in the direction in which the current flows into the coil, the thumb pointing always to the north pole of the electro-magnet. Remember, current flow is from positive to negative although electron flow is in the opposite direction. In this instance, current flow is used.

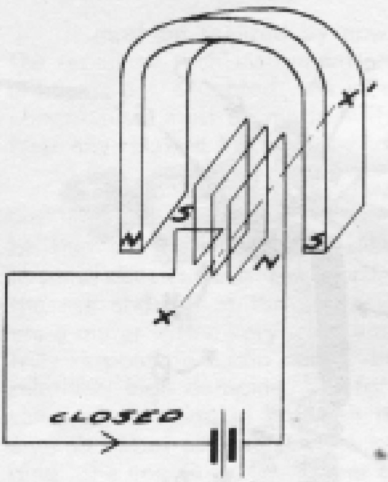


Fig. 4

It will readily be seen that the direction of rotation of the coil about its axis may be reversed by reversing the polarity of the applied direct current and, therefore, measuring devices of this type must be connected with respect to the polarity of the circuit under test.

As explained with the simple galvanometer, an alternating current passing through the coil would set up an alternating magnetic field around the coil resulting in a practical cancellation of any coil movement or at least a reduction to a condition of vibration of the needle pointer.

5—THE MODERN D'ARSONVAL METER

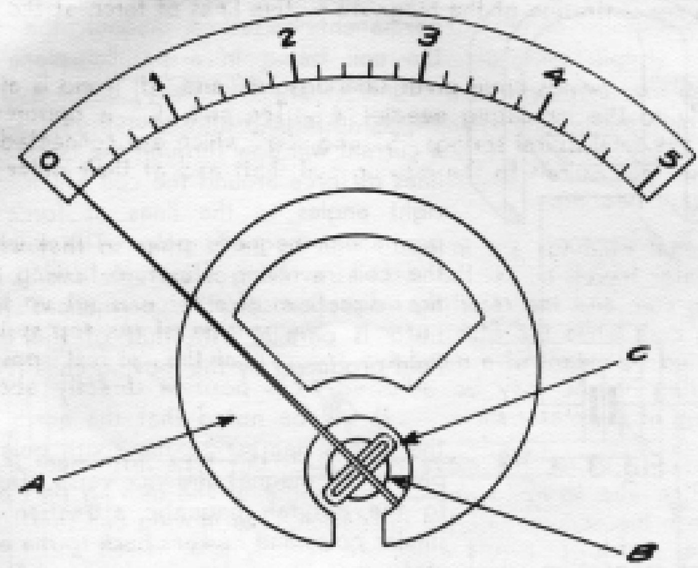


Fig. 5

Figure 5 shows a simplified drawing of one of the modern Supreme Fan Shaped D'Arsonval type meters, which is also pictured, without its permanent magnet, in Figure 6.

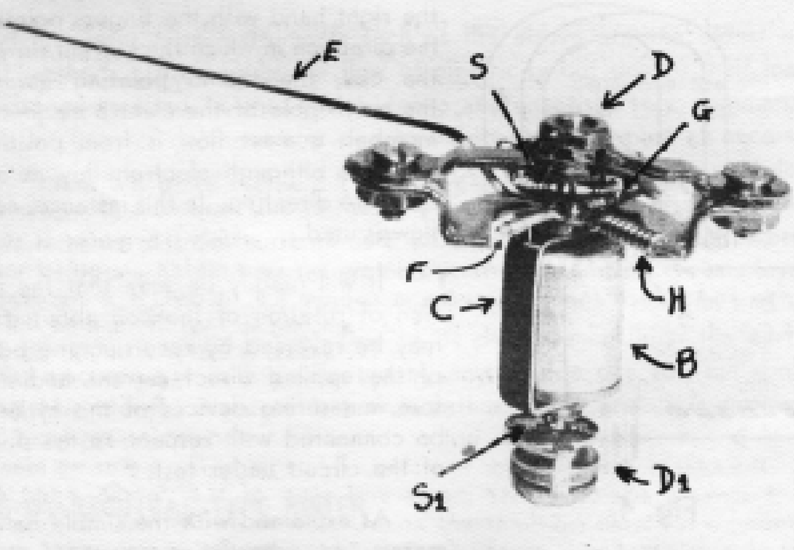


Fig. 6

The actual design of the permanent magnet "A" and the core "B" is such that only sufficient clearance is left in which to revolve the coil. This results in a concentration of the magneto-motive lines of force at the proper location.

The coil "c" swings upon pivot bearings "d" and "d_1" and is attached permanently to the indicating needle "e". The coil "C" is opposed from turning by the small spiral springs "S" and "S_1" which are connected at the inner end of their spirals to the moving coil shaft and at their outer end to the stationary bearing.

The spiral windings are in opposition to each other so that when the needle pointer travels across the scale as a result of current flowing through the moving coil, and the resulting magneto-motive force is set up thereby, one spring coils while the other uncoils. The tension of the top spring "S" can be varied by means of a moveable arm so that the "at rest" position of the indicating needle may be adjusted to a position directly above the zero position of the meter scale.

To reduce friction, the moveable coil of this type instrument is wound with very fine wire so as to reduce the weight of the moving part and not interfere with the accuracy of the indication. The moving coil shaft revolves in the upper and lower pivots which are actually small jewels and the whole mechanism is built as finely as a watch.

To counterbalance the indicating needle so that it will properly come to rest at the same position on the scale (zero) no matter at what angle the meter is resting, small pieces of wire are wound on the two ends of the cross piece and on the rear end of the indicating needle. These are shown in Figure 6 as F, G and H.

It must be realized by now that the construction, and when necessary, the repair of such instruments must be extremely precise if accurate measurements are expected. As in every other piece of mechanical equipment, compromises must be made in its design and construction which by no means bear any relation to, or reflection upon, its quality.

For instance, there has always been a question as to the exact "damping" necessary for various types of meters and the most logical answer would be that this should be governed by the use to which the meter is placed. In some circuits, such as recording systems, where a meter is used to indicate the rise and fall of the audio volume cut on the record, it is necessary to use a meter with a very small amount of damping so that the needle will more truly respond to audio peaks. In other instances, a meter must be used with relatively high damping, but for average service work there should be some value of damping in between maximum and minimum. This should be fast enough to not appear sluggish but contain sufficient damping to avoid "pegging" the needle against either end stop. By pegging the meter we mean the violent striking against either meter end stop of the needle when either indicating a full scale measurement or returning to its "at rest" position. The result of over pegging is usually damage to the needle or movement and can also be caused by applying too great a voltage across the meter terminals or stated in another way, allowing too much current to flow through the meter coil, but bending of the needle may easily result from too little damping.

Heavy damping of the instrument can be obtained by winding the moveable coil upon a thin non-magnetic metallic frame such as aluminum and in this case, at the instant the coil moves, eddy currents are induced in the frame in a direction such as to buck the coil's movement.

The air-gap in this type instrument must not only be extremely powerful but also radially uniform otherwise equal scale division will not result.

As explained previously, to keep the total weight of the moving body at a minimum, and its magneto-motive force with any given current at a maximum, it is usual to use extremely small wire and a greater number of "ampere turns" in winding such a coil. The actual ohmic resistance of the wire comprising the moving coil and its short leads to the meter terminals constitute its "meter internal resistance". This resistance will vary as much as 5% between individual meters of the same type and must be compensated by adding series resistance externally to a pre-determined value as explained later.

The amount of current required to flow through a coil so as to deflect the meter needle completely or "across to full scale" is called its "meter sensitivity" and is measured usually in milliamperes or microamperes. This may also be stated as so many ohms per volt; i. e., a 1-milliampere meter has a sensitivity of 1,000 ohms per volt as it requires, with a potential across the meter circuit of 1-volt, a total of 1,000 ohms internal and external meter resistance to produce a full scale deflection of 1-milliampere, therefore, an indication of a 1-volt potential. A 2-mil. meter would only require a total resistance of 500 ohms in the same circuit and would thereby be relatively less sensitive inasmuch as it would require twice the current for full scale deflection. The higher the "ohms-per-volt" rating of a meter, the higher the sensitivity thereof and in some service instruments a 200-microampere meter is used with a sensitivity of 5,000 ohms-per-volt.

Inasmuch as the construction of such a measuring instrument must be so precise, it is hardly possible to successfully build a meter in the service shop or home laboratory as its construction must of necessity still be a specialized commercial science just the same as that of fine watch making, otherwise, although results may be obtained, they will be far from the degree of accuracy necessary for laboratory or service work.

6—ACCURACY OF METER MEASUREMENT

The degree of accuracy of a measuring instrument is probably its most important characteristic and usually is in direct proportion to the cost of the unit. Meters may be purchased for from less than a dollar up to several hundred dollars and the variation in accuracy will be just about as great. For all ordinary service purposes, if a meter has an overall accuracy tolerance of 2% of full scale value, such a device will be wholly satisfactory for service work. Commercial radio sets are constructed with potential and current allowances of within an accuracy of 10% or more, so, if we allow 2% of full scale value for the meter we shall have an instrument which will prove eminently satisfactory for service use. Of course, where laboratory precision is not only desired but absolutely necessary, it is imperative that the purchaser buy a much more expensive type meter. The specified degree of accuracy should be maintained over a period of years which necessitates good quality material for the construction of the permanent magnet in the instrument.

Some types of laboratory instruments are equipped with a scale under which is placed a mirrored surface which is viewed either through a slot cut in the meter scale or the mirror is allowed to project above or below the actual meter scale. Due to the fact that the needle does not actually touch the surface of the meter scale, observational errors may be introduced through what is known as "paralex", or viewing the indication from a point at which the meter needle does not intersect an imaginary line drawn between the eye and the scale, such a line being at a 90 degree angle from the plane of the meter scale. Therefore, a good rule to follow in reading meter indications is to always place yourself directly in front of the meter (if it is in a vertical position) or directly over the meter if the meter is lying flat.

Due to the internal construction of magnetic type meters, the meters are actually most accurate between one-half to four-fifths scale deflection and the meter error increases as the further to the left the reading on the scale is taken. Because of the initial starting torque necessary, bearing resistance, and also due to the fact that in the "at rest" position the meter moving coil is almost out of the permanent magnet field, the error sometimes runs rather high on the first one-fifth of the scale. This is one of the reasons for instrument manufacturers designing their test equipment so that a multiplicity of ranges are available. Sufficient ranges should be provided so that no accurate measurements need be taken within this first one-fifth portion of the meter scale.

Another cause for meter inaccuracy is the condition wherein the meter needle is not exactly "zero adjusted". All commercial type meters are provided with an adjustment screw which, as explained previously, varies the tension on one of the springs, allowing the meter needle's "at rest" position to be varied over several scale divisions so that it may be exactly centered over the zero position on the meter scale. Always be careful that delicate test instruments are not subject to rough handling or over-loaded as such jars are likely to demagnetize the permanent magnet to a certain extent and result in incorrect readings. Any piece of mechanism with such precise moving parts and jewel bearings must be given a reasonable amount of careful handling, otherwise injury to the parts may result in incorrect or irregular readings.

There are many additional features which should be mentioned in connection with the commercial type meters as utilized by the Supreme Instruments Corporation in their 1937 line of instruments.

7—SUPREME INSTRUMENTS FAN SHAPED METER

Figure 7 illustrates the Supreme Fan Shaped meter used in the 1937 standard models (400 series).

This meter is designed for universal application in radio testing equipment where only one scale window is necessary. The scales are more than

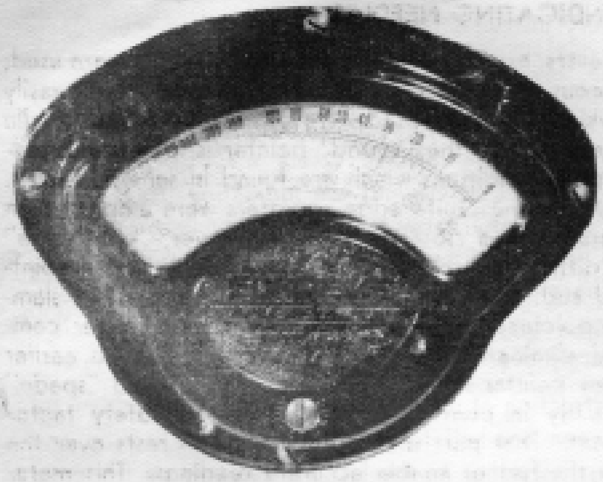


Fig. 7

26% longer than the usual round type meter scales, and are scientifically proportioned and divided for easy readability of the intermediate as well as the numbered deflection points, so that fractional values can be read as quickly and as easily as even values. The current measuring and potential measuring ranges are evenly divided to correspond with the linear characteristics of the D'Arsonval movement. This is true for both D. C. and A. C. voltage measurements. The actual meter movement may be a 10-mil., 1-mil., or less value depending upon the circuit and use to which the meter and associated parts are to be placed. The scale, of course, would depend upon these conditions also and we might point out that a 1-mil. movement meter used for analysis purposes and a 1-mil. movement used as a tube test meter are exactly the same in internal construction only differing in their indicating scales. We will see later how one meter can be used for both functions. In the case of the meter illustrated in Figure 7, the scales are designed for current measuring ranges of 0-5 and 0-125 milliamperes; for A. C. and D. C. potential measuring ranges of 0-5, 0-125, 0-500 and 0-1250 volts; for ohmmeter ranges of 0-2,000 and 0-200,000 ohms with a 4.5-volt battery. If desired, an external 45-volt D. C. source may be used in connection with the meter for a higher range of 0-2 megohms, or a 450 D. C. potential used with the meter for a higher range of 0-20 megohms. This, of course, depends upon the circuit used and full information on these circuits will also be given.

The upper arc of the meter is used for an ohmmeter scale and, although ohmmeter ranges are not linear in characteristic, this scale is divided so that easier readability is provided than with the usual ohmmeter scale. Large figures are used for the ohmmeter range as well as for all other ranges of the meter, once more assuring an easy readability unusual for meters in radio testing equipment. This feature is especially appreciated by those professional radiomen who have occasion to use their testers in customers' homes in which radios are not always located where lighting conditions are good. The large figures along the scale of this meter are also helpful to those radiomen who sometimes want to place their testers on the back of their work benches, out of the way, and still be able to read the meter deflection.

With a meter of this type, accuracy tolerance is placed at a maximum of 2%, based on full scale values, so that the maximum possible calibration error cannot exceed more than one division on any range of the meter for any measurement. Its handsome bakelite case and 26% longer scale combine beauty, ruggedness and accuracy in a unit which is built for wear and tear but constructed as finely as a Swiss watch.

8—DESIGN OF METER INDICATING NEEDLES

For earlier types of meters, heavy "spade" pointers or needles were used; and these were advantageous in that they were heavy and were not easily bent when the meters in which they were used were overloaded or the needle was "slammed" or "pegged". Also, the "spade" pointer is more easily followed under the poor lighting conditions which are found in some locations. In later meter types, the use of the "knife edge" pointers were employed on the basis that such pointers enabled closer reading. However, "knife edge" needle pointers are more difficult to follow in bad light than "spade" pointers. They are less rugged and, therefore, are more easily bent when "slammed" or "pegged". The pointer on the Fan Shaped Supreme meter combines the advantages and eliminates the disadvantages of the two earlier types of pointers. The new pointer has a heavy body like the old "spade" pointer. This assures visibility in poor light and provides a safety factor against its being easily bent. That part of the pointer which rests over the scales is flat in "knife edge" style to enable accurate readings. This meter style is gradually being adopted by several meter manufacturers, because of the obvious advantages over old style pointers, and is only another advantage in designing a meter for specific radio tester requirements.

9—METERS AS USED IN TEST INSTRUMENTS

Those servicemen who have used test instruments for a number of years will recognize the swing toward instruments which employ one, or at the outside two, meters for making all functional measuremeats. During radio's "babyhood" a test instrument was not complete without a multiplicity of meters, each one being used for but one function. However, with the advent of the multi-gang switch and also the method of testing which uses pin plugs and jacks, (sometimes nicknamed "shoe strings") but better known as the "Supreme Free Reference Point System of Analysis", test instrument design boiled down to some system of switching one or, at the most, two meters to perform all types of measurements including voltage, current, resistance and capacity measuring functions. Inasmuch as these measuring devices are all basically current measurers, it is only necessary to add sufficient resistance in series with or across the meter, and in the case of resistance and capacity measurements supply the circuit with proper potentials, to perform all the necessary functions with but one meter.

10—THE NEW SUPREME QUADRIMETER

In keeping with Supreme's pledge to the serviceman to always incorporate the newest and best of laboratory tested parts and circuits in their new models as introduced, Supreme takes great pleasure in offering the new and exclusive Supreme Quadrimeter with its Bi-Indicating Sword pointed needle and Dual Viewing Windows. In Supreme models for which an A. C. supply is necessary, these dual upper and lower viewing windows are indirectly illuminated by means of small light bulbs.

Figure 8 pictures the new quadrimeter which has an overall size of 5-1/4" x 7-1/4" with full 3-3/4" long, evenly spaced, and clearly marked scales. The double ended indicator is centrally balanced, being powered by

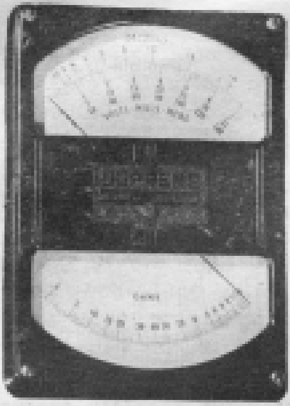


Fig. 8

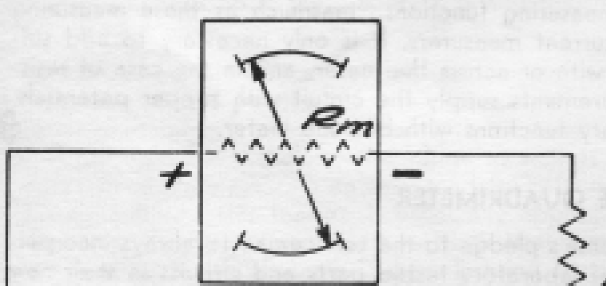
a high torque meter movement which is heavily damped and utilizes a large hi-permeability magnet with welded pole tips. The quadrimeter is available in two movements. Most of the Supreme 1937 instruments use the 1-mil. movement, while the circuit requirements of several other models necessitate a 200-microampere movement.

As can readily be appreciated, the dual viewing windows allow the combining of a number of ranges and functions on double scales so that only one or two meters need now be used for all tube and radio testing circuits. On instruments whose former models used but one meter, the double scaled quadrimeter used on this year's models allows still greater readable meter window space, resulting in clearer and larger indicating points and a higher degree of reading accuracy. The front cover of the meter is of beautifully moulded bakelite and is easily removeable for replacement of viewing window illuminating bulbs.

There is no doubt that this new Supreme Quadrimeter will become even more popular than the Supreme Fan Shaped meter with technicians who desire the very latest and best in test instruments.

11—EXTERNAL METER SERIES RESISTOR

We have previously explained that the internal resistance of this type meter varies over a considerable range, even between individual units, and for simplification in quantity production of test instruments, it is advisable to use a resistor connected externally in series with the meter, the combination resistance of the external resistor and the internal armature resistance of the meter to total some pre-determined round figure. This may be illustrated in Figure 9 in which the average internal resistance (R_m) of a 1-mil. Supreme Fan Shaped meter is approximately 115 ohms, and the combination of this resistance and an external resistor of approximately 185 ohms (R_s) would give a 300 ohm total meter resistance of R_t. By accurately winding and calibrating the series external resistor to each individual meter, a standard total R_t value may be used to calculate the various



$$R_m + R_S = R_T$$

Fig. 9

circuits which are to be connected to the meter for different measuring functions. The Supreme Quadrimeter in the 1-mil. type has an internal resistance of approximately 80 to 100 ohms. An "R_s" value of approximately 210 ohms is used with this meter movement to allow a constant "R_t" of 300 ohms, regardless of individual internal armature resistance variations. The Supreme Quadrimeter in the 200 microampere type has an average "R_m" of 1450 ohms, an average "R_s" of 200 ohms and, therefore, a constant "R_t" of 1650 ohms. It will be noted that the 200 microampere movement has a considerably larger internal armature resistance due to the greater number of armature turns and the finer wire used. 200 microampere movements could be developed with lower armature resistance, but they would have a lower torque unless extremely expensive magnet material were used to supply the lacking lines of force. The resulting meter would be no better for the circuits involved and, therefore, would add to the price of the meter unnecessarily. The lowest permissible torque level would be .095 to .1 M.M.G. The 1-mil. Quadrimeter has a .33 M.M.G. torque and the 200 microampere meter a .260 M.M.G. torque. The accuracy of the meter is plus or minus 2% of full scale angular deflection.

CHAPTER III. SET TESTER CIRCUITS

12—DESIGN OF D. C. VOLTAGE CIRCUITS

As shown in the foregoing, whether the meter movement is used to measure fall of potential (voltage) or current, the movement actually is always measuring current. When used as a voltmeter, it is connected in series with an external high value resistance of a pre-computed value and when used as an ammeter or milliammeter it is connected in parallel with a pre-computed relatively low value resistor.

When a meter has a full scale value of 1.0 milliampere, the required series resistance necessary to make the meter read a 1-volt potential at full scale deflection is 1,000 ohms. This is the "ohms-per-volt" designation as given previously and is always equal to the total resistance of the internal meter armature resistance and the external series resistor, or R_t, divided by the required maximum voltage for full scale deflection. Stated as a formula:

$$R_{pv} = \frac{R_t}{E_t}$$

As the resistance per volt value of the meter is equal to the total external and internal meter circuit resistance divided by the maximum voltage for full scale deflection value, to compute the total external and internal resistance value for any voltage range, it is only necessary to multiply the "ohms-per-volt" value of the meter times the maximum voltage for full scale deflection required.

This formula is as follows: $R_t = R_{pv} \cdot E_t$

In other words, as a 1-mil. meter has an "ohms-per-volt" value of 1,000 if a total deflection scale value of 7 volts is required, it is only necessary to multiply 1,000 times 7 equalling 7,000 or the necessary number of ohms internal and external resistance for a 1-mil. meter to be used as a 7-volt full scale voltmeter. As the internal armature resistance of the meter is approximately 90 ohms and, therefore, the external resistor necessary to bring it up to a common 300 ohm value is approximately 210 ohms, the additional resistance necessary to be used in the 7-volt voltmeter circuit would be 6700 ohms.

A typical multirange voltmeter circuit (as used in most of this year's radio testers) utilizing a 1-milliampere meter is illustrated in Figure 10. As can be

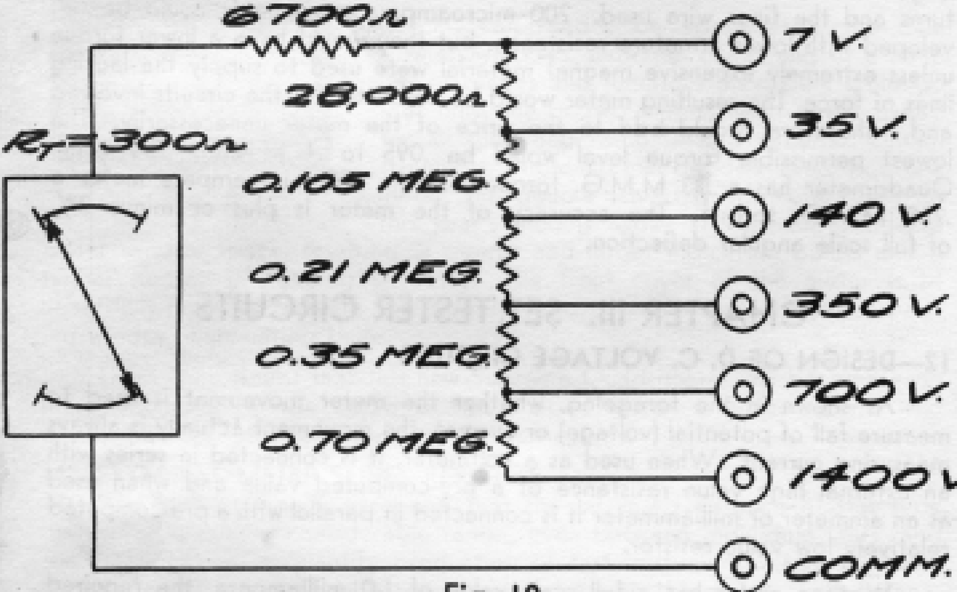


Fig. 10

seen by the diagram, the 35-volt range, inasmuch as the meter has an "ohms-per-volt" value of 1,000 would require a total of 35,000 ohms, this being made up of the internal resistance of the meter (90 ohms approximately), the external compensating resistor (210 ohms approximately), the 6700 ohm resistor for the 7-volt range and the 28,000 ohm additional resistor to make up a total resistance of 35,000 ohms. The 140-volt range would require 140,000 ohms and, inasmuch as we already have a total series resistance of 35,000 ohms it is only necessary to add a 0.105 megohm resistor to make up the correct value. The balance of the ranges are calibrated in exactly the same manner.

In the Model 590 Multimeter and Model 595 P. A. and Radio Analyzer, a meter having a 200 microampere movement is used which, according to the above formula has an "ohms-per-volt" value of 5,000. In Figure 11, we see the Model 590 voltmeter circuit. The total internal resistance of the meter plus an external calibration resistor in this case is equal to 1650 ohms, and as the first range of 5 volts necessitates a 5 x 5,000 ohm resistor (25,000 ohms) the actual resistor is 23,350 ohms which, together with the internal and external meter resistance result in the correct value. The 25 volt range requires a total resistance value of 125,000 ohms and, therefore, a 0-1 megohm resistor is added to the previous 25,000 ohms. The balance of the other ranges are computed in the same manner.

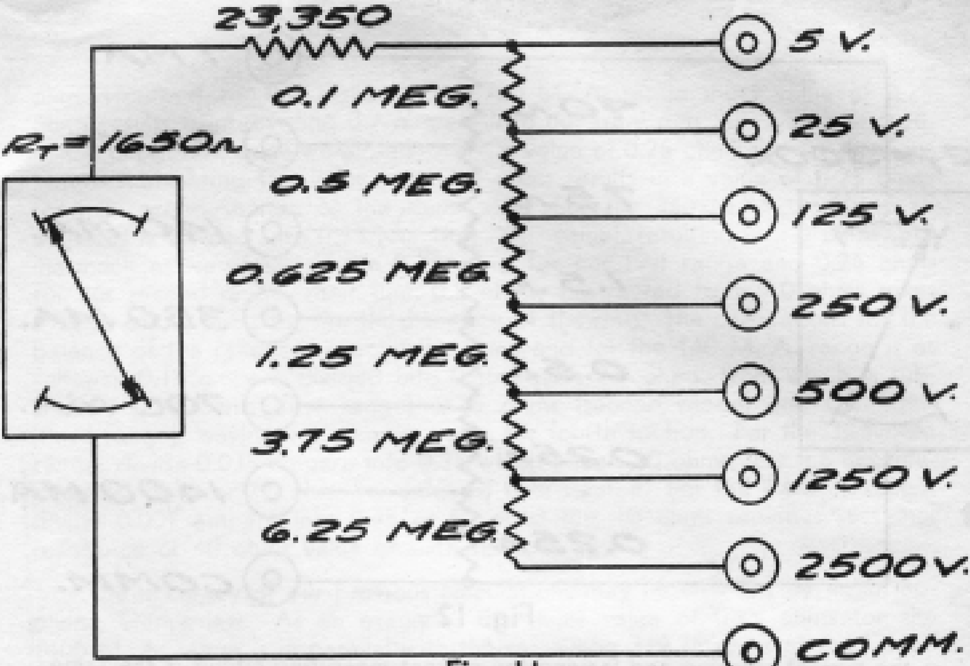


Fig. 11

13—DESIGN OF DIRECT CURRENT MEASURING RANGES

When using a meter to actually measure the current passing through any circuit, it must be borne in mind that the total current passing through the circuit to be measured must also pass through the meter or be bypassed around the meter through the use of a "shunt" resistor. This is analogous to a one-way highway which is just broad enough for seven cars abreast. If the road now must pass over a river, and it is still to carry the same seven cars abreast, it is possible to either build one bridge wide enough for the seven cars or one bridge one car in width, and another bridge six cars in width. If a circuit to be measured is carrying a current of 7 milliamperes, we may use a 7 milliampere meter or a 1-milliampere meter and a shunt resistor which will bypass the balance of the 6 milliamperes of current. In radio servicing work, it is not possible to standardize on any one meter movement which will take the total current to be measured, and also give an indication of the smallest amount of current to be measured, without using some combination of shunt resistors.

In the 1-milliampere meter circuit designed for current measurements and used with most of the 1937 Supreme line, the total shunt resistor has a value of 50 ohms and is tapped for lower shunt resistor values according to the various higher current ranges desired, as shown in Figure 12. In this case, if a total current of 7 milliamperes must pass through the meter circuit and only 1-milliampere maximum may flow through the meter, a resistor which is exactly one-sixth the total external and internal meter resistance must be used to bypass or "shunt" the other 6 milliamperes of current. As the total meter resistance is 300 ohms, 1/6 of 300 ohms would be 50 ohms.

Another method of determining the total shunt resistance is through the use of Kirschoff's law which states that the sum of the currents in any circuit is equal to the total current passing into and out of that circuit. Inasmuch

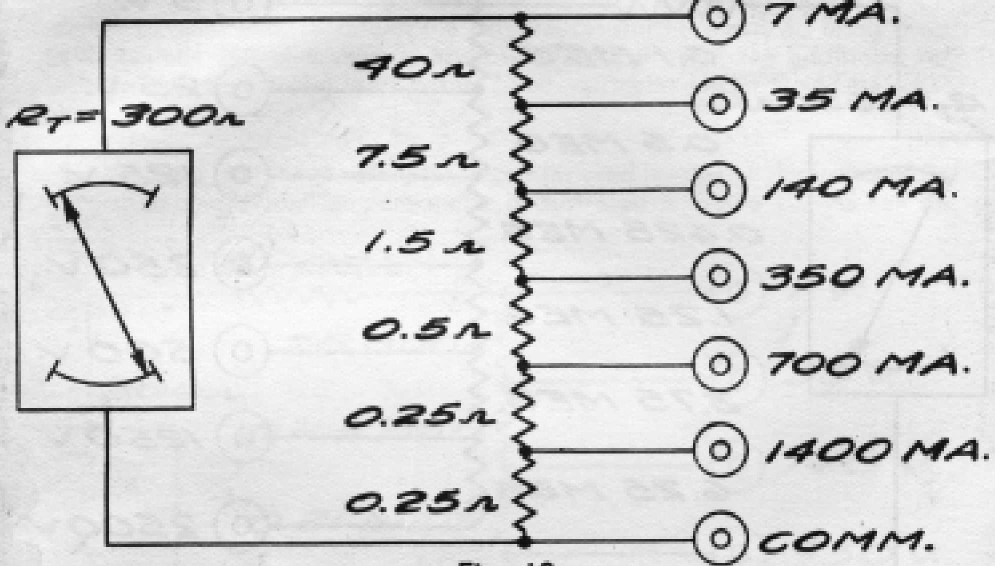


Fig. 12

as the current entering and leaving the current measuring circuit is the same, any resistor or resistance value placed across these two points will have the same potential placed across it as is across the current measuring circuit. The meter, with its resistance built up to a value of 300 ohms, requires a potential of 0.3 volt (300 millivolts) to cause a full scale current of 1.0 milliampere to pass through the meter. This is determined by applying Ohm's law which states that the voltage across a circuit is equal to its resistance times the current flowing through the circuit ($E = IR$). As a current of .001 ampere is necessary to cause a full scale deflection of the meter, and the total internal and external meter resistance is 300 ohms, the product of this would be 0.3 volt or 300 millivolts.

Inasmuch as the same potential would be applied across any shunt resistor connected in parallel across the meter, and as the current necessary to be bypassed is .006 amperes, the necessary resistance can be computed once more using Ohm's law, by dividing the current (.006 amperes) into the voltage impressed across the circuit or 0.3 volts, the product of this being 50 ohms. The formula in this case being: $R = \frac{E}{I}$.

For the current measuring ranges above the 7.0 milliampere range, the 50 ohms shunt resistor is tapped at several smaller resistor values, thereby forming what is known as a "ring type" shunt, the total "ring" resistance value being 350 ohms. The sectional resistance values of the 50 ohm shunt resistor are calculated by multiplying the total "ring" resistance (350 ohms) by the full scale current of the meter (.001 ampere), dividing the result by each range value, in turn, from the common terminal, and substracting the sum of the preceding values from each newly determined value. So, by multiplying 350 ohms (the "ring" resistance) by .001 ampere (the full scale meter current) we have a value of 0.35 into which each range value is divided, in turn, for determining the required shunt values. Taking the shunt value for the highest range (1400 M. A.) as our first problem, we divide 1.4 amperes into 0.35 (our total ring "IR" value) and find that a value of 0.25

ohm is correct for this resistor. The 700 M. A. range shunt value of 0.25 ohms results from dividing 0.7 ampere into our total ring "IR" value of 0.35, or 0.5 ohms, but, since we already have a value of 0.25 ohms for our previous range, subtracting this value from 0.5 ohms results in a value of 0.25 ohms for the second section of the shunt also. For the 350 M. A. range, 0.35 amperes is divided into 0.35 (our ring "IR" value), resulting in 1.0 ohms, but inasmuch as we already have 0.25 ohms for our first range and 0.25 ohms for our second range, their sum, 0.5 ohms, subtracted from 1.0 ohms gives a value of 0.5 ohms for the third section of the ring. The calculations for the balance of the ranges is exactly the same and for the 140 M. A. range is as follows: 0.14 ampere divided into 0.35 equals 2.5 ohms, from which is subtracted 0.25 ohms (first range), 0.25 ohms (second range) and 0.5 ohms (third range), leaving 1.5 ohms as value for fourth section. For the 35 M. A. range, divide 0.035 ampere into 0.35 which equals 10 ohms, less the accumulated 2.5 ohms or 7.5 ohms for value of fifth section. For the 7 M. A. range, divide 0.007 ampere into 0.35 or 50 ohms less 10 ohms previous sectional resistance or 40 ohms value of sixth section.

The accuracy of our previous calculations may be checked by again applying Ohm's law. As an example, the shunt value of 0.25 ohms for the 1400 M. A. range is in parallel with the remaining 349.75 ohms of the "ring" circuit which, when multiplied by the meter current of 0.001 ampere, produces a potential drop of 0.34975 volts. With 0.001 ampere going through the meter, the remaining 1.399 amperes will go through the 0.25 ohm shunt, producing a potential drop of 0.34975 volts. Since the potential drop across both parallel paths is identical by Ohm's law, it is concluded that the calculations are correct. The other ranges may be "checked" by the application of Ohm's law in a similar manner.

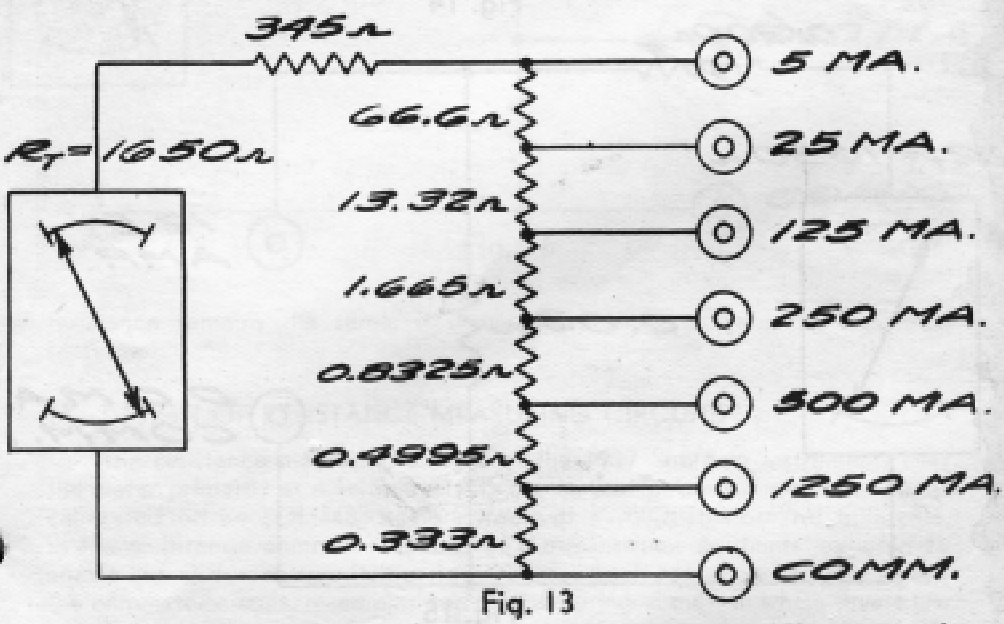


Fig. 13

In Figure 13, we see the same general circuit, but a different set of values as computed for the Model 590 Multimeter and Model 595 P. A. Tester. These two models use a 200 microampere meter and the value for the full scale current through the meter should be .0002 ampere with a total internal and external meter resistance of 1650 ohms. The balance of the values can be worked out as previously described and could be used by the reader as a problem to solve so that he might assure himself of a complete understanding of "ring" circuit design. The correct values for the various sections are shown in Figure 13. In the Models 490 and 495 there is also included a 250 microampere range, and on the Model 495 a 12.5 ampere range. The circuit and values for these two ranges are shown in

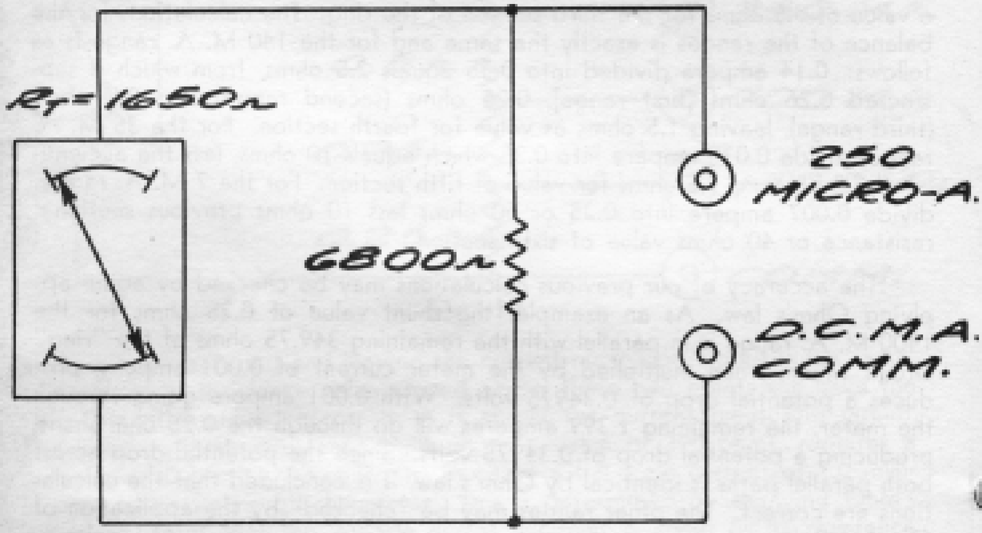


Fig. 14

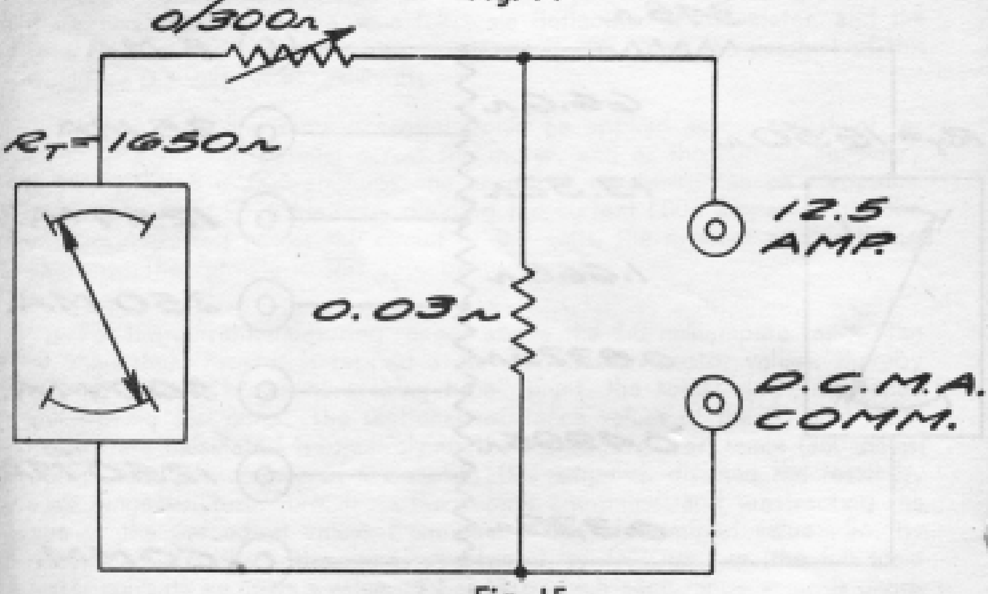


Fig. 15

Figures 14 and 15 respectively and were computed by using the same formulas as above.

It might be added that, when handling current above about an ampere or two, large binding posts and heavy bus wire should be used whenever necessary so that no appreciable resistance is added to the external circuit. All connections should be made before introducing the current through the measuring circuits so that there is no arcing at the connecting terminals, as, with high current values, heavy pitting of the terminals will result from making and breaking connections "hot".

Care should be taken when measuring current values with the 250 microampere meter range, as any meter when used on its most sensitive (lowest) range is more vulnerable to unintentional overloads than when being used on the higher ranges.

The Supreme Model 510 Meter Kit and the Supreme Model 540 Radio Tester utilize somewhat less extended current measuring ranges. This circuit is shown in Figure 16 and the reader will note that, although the total "ring"

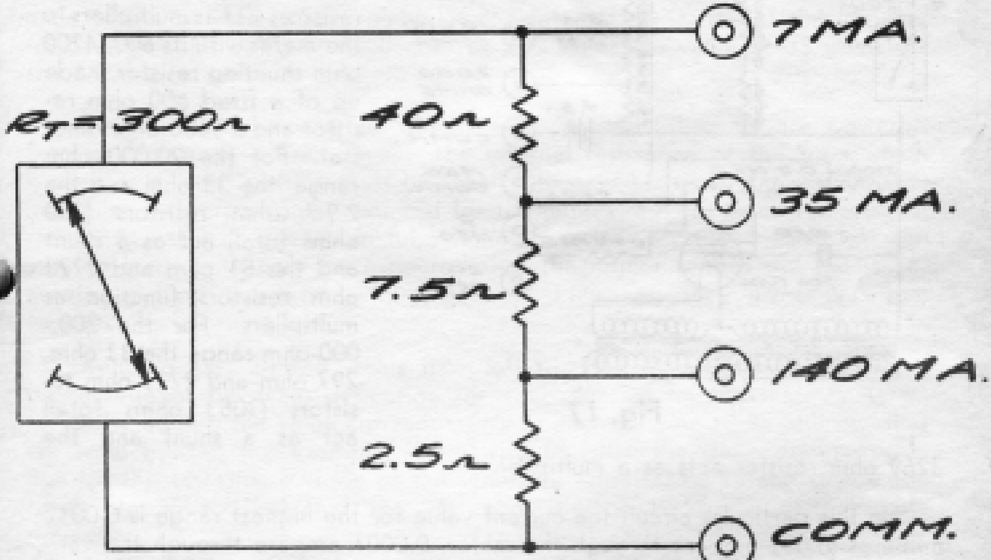


Fig. 16

resistance remains the same, it is necessary to recalculate the individual sections.

14—DESIGN OF RESISTANCE MEASURING CIRCUITS

The resistance measuring circuits of the 1937 Supreme Instruments uses the meter primarily as a voltmeter with the current passing through the meter calibrated on an "OHMS" scale instead of a "VOLTS" or "MILS." scale. In the multirange ohmmeter circuits of these instruments shunts are used to enable the different sensitivities required for each range and to this extent the ohmmeter circuit, resembles current-measuring circuits in which shunts are usually required.

In the design of ohmmeter functions, it is necessary to take into consideration (1) the current required by the meter for full scale deflection, (2) that a small amount of current must be allowed for passage through a variable "Zero Adjustment" rheostat to compensate for the natural depreciation of a new battery, (3) that another small amount of current must be allowed for passage through the fixed shunt for the highest resistance measuring range, (4) that these three current values, when added together, constitute the load for the highest resistance measuring range possible with the available battery potential, and (5) that the current loads for the lower ranges must be deci-multiples of the current load for the highest range in order that all ranges fall on the same "OHMS" scale.

Consider the circuit shown in Figure 17. This is a circuit diagram of the ohmmeter used in the Supreme Model 585. A close analysis of the circuit will show that for the lowest, or 2,000-ohm range, the 33 ohm resistor is a shunt resistor while the 297 ohm and the 2723 ohm resistors act as multipliers to the meter with its 600/4200 ohm shunting resistor made up of a fixed 600 ohm resistor and a 3600 ohm rheostat. For the 20,000 ohm range, the 33 ohm and the 297 ohm resistors (330 ohms total) act as a shunt and the 51 ohm and 2723 ohm resistors function as multipliers. For the 200,000-ohm range the 33 ohm, 297 ohm and 2723 ohm resistors (3053 ohms total) act as a shunt and the 3269 ohm resistor acts as a multiplier.

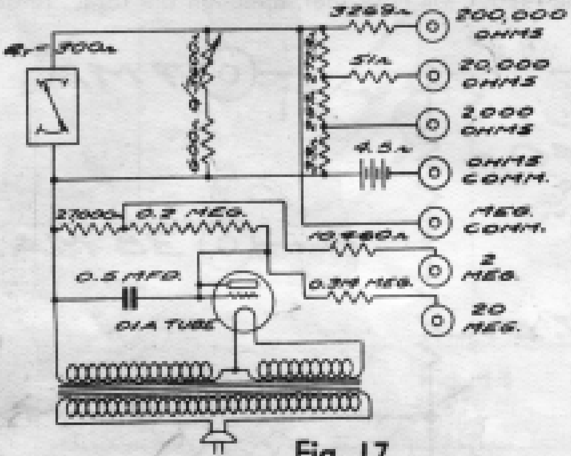


Fig. 17

In this particular circuit the current value for the highest range is 0.0012 amperes (0.001 ampere through the meter, 0.0001 ampere through the variable "zero adjustment" shunt, and 0.0001 ampere through the fixed shunt made up of the 33,297,2723 ohm resistors). For the next range the current is 0.012 ampere total and for the lowest range the current is 0.120 amperes. The current for the lowest range is about the load limit for a small 4.5 volt battery to carry and still give economical service.

Using the values indicated in Figure 17, and assuming an average battery potential of 4.25 volts (halfway between a new battery value of 4.5 volts and a discard value of 4.0 volts) we can determine, by different applications of Ohm's law, that the variable shunt rheostat should be set at a position so that the total of the used portion and the fixed 600 ohm resistor total 1400 ohms when the rheostat is adjusted to "Zero Ohms" with the lowest range terminals short circuited. On the basis of the circuit conditions then prevailing, it may be of interest to the reader to analyze the elements involved to show that the effective internal resistance of the network is 35 ohms for the lowest range and deci-multiples of 35 ohms for the higher ranges. The joint resistance of the 1400 ohms resistance in parallel with the meter resistance value of 300 ohms is 247 ohms. This value added to 2724 ohms and 297 ohms gives a total value of 3267 ohms. This value of 3267 ohms may be considered in parallel with the 33 ohm shunt for the lowest range. The joint resistance of 3267 ohms in parallel with 33 ohms is 32.67 ohms. This value of 32.67 ohms when added to the internal battery resistance of 2.33 ohms gives a total effective internal resistance value of 35 ohms for the 2,000 ohm range. For the 20,000 ohm range, the joint resistance value of the meter and its shunt, 247 ohms, is added to 2723 ohms giving a value of 2970 ohms which is in parallel with a value of 330 ohms made up of the two sections of 33 and 297 ohms. The joint resistance of 2790 and 330 ohms, is 297 ohms which when added to the 51 ohm resistor and the battery resistance give a total effective joint resistance value of 350 ohms for the 20,000 ohm range. This value of 350 ohms is 10 times the effective joint resistance for the 2,000 ohm range. For the 200,000 ohm range, the joint meter and shunt value of 247 ohms is in parallel with 3053 ohms, made up of the 33 ohm, 297 ohm and 2723 ohm sections. The joint resistance of 247 and 3053 ohms is 229 ohms. The total of 229, 3269 and the internal resistance of the battery is 3500 ohms for the internal resistance of the 200,000 ohm range. This value of 3500 ohms is 100 times the value of 35 ohms for the 2,000 ohm range.

The resistance measuring ranges beyond 200,000 ohms are powered from a miniature "power pack". The internal resistance of the tube which is used as a rectifier tube must be taken into account when determining the multiplier resistance values required for the higher ranges. Since the internal resistance value of a vacuum tube is not a constant value, but varies with varying loads, it cannot be expected that the higher ranges will be as accurate as those powered with a battery. However, they are well within tolerance.

Reading the "OHMS" scale from left to right, the pointer deflection in percentage of full scale deflection for each division on the scale is determined by adding the value corresponding to each division to 35 and dividing the total by 35. For example, if we wish to know the deflection percentage for the 100 ohm division of the scale, we add 100 to 35 and divide the total into 35 to find that the 100 ohm division is 25.9% of full scale deflection.

Figures 18 and 19 show the ohmmeter circuits for other models which have been designed in a similar manner.

For low ohmmeter ranges such as used on the 0-200 ohm range on the Models 585 the shunt type of ohmmeter is used. This type measures the change in current caused by placing an unknown resistor across the "Low Ohm" terminals. These changes of current are calibrated on an "OHMS" scale directly in ohms. The normally open switch shown is incorporated to protect the battery. Due to the high current required by this circuit, the battery would soon reach its discard value unless some means were provided to leave the battery disconnected until the ohmmeter is actually in use. This circuit is shown in Figure 20.

15—A FEW A. C. FUNDAMENTALS

While in D. C. potential or current measurements polarity must be observed, when making A. C. measurements we have no such condition, due to the fact that the current and voltage are always in a state of "flux" or change.

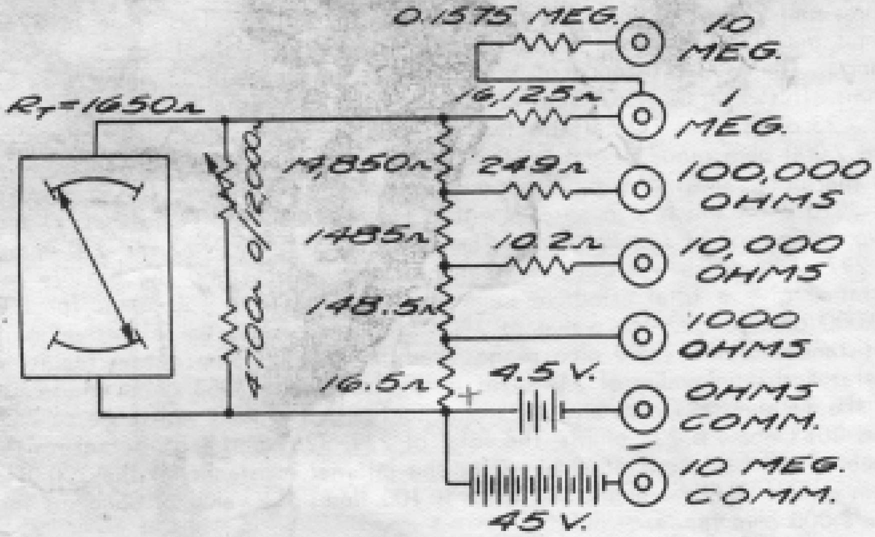


Fig. 18

At one instant of time, one side of the line may be positive with respect to the other side, while only a moment later, the condition will be reversed.

While it is not within the province of this manual to take up with any degree of depth A. C. fundamental theory, certain points must be touched upon before proceeding.

A sine-wave is shown in Figure 21. There are three methods of measuring A. C. potential values. (1) Peak, (2) Root Mean Square, (3) Average.

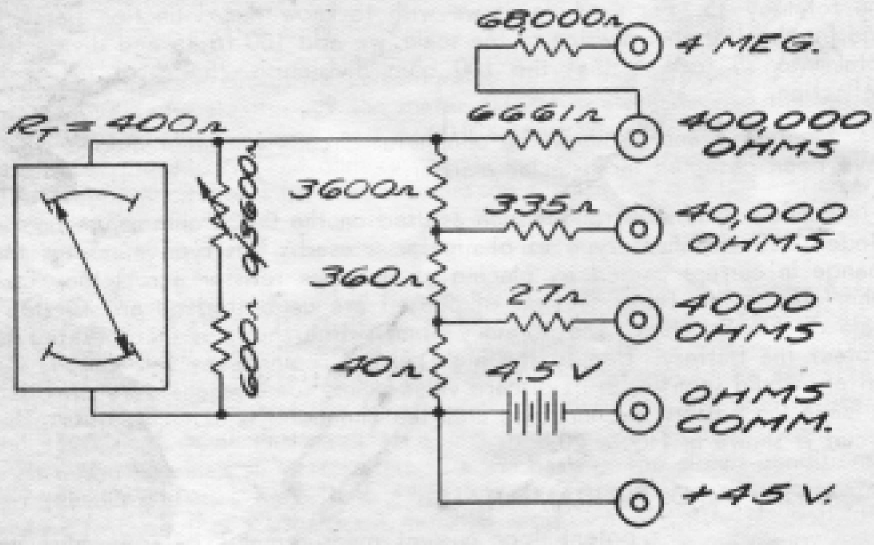


Fig. 19

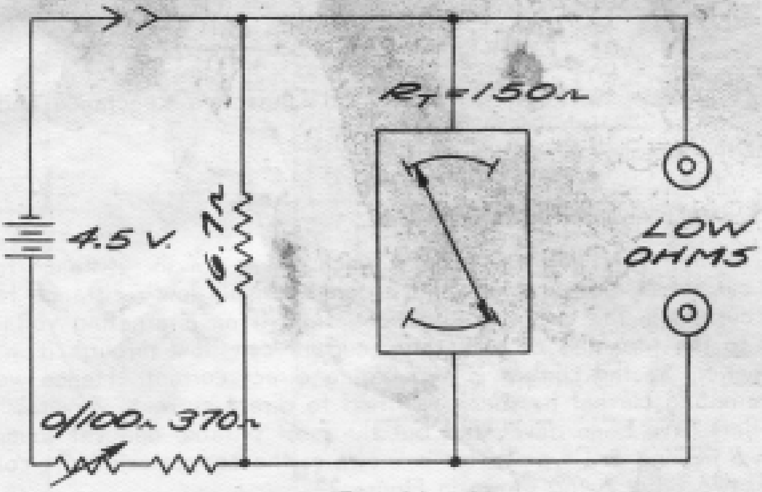


Fig. 20

Peak values are equal to the maximum plus or minus swing of the A. C. supply and are only instantaneous voltages. **R. M. S.** (Root Mean Square) values are considered as A. C. potential and current values having the same heating effect as equal D. C. potential and current values. R.M.S. values are always approximately .707 of peak values; i. e., peak values are approximately 1.4 times R.M.S. values. Usual types of straight A. C. meters indicate R.M.S. values, but D. C. meters used with some method of rectifying the A. C. voltage, so as to be used across A. C. potentials, actually indicate **average** values which are lower than R.M.S. values by the ratio of 1:1.11.

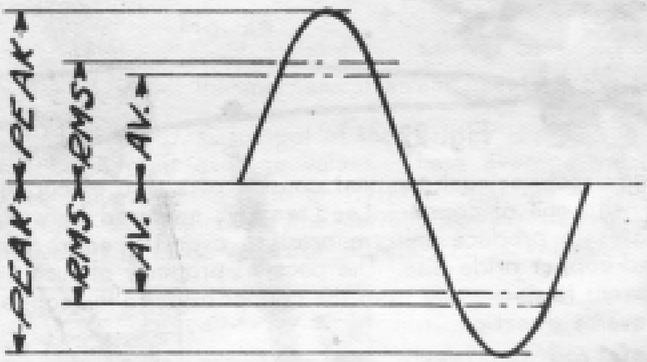


Fig. 21

Variation in A. C. Potential measurements from a linear scale is caused by the "current density" characteristic of instrument rectifiers, and this must be taken into consideration, as explained later, so that the A. C. potential measuring scales will remain linear.

"Leading" or "lagging" currents or potentials in A. C. circuits are accomplished by adding inductance or capacitance in series with the circuits. Therefore, besides the straight resistance of an A. C. circuit, we may have "Inductive Reactance" and "Capacitive Reactance", and the three values, combined, constitute an A. C. circuit's "Impedance" and is expressed by the equation:

$$Z = \sqrt{R^2 + \left(2\pi f l - \frac{1}{2\pi f c}\right)^2}$$

where Z = Impedance, R = Resistance, $2\pi fl$ = Inductive Reactance and $\frac{1}{2\pi fc}$ = Capacitive reactance.

16—INSTRUMENT RECTIFIER DESIGN

A rectifier is defined as a device which offers a high resistance to the flow of current in one direction and a comparatively low resistance to the flow of current in the opposite direction. Thus, if an alternating voltage is applied to the terminals of a rectifier, current can flow through it in only one direction, so the current is a pulsating direct current. Hence we say that alternating current has been rectified to direct current. Several forms of rectifiers have been developed but the most suitable one yet found for use with a moving coil type meter is known as the **copper-oxide** dry-contact rectifier, two types being shown in Figure 22.

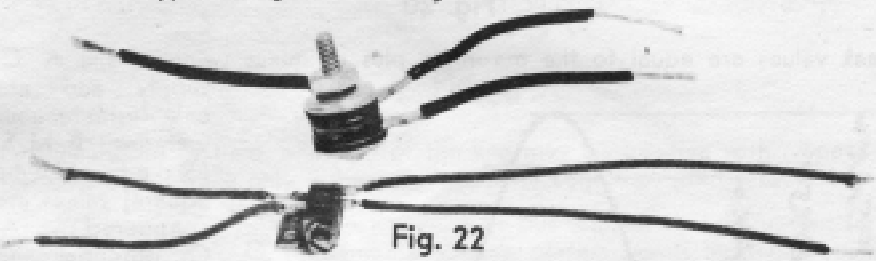


Fig. 22

In the copper oxide rectifier each element consists of a disc of copper oxide held in contact with one of copper. Lead washers are used between the brass terminal plates to produce uniform pressure over the entire surface of the copper and copper oxide disc. The peculiar property of such an arrangement allows current to pass easily from the copper oxide to the copper disc, but not in the reverse direction.

In the design of the Supreme 1937 instruments, it was desired to have the smoothest possible D. C. output from the rectifier unit. This was accomplished by using the arrangement shown schematically in Figure 23.

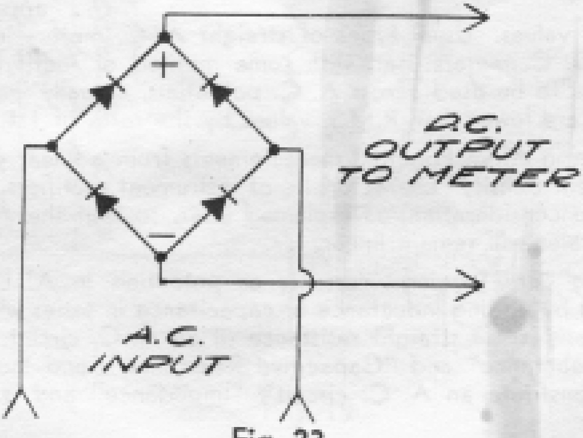


Fig. 23

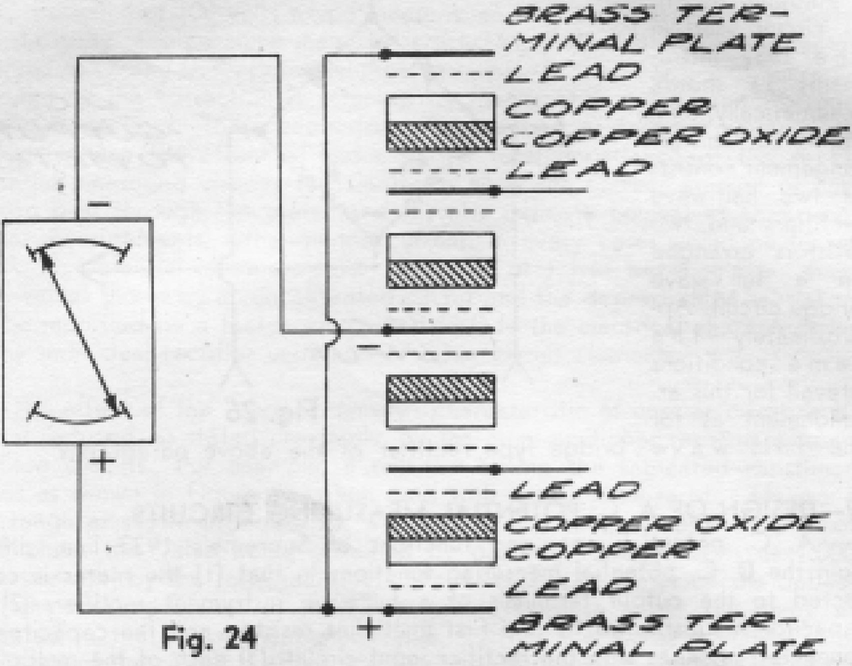


Fig. 24

Figure 24 shows the mechanical arrangement of the parts of the rectifier.

Since the D. C. output of the rectifier is pulsating in characteristic, the meter will read average values. These average values are equivalent to D. C. values by the ratio of 1:1.11 so that the external circuit must be so arranged as to increase the current flowing through the meter to values equivalent to D. C. values or "R.M.S." A. C. values.

MILLI-AMPERES	OHMS
1.0	500
0.9	530
0.8	560
0.7	620
0.6	685
0.5	760
0.4	870
0.3	1030
0.2	1300
0.1	2000

Fig. 25

The "current density" characteristic of instrument rectifiers is another matter which must be taken into consideration when designing commercial testers. This characteristic manifests itself in the form of an increase in the rectifier resistance with a decrease in the electrical load. The current density characteristics may be better understood by studying the tabulation of current and resistor values through a typical rectifier as shown in Figure 25. The effect of this characteristic is reduced, however, by the usual multiplier resistance used in a voltmeter circuit. It may be further compensated by introducing a capacitive reactance within the circuit. The proper capacitive reactance will introduce an effect which is approximately equal and opposite to that of the current density characteristic and will, therefore, tend to keep the circuit's A. C. impedance approximately equal regardless of load.

Another rectifier circuit used in the 1937 instruments is shown, schematically, in Figure 26. This arrangement consists of two half-wave rectifiers and two resistors arranged in a full-wave bridge circuit. Approximately the same conditions prevail for this arrangement as for the full-wave bridge type rectifier of the above paragraphs.

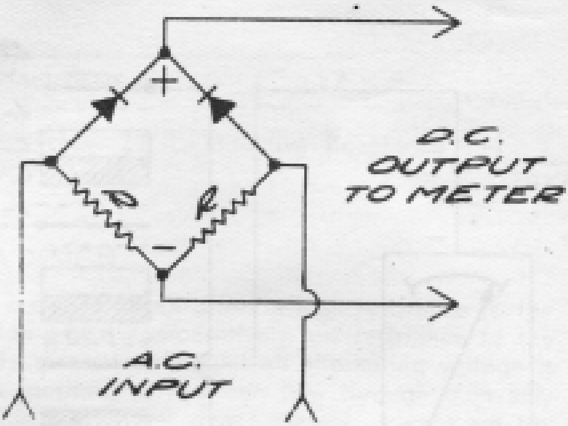
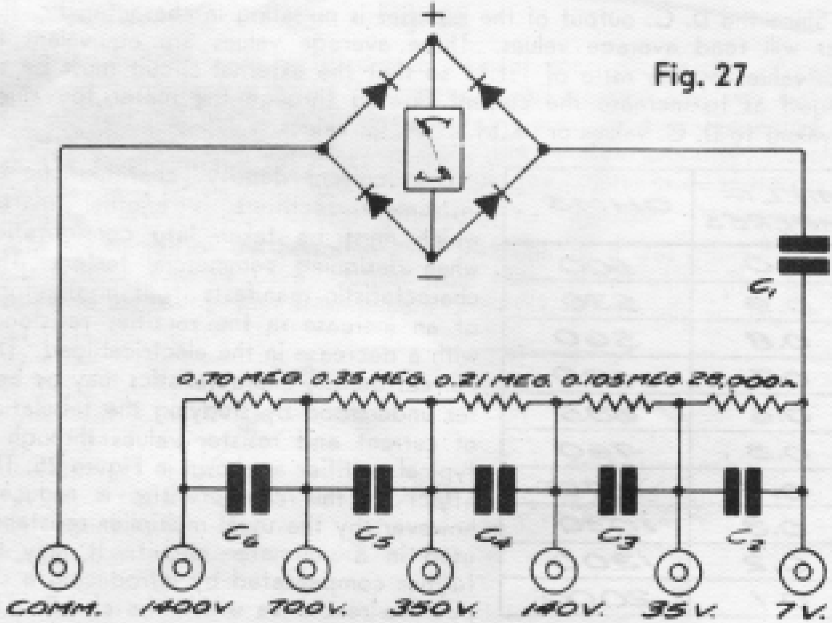


Fig. 26

17—DESIGN OF A. C. POTENTIAL MEASURING CIRCUITS

A. C. potential measuring functions of Supreme's 1937 line, differ from the D. C. potential measuring functions in that (1) the meter is connected to the output terminals of a full-wave instrument rectifier, (2) a capacitor is substituted for the first multiplier resistor, and the capacitor is connected in series with the rectifier input circuit, (3) each of the multiplier resistors above the first range are bypassed with a calibration capacitor. A typical A. C. potential measuring circuit is shown in Figure 27.

Fig. 27



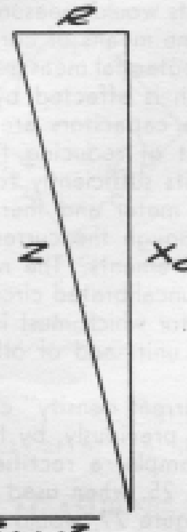
As stated previously, alternating current values, as measured by uncompensated D. C. meter—copper oxide rectifier circuits will not measure R.M.S. or "equivalent D. C." values, but will measure "average" values which are approximately 10% lower than R.M.S. values. For example, an

A. C. potential of 100 volts would measure, on such a circuit, about 90 volts. This difficulty requires some means of correcting the sensitivity of the meter between A. C. and D. C. potential measurements. In the 1937 line of Supreme Instruments, the correction is effected by means of a series capacitor and parallel capacitors. These capacitors are arranged as to their capacity so that they have the effect of reducing the total impedance of the A. C. potential measuring circuits sufficiently to allow the correct amount of current to pass through the meter and thereby indicate equivalent D. C. potential measurements, although the current, in every case, would be larger for A. C. potential measurements. The radio of 1:1.11 between the "average" values shown by an uncalibrated circuit and the desired "R.M.S." values will be modified by a factor which must include the electrical characteristics of the individual rectifier units and of other circuit elements.

The effect of the "current density" characteristic of copper oxide rectifiers is reduced, as stated previously, by the usual multiplier resistors as used in these circuits. For example, a rectifier having the tabulated resistance values as shown in Figure 25, when used with a multiplier resistor for the 7 volt range as shown in Figure 27, would require a total circuit resistance of 6363 ohms, this value being obtained by dividing 7,000 (7 volts at 1,000 ohms-per-volt) by the form factor 1:1.11. At half scale meter needle deflection, the total resistance of the circuit would increase about 260 ohms, as indicated in the above mentioned table, so that the increase in the total resistance of the circuit is about 4% as contrasted with an increase of about 52% if the meter were used without a multiplier for measuring a current value corresponding to half scale deflection. The effect is still further reduced when the range of the meter is extended to higher voltage ranges as more multiplier resistance is added.

In the design of the A. C. potential circuit under discussion, it was found advantageous to minimize the effect of the instrument rectifier's current density characteristic by using a series capacitor (C_1 in Figure 27), as a multiplier reactor for the low range, instead of utilizing a multiplier resistor. This arrangement constitutes an impedance circuit wherein the potential developed across the capacitive reactance is 90 degrees out of phase with the potential developed across the meter and rectifier resistance, so that the impedance elements may be represented by a right-angled triangle in which the resistance of the circuit is represented by a short leg of the triangle and the capacitive reactance by a long leg; the resulting impedance is, of course, represented by the hypotenuse of the triangle. This condition is graphically represented in Figure 28 in which the resistance of the meter plus the resistance of the rectifier unit at full scale deflection (1 M. A.) is shown as "R" and has a value of 800 ohms. The capacitive reactance—"Xc"—may be considered as having a value of 3490 ohms, which is the reactance of a 0.76 mfd. capacitor at 60 cycles. The resulting impedance "Z" is 3580 ohms, as determined by the solution of the impedance formula.

It will be observed from Figure 28 that slight variations in the length of that side of the triangle which represents the resistance will have comparatively little effect on the length of the hypotenuse, whereas the variations of the rectifier resistance would be considerable if the elements of the circuit impedance were additive; that is, capable of being represented by a straight line instead of by a triangle such as that described. It was shown



$$Z = \sqrt{R^2 + X_c^2}$$

Fig. 28

above that the increase in the total resistance of a 7-volt circuit at half-scale deflection, by reason of the current density characteristic, when a 6700 ohm multiplier resistor is employed, amounted to about 4% of the total resistance. However, when substituting the capacitor for the resistor in this circuit, an increase of 260 ohms of the resistance leg of the triangle increases the length of the hypotenuse (Z) only 67 ohms (instead of 260 ohms) or less than 1% of the total resistance. In this way, by using a capacitor as a multiplier reactor instead of using a multiplier resistance, the low voltage A. C. range readings are made to conform very closely to uniform scale distribution for practically all measuring requirements.

The adjustment of the 7-volt range is accomplished by adjusting the capacitor C1 until the meter needle deflects to 5 volts with a 5-volt applied potential (5/7ths scale). This capacitor—C1—also serves to isolate the A. C. from the D. C. measuring functions of the tester so that the meter will not register D. C. values on the A. C. circuit and output measurements are thereby enabled across the plate circuits of power tubes.

After having adjusted the 7-volt range for measuring A. C. potentials, it is next necessary to consider the means employed for adjusting the higher ranges. As stated before, it is necessary to pass more current through the meter when measuring A. C. values than is required when measuring D. C. values. This is accomplished in the higher A. C. ranges by bypassing the multiplier resistors which are required for D. C. potential measurements. In view of the fact that another triangle is formed when a range somewhat higher than the basic 7-volt range is considered, it may be found that the higher range, indicated in Figure 27 as a 35-volt range, may not require a bypassing capacitor. A triangle which would represent the impedance of the 35-volt range would have a reactance leg represented by the capacity C_1 as in the first triangle, but with a resistance leg increased from 800 to 28,800 ohms. The resulting impedance, represented by the hypotenuse of the new triangle, may generally be found sufficient for the 35-volt range. However, the ranges above the 35-volt range require the use of small bypass condensers. Their values average as shown in Figure 29 (for 60 cycle measurements).

The means employed for obtaining a uniform scale distribution for A. C. indications, as described above, are found to be accurate within 5% or better of full-scale values which is generally accepted as being sufficient for all practical A. C. measuring purposes.

A normally-closed push button switch is connected across the A. C. input terminals of the instrument rectifier, as shown in Figure 27, so as to protect it against overload electrical surges from transformers, capacitors, chokes, etc. It is expected that such surges will be dissipated through the switch before the operator has time to depress the switch button. A fuse, or other protective device cannot be used because the surges are more or less instantaneous and they can damage the rectifier before heating a fuse enough to open the circuit.

AVERAGE VALUES OF CAPACITORS IN A.C. CIRCUIT FOR SIXTY CYCLE OPERATION		
RANGE	CAP.	VALUE
7	C_1	0.447
35	C_2	0.0011
140	C_3	0.0135
350	C_4	0.0073
700	C_5	0.0036
1400	C_6	0.0015

Fig. 29

18—DESIGN OF D. B. (Decibel) MEASURING CIRCUIT

When the vast system of telephones was still in its infancy, electrical engineers realized the need for a unit to describe the amount of attenuation between the transmitter and the receiver. They used as a standard, the amount of attenuation or "drop in voice level" of one mile of standard telephone cable. This was termed "a transmission unit" or "T. U."

Later the name was changed to the "bel" as a mark of honor to the inventor of the telephone, Dr. Alexander Graham Bell. Within its limited application, the bel proved quite satisfactory until the advent of the "wireless age", and at that time it was necessary to decimate the bel to one tenth of its original value and this new unit was called the decibel, or "one tenth bel".

The decibel does not represent any definite quantity of electricity, such as the ampere, nor does it represent any definite electro-motive force such as the volt. It does not represent the power introduced into a circuit or the power derived from the circuit. It does, however, represent the **ratio** of the power gain or loss in a circuit. All decibel measurements use as a reference point "Zero" D. B. which is considered for all practical purpose to be the threshold of hearing, although theoretically this is incorrect. Zero D. B. is considered as being .006 watt (6 milliwatts) and all D. B. meters are calibrated to measure zero D. B. when 6 milliwatts are present in a 500 ohm line at 1000 cycles.

The decibel gain (or loss) of any piece of equipment is equal to ten times the log to the base ten of the equipment's "watts output" divided by the equipment's "watts input". In other words, if we had an amplifier which required a one watt input to deliver a 100 watt output, its decibel gain could be calculated by multiplying 10 times the log to the base ten of 100 divided by one. For those not familiar with logarithms, may we give a practical scale which will suffice. Starting at .006 watt as zero D. B. (or reference level) plus 10 D. B. is equal to .06 watt (or 10 times the original), and plus 20 D. B. is equal to .6 watts (or 100 times the original), plus 30 D. B. is equal to 6.0 watts (or 1,000 times the original) and plus 40 D. B. would be equal to 60.0 watts or 10,000 times the original. You will note that decibel measurements proceed "logarithmically" rather than "arithmetically", in other words, arithmetical progression would dictate that if .006 watt equals zero D. B. and .06 watt equal 10 D. B., plus 20 D. B. could only equal twice the value of plus 10 D. B. or .12 watt instead of .6 watt or 10 times plus 10 D. B. Further, we can see that while there is a variation of only 5.4 watts between plus 20 and plus 30 D. B., there is a variation of 54 watts between plus 30 and plus 40 D. B.

Many devices such as microphones do not have an output equalling .006 watt and for these measurements, we use "minus" D. B.'s or, in other words, some quantity less than the reference level of zero D. B. If zero D. B. is considered to be .006 watt, minus 10 D. B. will be .0006 watt and minus 20 D. B. will be .00006 watt, etc. When we state that an amplifier has an output of plus 40 D. B. we merely mean that its output bears a certain ratio between a 60 watt output and an accepted "Zero" level of .006 watt. Conversely, when we say that a carbon microphone has an output of minus 20 D. B. we merely state that its output bears a certain ratio between .00006 watt and the accepted level of .006 watt.

In practical application, the decibel is used to (1) indicate the power output of an electrical device with respect to a zero level of .006 watts, (2) indicate the input to output the gain or loss ratio of an amplifier or associated equipment.

Let us take a practical application of the D. B. in public address work. We shall consider that we have at our disposal three pieces of equipment, (1) a carbon microphone having an output power of minus 20 D. B., (2) a crystal microphone having an output power of minus 70 D. B., (3) an amplifier which requires an input power of zero D. B. (or .006 watt) to furnish an output power of plus 40 D. B. or 60 watts. If the amplifier requires at its input a zero D. B. level to function at its full 60 watt output, it could readily be seen that neither of the two microphones would prove satisfactory without an additional amplifying stage between the microphone and the amplifier. The first microphone requires additional amplification of 20 D. B. whereas the second microphone requires a 70 D. B. gain.

Let us say that we purchased an additional two stage amplifier which had a total gain of 80 D. B. with a per stage gain of 40 D. B. In this case, only one stage of this amplifier would be required for the carbon microphone with a minus 20 D. B. output although, even if we worked the carbon microphone into this one stage, it would overload the complete circuit. Therefore, a "losser" circuit or "resistance network" equalling about 20 D. B. should be introduced between the microphone and the preamplifier stage or between the preamplifier stage and the main amplifier stage (besides the usual additional "losser" circuit for volume control.)

The crystal microphone with an output of minus 70 D. B. and a "losser" circuit of 10 D. B. will work nicely into the two stages having a total gain of 80 D. B., bringing the crystal microphone level up to zero D. B. and fully exciting the main amplifier.

Many theatre owners have sound equipment which requires about a minus 20 to zero D. B. input into the main amplifier to give sufficient power output to fully excite the screen speakers. When using the now obselete talking records, the pick-up usually worked directly into the main amplifier, as a device of this type has about a zero D. B. output level. With the advent of sound-on-film, the photo electric cell with an approximately minus 60 D. B. output, required a "head" amplifier, "peck" amplifier or "preamplifier" to bring its level up to the necessary input level of the main amplifier for full power output. This is also true if the theatre owner desires to use a crystal microphone for announcing purposes. If the main amplifier has a required input of minus 20 D. B., and the crystal microphone only supplies a minus 60 D. B. output, it is necessary to incorporate between the microphone and the main amplifier a preamplifier having a gain of at least 40 D. B.

The above are a few illustrations of decibel measurements and we might also mention in passing that decibel measurements are used when computing audio frequency amplifier frequency response curves.

In the design of Decibel measuring circuits, we must keep the following facts in mind (1) D. B. meters are essentially A. C. voltmeters, measuring the A. C. voltage across a 500 ohm line in which a certain current is flowing (the product of the voltage and current being the Audio Watts expended in the circuit). (2) if the wattage is known and the resistance of the line is known, the current flowing through the circuit can be computed by the formula $I = \sqrt{\frac{W}{r}}$. (3) Finding the current flowing in the circuit, the potential appearing across the circuit may be found by employing the formula E = IR. Figure 30 shows a D. B. to voltage conversion chart. (4) Working out a table of voltage values for all major points on the D. B. ranges, we can ascertain the series multiplier resistances necessary to cause the needle to indicate a pre-determined percentage deflection of full scale for each Decibel value, by using the same calculations as when designing straight A. C. voltage circuits. A chart giving the percentage of full scale deflection for each D. B. from minus 10 to plus 6 D. B. is given in Figure 31.

D.B.	VOLTS	RANGE
4	1.08	-10
-10	0.5476	0
0	1.73	0
+4	2.76	0
+6	3.44	0
0	1.73	+10
+10	5.47	"
+14	8.70	"
+16	10.89	"
+10	5.47	+20
+20	17.30	"
+24	27.50	"
+26	34.40	"
+20	17.30	+30
+30	54.75	"
+34	87.00	"
+36	108.75	"
+30	54.75	+40
+40	173.00	"
+44	275.00	"
+46	344.30	"

Fig. 30

By reference to Figure 32 we see the actual D. B. measuring circuit. As the meter used has a .0001 ampere (1 m. a.) movement, full scale deflection would require 1 m. a. of current flowing through the circuit. The plus 4 D. B. marking is 69.25% of full scale deflection so that 69.25% of 1 m. a. would have to flow through the circuit at this point (.0006925 amperes). However, this is **Direct** current which has been rectified by the copper oxide rectifier and, as shown in calculating the regular A. C. Potential Circuits, the resistance of the copper oxide rectifier varies with load. An average rectifier resistance chart for varying loads is shown in Figure 33.

Also remember that rectified Direct current will show "average" rather than "R.M.S." values and that the ratio between D. C. and A. C. is as 1:1.11. This is, of course, variable according to the form factor of each individual rectifier and also varies between different models of rectifiers. An average run of rectifiers used in Supreme equipment results in an average form factor of 1.212.

PERCENTAGE OF FULL SCALE DEFLECTION FOR POINTS ON -10 TO +6 D.B. SCALE	
D.B.	%
-10	10.10
-9	11.50
-8	13.23
-7	15.15
-6	17.75
-5	20.30
-4	23.15
-3	26.88
-2	30.85
-1	35.73
0	40.53
+1	45.90
+2	52.78
+3	60.40
+4	69.25
+5	78.98
+6	89.43

Fig. 31

Therefore, it is necessary to allow 1.212 more alternating current to flow through the circuit than would be the case if we were dealing with Direct current.

The calculations for the multiplier resistance of the minus 10 to plus 6 D. B. range was made at plus 4 D. B. and is as follows:

Multiplied by Equals

.0006925 = Desired Direct current through meter.
1.212 = Form factor of rectifier.
.0008393100 = Necessary Alternating current through external circuit.

Divided by Equals

2.76 = A. C. Potential developed across 500 ohm line at plus 4 D. B. (See Fig. 30).
.00083931 = Alternating current through external circuit.
3288 = Total Resistance of first D. B. range.

Add

300 ohms = Meter resistance.
640 ohms = Approximate Rectifier resistance (See Fig. 33).
940 ohms

Subtract

3288 = Total circuit resistance.
940 = Meter and Rectifier resistance.
2348 = Multiplier for first range.

The plus 10 Decibel range may be calculated in the same manner. As plus 14 D. B. point should fall directly over the plus 4 D. B. point on the meter scale, the desired current through the meter remains the same, not only for plus 14 D. B., but for plus 24, plus 34 and plus 44 D. B.

The calculations for the multiplier resistance for the 0 to + 16 D. B. range taken at plus 14 D. B. is as follows:

Multiplied by Equals

.0006925 = Desired Direct Current through meter.
1.212 = Form factor of rectifiers.
.0008393100 = Necessary Alternating current through external circuit.

	8.70	= A. C. Potential developed across 500 ohm line (See Fig. 30).
Divided by	.00083931	= A. C. through external circuit.
Equals	10365	= Total Resistance for second D. B. Range.
Minus	3288	= Total Resistance of first D. B. Range.
	7077	= Multiplier Resistance for second range.

The calculations for the multiplier resistance for plus 10 to plus 26 D. B. range taken at plus 24 D. B. is as follows:

	27.50	= A. C. Potential developed across 500 ohm line (See Fig. 30).
Divided by	.0008391	= A. C. through external circuit.
Equals	32764	= Total Resistance for third range.
Minus	10365	= Total Resistance for second range.
	22399	= Multiplier Resistance for third range.

The balance of the ranges work out in exactly the same manner.

Inasmuch as the rectifier form factor changes slightly with various loads, it is necessary to take this into consideration when plotting intermediate D. B. points to each side of the basic point on each range. Once this form factor curve is taken the balance of the D. B. points may be plotted or may be ascertained experimentally. Fig 31 gives the actual results.

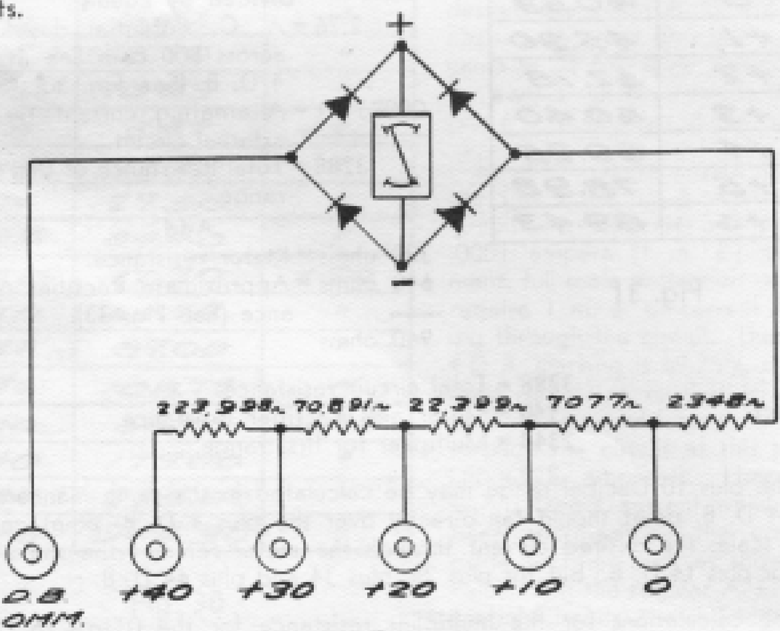


Fig. 32

19—DESIGN OF CAPACITY LEAKAGE CIRCUITS

The circuit utilized for testing electrostatic capacitors for leakage is shown in Figure 34. The required D. C. potential is supplied by a self-con-

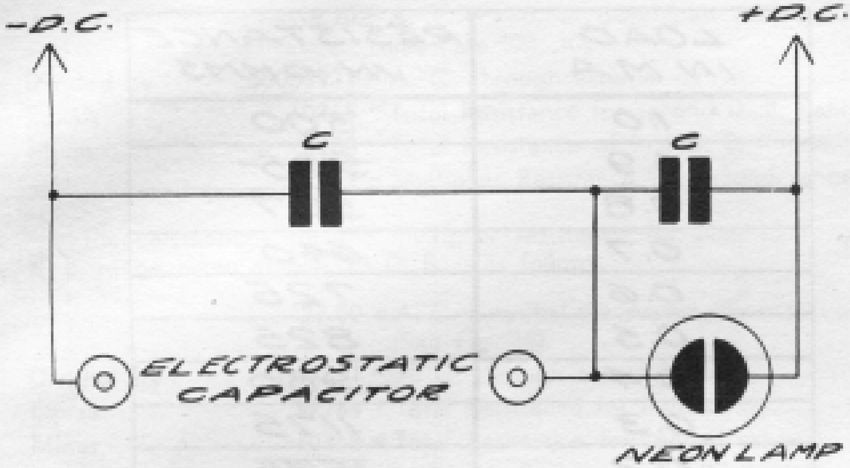
LOAD IN M.A.	RESISTANCE IN OHMS
1.0	500
0.9	525
0.8	587
0.7	640
0.6	725
0.5	825
0.4	950
0.3	1175
0.2	1575
0.1	2400
0.05	3350
0	∞

Fig. 33

tained power supply. After the initial surge through the electrostatic capacitor under test, there will be no current through the neon lamp unless there is a leaky or short circuited condition within the capacitor across the "Electrostatic Capacitor" pin jacks. If the capacitor under test is short circuited or has a very low D. C. resistance one element of the neon lamp will glow continuously, indicating the passage of direct current through the capacitor. If the capacitor under test is not short circuited but has a high resistance leakage, the leakage resistance will periodically discharge the accumulated charges of the capacitor C through the neon tube so that the presence of such resistance (leakage) in the capacitor under test will be indicated by intermittent flashes of the neon lamp.

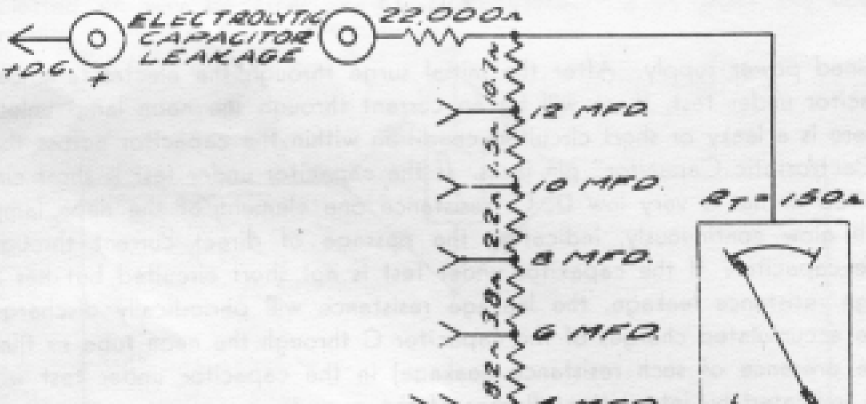
Two different types of circuits are used for electrolytic capacitor leakage. The circuit shown in Figure 35 is that used in the Supreme Models 500 and 585. The condition of the electrolytic capacitor is indicated on a "Good-Bad" scale on the meter. The required D. C. potential is supplied by a self-contained minature "power pack". The D. C. potential is supplied through a resistor R which limits the current to a safe value for good capacitors and protects the meter against a shorted capacitor.

The circuit shown in Figure 36 is that used in Model 550. In this circuit capacitors are tested at their rated voltage and the leakage current is read on the meter scale in milliamperes. This current value is then divided



-D.C.
+D.C.
C
C
ELECTROSTATIC CAPACITOR
NEON LAMP

Fig. 34



ELECTROLYTIC CAPACITOR LEAKAGE
22,000Ω
+D.C.
10.7Ω
12 MFD.
1.5Ω
10 MFD.
2.2Ω
8 MFD.
3.8Ω
6 MFD.
8.2Ω
4 MFD.
30.4Ω
2 MFD.
108.2Ω
1 MFD.
RT = 150Ω
-D.C.

Fig. 35

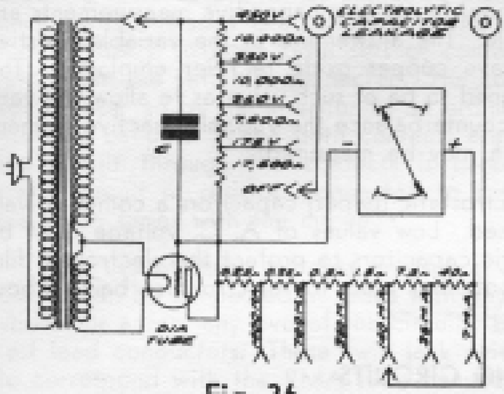


Fig. 36

by the rated capacity of the capacitor in microfarads to give the leakage in terms of milliamperes per microfarad. The recommended permissible leakage for a capacitor tested under the conditions imposed in the circuit of Figure 36 is one milliampere per rated microfarad.

To the casual observer there appears to be no protection for the meter in this circuit. A closer inspection will show that if the range selector of the milliampere circuit is set at an adequate range for the first test of the electrolytic capacitor under test, the meter will not be slammed if the capacitor is short circuited.

A normally open switch has been incorporated in the power supply to keep the high D. C. potentials away from the "Electrolytic Capacitor Leakage" pin jacks until the user is ready to make the leakage test.

20—DESIGN OF CAPACITY MEASURING CIRCUITS

In the capacity measuring functions of the Supreme 1937 instruments, the resistance value of the meter, shunts and multiplier resistance associated with the measuring circuit shown in Figure 37 constitute one leg of an impedance triangle. The capacitive reactance of a capacitor of unknown value, connected into the circuit for determining its value, constitutes the other leg of the impedance triangle. It is obvious that the resistance value of the meter, shunt and multipliers will be a constant value for any particular range and that the vector's capacitive reactance is in every case determined by the capacitive value of the capacitor inserted into the circuit for the purpose of determining its value It is further true that the meter current is related directly to the hypotenuse length of the impedance triangle and will not have linear relation to the capacitive values. For example, let us assume that we have an impedance triangle in which the full scale meter current corresponds to a capacitive value of 5.0 microfarads; if we remove the 5.0 microfarad capacitor and replace it with a 2.5 microfarad capacitor, the length of the reactive leg of the triangle will be doubled, but the length of the hypotenuse of the impedance triangle will not be doubled, and, therefore, the meter current will not be reduced to

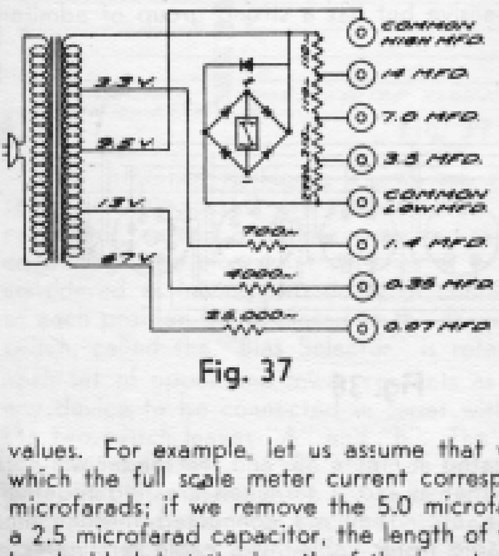


Fig. 37

one-half its former full scale value.

From the foregoing it is natural to ask how capacitive measurements are made on an evenly divided scale. The answer lies in the variable resistive value introduced by the full wave copper oxide rectifier employed. The shunts and multipliers were designed to be of such value as to allow the variable element of the rectifier to counterbalance the variable reactive element of the different capacitors which may be measured.

For the measurement of electrostatic (paper) capacitors a comparatively high A. C. potential may be used. Low values of A. C. voltage must be used on the high value electrolytic capacitors to protect the electrolytic film of such capacitors the actual potential used for electrolytics being about 9.5 volts.

21—RADIO TESTER SWITCHING CIRCUITS

There are two general classifications of radio tester switching circuits. (1) A system in which all meter ranges and other external test circuits terminate at pin jacks, and where "jumpers" or test leads are used to place these external devices in series with any radio tube circuit or across any two circuits. (2) A system in which two multi-gang, multi-point switches are used to connect any external test circuit in series with any radio tube circuit or across any two circuits, automatically, and without the use of "jumper" test leads. The "jumper" type has several advantages and only one possible disadvantage over the switch type. The "jumpers" system is very flexible, not easily subject to obsolescence, compartively cheaper to build and absolutely "sure fire" in use. This system is utilized in all Supreme 1937 radio testors employing a radio tester cable circuit with the exception of the Model 595 P. A. tester in which is employed the multi-gang, multi-point switch system This second system has as its biggest advantage—Speed of operation, although many proponents of the "jumper" system declare their ability to make changes about as quickly. As it employs two multi-gang, multi-point switches, it is relatively more expensive but has a strong group of admirers nevertheless.

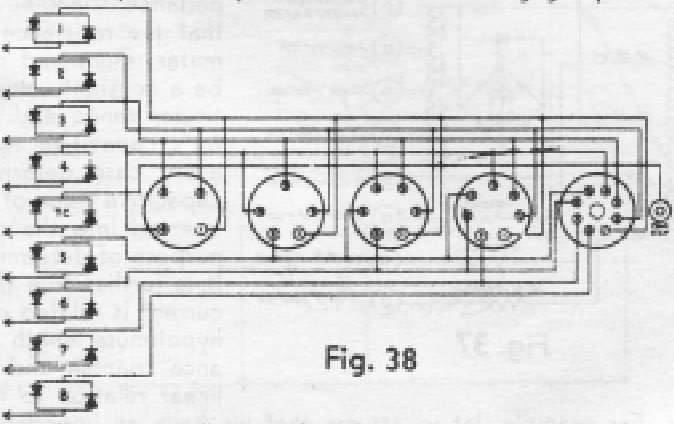


Fig. 38

The "jumper" system is illustrated in Figure 38, and the reader will note that six sockets are connected so that all No. 1 terminals are tied together, all No. 2 terminals tied together, etc. They are connected through nine circuit-breaking switches to the radio tester cable. This cable terminates in a "top-cap" lug and an analyzing plug with seven pins and one receptacle contact for the eighth pin of an 8-pin analyzing plug adapter. These circuit-breaking switches are rather unique in their simple construction, as actually, each switch includes two normally closed contacts in parallel. It is, therefore, necssary to open both sets of contacts in order to open the circuit into which the switch is connected. The contacts are designed so that they can be opened by the insertion of an ordinary pin plug which makes contact with the circuits. When both contacts are opened by a pair of pin plugs, the circuit through the contacts is broken and any device, such as a meter circuit or resistor, connected to the two pin plugs, is automatically placed in series with the circuit.

The use of these switches enables a very flexible arrangement, as any device can be connected in series with any one of the circuits, as explained above, or across any two of the circuits, by means of pin plug terminated test lead conductors. These twin jack switches are numbered and lettered to correspond with the RMA tube connector numbering system used in all Supreme Radio Tester circuits and the top cap pin jack. In this manner the radio technician has a full knowledge at all times of the circuits with which he is dealing.

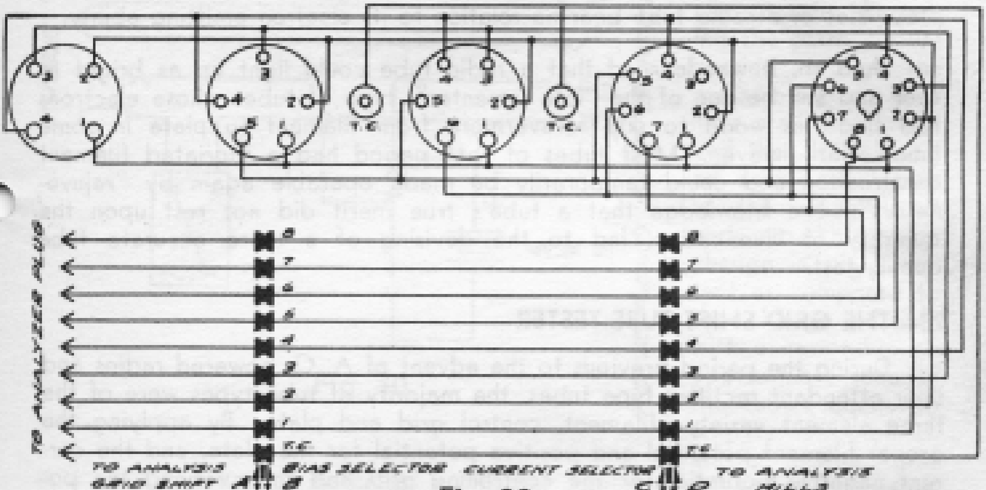


Fig. 39

By reference to Figure 39, we see the second system illustrated. The same six tube sockets are connected to the same type analyzer plug and cable, but, instead of being connected through twin jacks, are now connected through two nine point switches of unusual design. Each switch may be considered as having two decks of contacts, the upper and lower contact of each position being closed in the normal position. When the double leaf switch, called the "Bias Selector" is rotated, it opens the circuit between each set of upper and lower contacts as it passes between them, allowing any device to be connected in series with the circuit by connection across the two switch leaves "A" and "B". The same is true of the switch marked "Current Selector". When a fall of potential is desired across any two circuits, the "Bias Selector" is set to one circuit, the "Current Selector" to the other and the voltmeter circuit connected between the two switches. In the voltmeter position, points "A" and "B" are shorted together as are points "C" and "D" so that no cable circuit is opened.

CHAPTER IV. TUBE TESTER CIRCUITS

22—EARLY HISTORY OF TUBE TESTER DESIGN

Many "old timers" in the radio game remember how the original vacuum tubes sold for around $7.50 "per each" and were considered to be in good operating condition if they lighted (apparently, the more light, the better). The "DeLuxe" tube tester of that period was the old familiar flashlight bulb type. In this tester, a flashlight bulb was connected in series with one leg of the filament of a vacuum tube socket. If the flashlight bulb lighted when the tube was inserted, the vacuum tube was O. K., if not—a new tube was sold. Very simple, wasn't it? The first "English-reading" tube tester, a howling success, but wait—they began to hear about radio tubes which lighted, but still didn't "play"!

Every professional radio man nowadays knows that the illumination of a radio tube is only "waste" power and that the primary object of a filament is to emit electrons itself or to cause electrons to be emitted from a "cathode", that electron emission cannot be seen, and that the illuminating properties of a radio tube bear no relation to its electron emitting ability.

And so, it was learned that a radio tube could light up as bright as ever and still be one of the "late lamented" type of tubes whose electrons had fled this world to skip forevermore from filament to plate in some "molecular" heaven. Most tubes of that period had a thoriated filament construction and could temporarily be made operable again by "rejuvenators". The knowledge that a tube's true merit did not rest upon the quantity of illumination, led to the devising of a more accurate tube quality test.

23—THE GRID SHIFT TUBE TESTER

During the period previous to the advent of A. C. powered radios and their attendant rectifier type tubes, the majority of tube types were of the three element variety—filament, control grid and plate. By applying the proper filament potential and positive potential for the plate, and the correct negative potential for the controlling grid and then varying the potential applied to the grid by the well known "grid shift" method, a variation in plate current could be observed. This is roughly analogous to the test for "mutual conductance" of a tube, but cannot be called a mutual conductance test **unless made with rated D. C. potentials applied to the tube under test.**

Fundamental tube theory teaches us that a very small change in negative controlling grid potential produces a relatively large change in plate current. Inasmuch as all tubes of the same type are supposed to be as alike as possible, any variations between tubes of the same type indicate a variation in their quality or ability to control a large plate current with a small grid voltage. If a certain tube at one time has a certain variation of plate current on a grid shift test and later on has but half that variation, it may be assumed that the tube has lost some of its ability to amplify.

The testing of tubes by the "grid shift" method is only a makeshift quality test at best, and can only be used as a comparative test between two tubes of the same type (one known to be good) or between current readings of the same tube from time to time. No definite tube quality listings can be given for a tester which does not incorporate internally its own power supply, as variations in any one or more supply potentials would change the plate current readings and thereby obviate the possibility of using any standard reading tube quality list. This type of test, however, finds its field in portable P. A., Theatre or radio analyzers as in the first and second case, individual tube "histories" may be kept of the tube's ability to amplify and a new tube substituted upon noting a considerable falling off of this amplifying ability. In the third case, a radio technician can give preliminary service to a radio set in the customer's house by checking a new set of tubes against the owner's set, arriving at an approximate idea as to whether any of the old tubes need replacing. However, it must again be stressed—this type of test is only **comparative** and is not absolutely reliable at all times. Figure 40 shows a simple "grid shift" tube test circuit which may be utilized with our set testers. The filament and plate potentials for the example shown (a three element tube) and its nominal "C" bias are all obtained from the tube's socket in the radio or amplifier in which the tube normally operates. By noting the plate current passing through the milliameter under normal conditions and then introducing an added "C" bias in the grid circuit and noting the **change** in plate current as compared to the change possible with a new tube, an approximate idea of the tube's ability to amplify is obtained. This is a true "grid shift" test and cannot be called a "mutual conductance" test, unless **rated D. C. potentials are applied to a tube under test.** This is not a mutual conductance test because the D. C. potentials available from the particular radio used, bear no relation to tube manufacturer's rated potentials and will also vary from radio set to radio set.

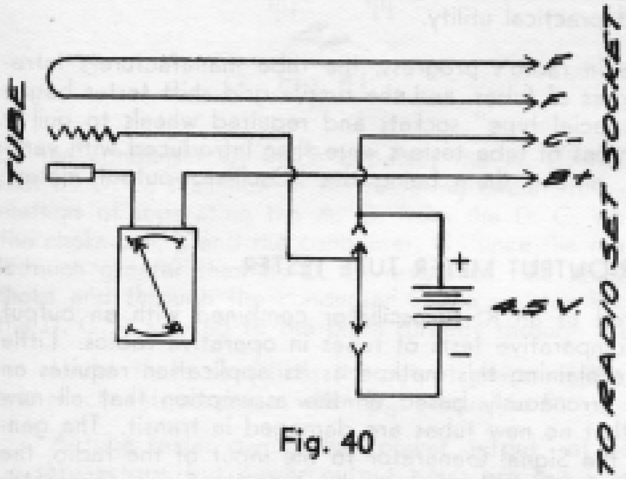


Fig. 40

24—THE MUTUAL CONDUCTANCE TUBE TESTER

Mutual conductance (or "Grid-Plate Transconductance") is the ratio of the change in the plate current of a tube to the change in the grid voltage with all other voltages remaining constant. The mutual conductance of a tube is expressed in micromhos.

Any variation from rated D. C. supply potentials will produce corresponding variations in mutual conductance ratings. Tube manufacturer's tables of tube characteristics may be checked to verify this statement. An 01A tube having a rated mutual conductance value of 725 micromhos when operated with a negative grid potential of 4.5 volts and 90 volts plate potential, has a mutual conductance of 800 micromhos when the grid potential is raised to 9.0 volts and the plate potential to 135 volts.

In this case, two potentials were varied to effect the change in mutual conductance, but either could be changed separately with a resulting change in mutual conductance. Therefore, in the design of a true mutual conductance tester, provision must be made to have available every D. C. potential necessary for every element of every tube on the market, with additional potentials available for any future tube types. It can be readily seen that such a tube tester, although probably very accurate in its final analysis, would require a number of adjustments to be made before a quality test of any tube could be taken. The complicated circuit set-up and operating procedure would result in a tester beyond the financial ability of but a very few and would require about half an hour to test a set of tubes.

Therefore, due to the inherit drawbacks of the **true** mutual conductance tester, tube tester design engineers have had to make such compromises in absolute accuracy as are necessary to effect an acceptable balance between laboratory precision and practical utility.

At about this time in radio's progress, the tube manufacturers introduced some 150 new types of tubes, and the simple grid shift tester began to acquire numerous "special type" sockets and required wheels to pull it around. Several other types of tube testers were then introduced with varying degrees of success, among them being the "Oscillator-output meter" type.

25—THE OSCILLATOR-OUTPUT METER TUBE TESTER

This design consisted of an R. F. oscillator combined with an output meter, so as to make comparative tests of tubes in operative radios. Little time need be taken in explaining this method as its application requires an operative radio and is erroneously based on the assumption that all new tubes are perfect and that no new tubes are damaged in transit. The general idea is to connect the Signal Generator to the input of the radio, the output meter to the output terminals of the radio, tune the Signal Generator to the radio's receiving frequency and note the variations between a new tube and the present tube in each of the radio's sockets. This method is a very rough check and is not one in which the customer can place much confidence. The radio man interprets the variations in reading according to his conscience as this test could not employ an English reading "GOOD-?-BAD" scale. This method is also very deceptive when applied to radios in which A. V. C. circuits are involved. It results in "weird noises" being emitted from the loud-speaker, much to the disgust of the customer and, while satisfactory in theory, does not measure up in practice.

26—THE DYNAMIC (Power Output) TUBE TESTER

Figure 41 represents the fundamental circuit for measuring the output power of a vacuum tube, and is shown in simplified form for ease of explanation.

When an alternating current (Eg.) is impressed on the grid of the tube in the above diagram, there is developed in the plate circuit a similar alternating current which can be computed by the formula $\frac{\mu \; Eg}{(R + R_o)}$, where

Eg = Alternating potential on grid.
R = Internal plate resistance of tube.
Ro = External load resistance in the plate circuit.

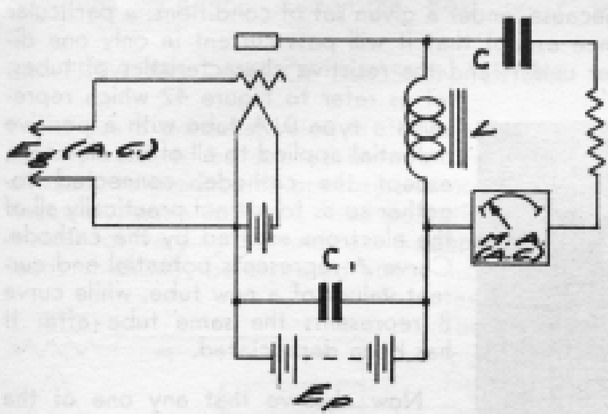


Fig. 41

In measuring the output power of the tube in Fig. 41, there is first applied an A. C. potential across the terminals Eg as previously mentioned, this causes an alternating current to be superimposed upon the steady plate current supplied by the battery Ep. This A. C. is eliminated from the battery current, Ep, by the condenser C, which bypasses the A. C. to the filament. In order that no D. C. shall flow in the metering circuit, it is necessary to provide a method of separating the A. C. from the D. C. which is accomplished by the choke-coil, L and the condenser, C. Since the reactance of the choke, L, is much greater than its D. C. resistance, the A. C. will flow around the choke and through the condenser C the resistor Ro, and the meter; while the D. C. is applied to the plate directly through the choke, L.

Under these conditions the output power of the tube is equal to $I^2 R_o$, and reaches its maximum when R_o is equal to R.

A tube tester giving the "power output" of power type tubes might be satisfactory, but power output tubes are but a small percentage of the total tube types. A power output tube tester assumes that the result will to be given in "watts", although the average tube is used as a voltage amplifier without regard to the power output of its plate. Therefore, any test given the average inter-stage tube with relation to its power handling ability is useless and a fallacy.

27—FUNDAMENTALS OF EMISSION TYPE TUBE TESTERS

As a result of the many disadvantages of all other types of tube testing circuits, the emission type tester has and is the most satisfactory all around tube tester circuit so far developed for general service use. After all, about all that can happen to a radio tube, aside from remote possibilities such as lightning strokes, air leakage, etc., is the gradual depreciate of the emitting qualities of the **Cathode** element. Therefore, why not test tubes **by measuring the emitting ability of the cathode?** There is no reasonable doubt but that with almost 100% of all radio tubes produced, a measure of the tube's cathode emitting ability is as satisfactory a tube quality measure as the grid shift, the mutual conductance, the "power output" or any other type tube quality test, because a tube loses its ability to amplify (mutual conductance) by reason of lowered cathode emission incidental to the tube's prolonged service.

For the purpose of analyzing the factors involved in the design of a tube tester of this type, it is convenient to resolve tube characteristics into equivalent resistance values; because, under a given set of conditions, a particular tube will act as a resistance except that it will pass current in only one direction. In order to better understand the resistive characteristics of tubes, let us refer to Figure 42 which represents a type 01A tube with a positive potential applied to all of the elements, except the cathode, connected together so as to attract practically all of the electrons emitted by the cathode. Curve A represents potential and current values of a new tube, while curve B represents the same tube after it has been depreciated.

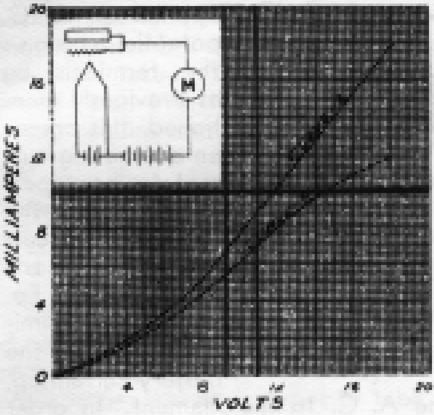


Fig. 42

Now observe that any one of the potential values taken horizontally from Curve A and divided by the corresponding current value, taken vertically from the same curve, will indicate the resistance value of the tube under the particular load conditions. It is seen that, with an applied potential of 18 volts, the current load on Curve A is 17.8 milliamperes, from which we derive, by Ohm's law, a resistance value of 1012 ohms. Similarly, with 18 volts on Curve "B", the current load is 11.8 milliamperes, from which we derive a resistance value of 1525 ohms. We can determine the percentage of depreciation at 18 volts by subtracting 11.8 milliamperes from 17.8 milliamperes, and dividing the difference by 17.8 or by subtracting 1012 ohms from 1525 ohms and dividing the difference by 1525; in either case, the tube depreciation from Curve "A" to Curve "B" is found to be about 34% at 18 volts. Accordingly, Curve "A" can be said to represent the resistance of a normal tube and Curve "B" can be said to represent the resistance value of the tube after its emission has depreciated.

A further consideration of the factors presented in the last paragraph leads us to conclude that our tube testing circuit should be capable of indicating the load changes which are directly related to the changes in effective

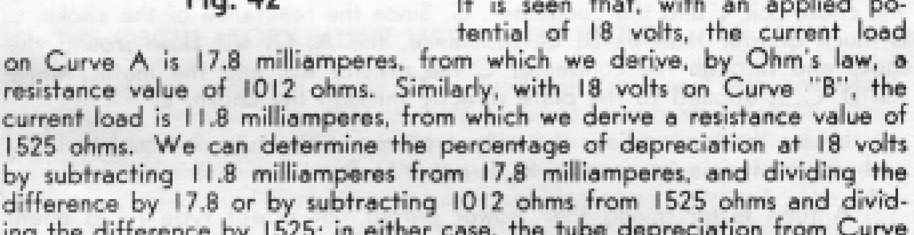


Fig. 43

internal resistive values of tubes as they depreciate in emitting quality so that, when the rated load of a normal tube is indicated in the "GOOD" sector of a meter scale, such as that shown in Figure 43, the reduced load resulting from depreciation of the same tube to a degree beyond satisfactory operation will be indicated in the "BAD" or "?" sector of the meter scale.

28—PREVIOUS TYPES OF EMISSION TESTERS

Since a potential value of 30 volts was accepted, generally, as a satisfactory value to be applied between the cathode and all other elements of all tubes to produce an approximate normal load for each tube, it would be necessary, when using this fixed potential value for all tubes to provide some means for varying the indicating range of the meter to cover all normal loads which may be expected of the different types of radio tubes which the tester will be required to accommodate. The most simple circuit for accomplishing such results is that indicated in Figure 44. Since current will pass through the tube only in the direction of the arrow in Figure 44, one side of the secondary winding is indicated as being negative and the other side is indicated as being positive, and it will be observed that the indicating range of the meter may be controlled over a wide range of load values, determined only by the basic sensitivity of the meter and by the resistance value of the rheostat, R. If a meter having a full scale load value of 10.0 milliamperes (0.010 ampere) with an internal resistance value of 10.0 ohms be used with a 100-ohm shunting rheostat, the indicating range of the meter would be controllable for any ordinary load value above 11.0 milliamperes. While the resultant measuring range would be inadequate for the requirements of a modern tube tester, the values indicated will serve the present purpose of discussing the design features of tube testers.

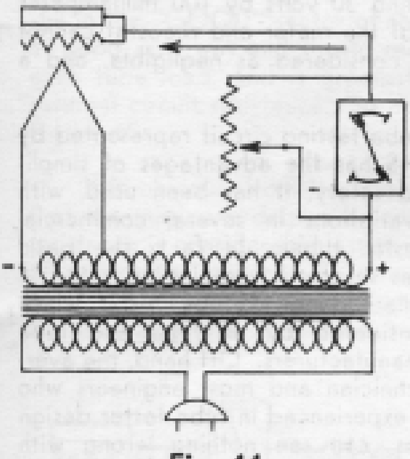


Fig. 44

Referring again to Figure 44, let's observe what might happen if a short-circuited tube were placed in the test circuit. A short-circuited tube would have zero resistance so that the only appreciable resistance remaining in the circuit would be that of the meter, across which the total circuit potential value of 30 volts would develop. The normal full scale potential drop across the meter is 100 millivolts (0.1 volt), obtained by multiplying the full scale current load of the meter by the resistance value of the meter. Therefore, a 30-volt potential value developed, because of a short-circuited tube, across a 0.1 volt meter would impose upon the meter a load which is about 300 times that for which the meter is designed to normally register. With such an overload, what would happen? It would be "goodbye" meter! And if the meter were to stay intact, then the transformer would soon pass out of the picture. This contingency suggests, then, that some means must be provided to protect the meter and transformer against short circuited tubes. A fuse is a logical suggestion, but a burned out fuse is an invitation to some people to use a brass lug or a bridging wire when a new fuse is not immediately available, so that the necessity for protecting the circuit with a fuse should be eliminated if such elimination be practicable.

Since meters are generally designed to withstand loads which are 10 times normal full scale loads, we may assume that the meter will safely withstand an applied potential of 1.0 volt, which would produce a current load of 100.0 milliamperes through the 10.0-mil. meter, regardless of the resistive value of the rheostat shunted across the meter. This safe overload limit suggests that, instead of using a fuse to protect the meter, we may introduce enough "limiting resistance" into the circuit to develop a potential drop of 29 volts, in the case of a short-circuited tube, leaving the safe value of 1.0 volts developed across the meter. A meter load of 100 milliamperes would produce a potential drop of 1.0 volt across the meter, and the circuit load would be limited to this value by a total circuit resistance value of 300 ohms, obtained by applying Ohm's law and dividing 30 volts by 100 milliamperes (0.100 ampere). Since the joint resistance of the meter and rheostat cannot exceed 10 ohms, this small value may be considered as negligible, and a 300-ohm resistor used as in Figure 45.

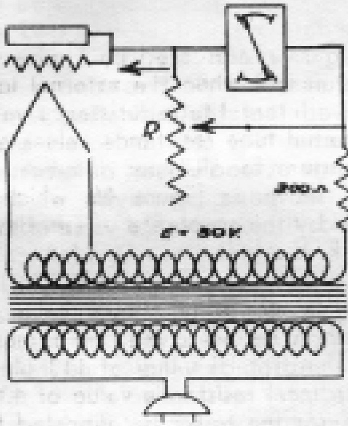


Fig. 45

The tube testing circuit represented by Figure 45 has the advantages of simplicity and safety; it has been used, with minor variations in several commercial tube tester tubes. In fact, the basic principles involved were incorporated in a so-called standard tube tester which was considered by all tube and tube tester manufacturers. Off hand, the average technician and most engineers who are not experienced in tube tester design problems, can see nothing wrong with the circuit and constants of Figure 45 as a tube tester of the emission type. What does the reader see wrong with it? The 300-ohm limiting or "load" resistor will reduce the potential applied to a tube, the amount of the reduction depending upon the conductivity of the tube; but that is not, in itself, objectionable; in fact, that may be desirable in some cases, so, what's the objectionable feature?

We have already observed, in our discussion of Figure 42, that any tube may be considered as having a definite resistance value under definite load conditions, so, let us analyze the test of a tube in which the effective internal resistance may be 600 ohms and which is subjected to test in the tester circuit represented by Figure 45. The ratio between the internal and external resistance values is, obviously, 600:300 or 2:1. When the tube depreciates to such an extent that it is just half as good as normal, its internal resistance will be about 1200 ohms; the ratio between the internal and external resistance values will then be 1200:300 or 4:1. The total resistance of the circuit, including that of the normal tube, was originally 900 ohms; after the tube resistance is doubled by depreciation, the total resistance of the circuit, including that of the depreciated tube is 1500 ohms. It is observed that, while the tube resistance has doubled by depreciation, the total circuit resistance has not doubled, so that the meter current will not be reduced in half; therefore, the meter reading will be deceptive, because it will indicate the tube as being better than it really is. If the same circuit with a fixed 300-ohm resistance value be used for testing a tube which has a normal internal resistance value of 100 ohms, the meter indication of a depreciated tube will be even more deceptive. With a 100-ohm tube, the ratio between the internal and external resistance values is 100:300 or 1:3; when the tube resistance is doubled the ratio is 200:300 or 2:3. Normally, the total of the two resistance values is 400 ohms; but when the internal resistance value of the tube is doubled by depreciation to a value of 200 ohms, the total circuit resistance is 500 ohms, or an increase of only 100 ohms in 400 ohms. If the meter reading before the tube is depreciated by 77 in the center of the "GOOD" sector of the meter scale of Figure 43, the meter reading, after the tube is depreciated, will be four-fifths of 77, or 61.6; or still in the "GOOD" sector of the scale, although the tube is only about half as good as it was and should register about 38.5. The error is different for each tube load, and is greatest when the tube resistance is less than the external circuit resistance. So, now we see what is wrong with the circuit of Figure 45.

It is obvious, from the analysis of the circuit represented by Figure 45, that the maximum degree of accuracy is obtainable when the external load resistance is considerably less than the effective internal tube resistance value of every tube, and that the ratio between internal tube resistance values and external circuit resistance values should be constant for all types of tubes; so, let us analyze the next tube testing circuit, shown in Figure 46, which is developed to incorporate these desirable features.

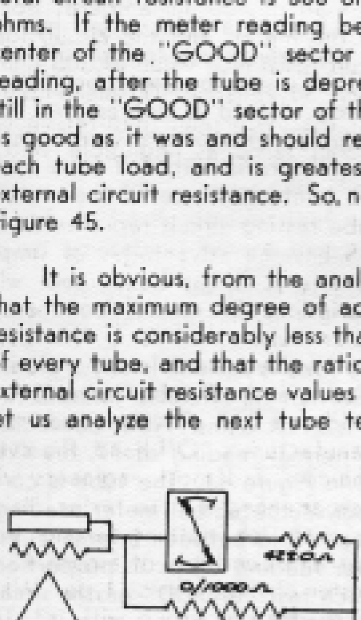


Fig. 46

In Figure 46, a resistance value of 4220 ohms is added to the 1 m. a. meter armature resistance value of 113 ohms, making a total resistance value of 4333 ohms. Since the tester is calibrated for normal tube readings at the center of the "GOOD" sector of the meter scale (shown in Figure 43), which is 77% of the full scale deflection, the current load is 77% of 1.0 milliampere, or 770 microamperes (0.00077 ampere). The current load of 0.00077 ampere multiplied by the total meter circuit resistance value of 4333 ohms produces a potential drop of 3.3 volts across the metering circuit, regardless of the setting required for the 1000-ohm potentiometer to produce a 77% meter scale reading. In other words, when the potentiometer setting is adjusted to accommodate the load conditions of any normal tube, with the meter pointer deflected 77% of its range, the potential drop across the meter is 3.3 volts, leaving 30 volts of the total potential value of 33.3 volts to be applied across the tube. Therefore, the ratio of the tube voltage to the meter voltage, or of the internal tube resistance to the external circuit resistance, is constantly 30:3.3 or 9:1 for any tube, regardless of the load.

Now, let's see what happens, in the circuit of Figure 46 when a short-circuited tube is encountered. Since there can be no potential drop across a short circuit, the 33.3 volt applied potential must develop across the metering circuit. With a resistance value of 4333 ohms and a full scale load value of 1.0 milliampere, the full scale potential of the meter is 4.3 volts. Since the meter can safely withstand 10 times its normal load an indefinite number of times, its overload potential limit is 43.3 volts, so that an applied potential of 33.3 volts, caused by a short-circuited tube, would be 10 volts under the safe overload limit of the meter.

Returning to our previous analysis of the test of a tube which has a normal internal resistance value of 100 ohms, and which was tested with an error of 60% by the tester shown in Figure 45, let's see how the tube tester circuit of Figure 46 will react to the same tube when it is depreciated to such an extent that its internal resistance is doubled. Keeping in mind that, when the tester is calibrated for normal tubes, the ratio between tube and circuit resistance is 9:1, we can determine the joint resistance of the meter and potentiometer, as follows:

$$9:1 = 100:x$$
$$9x = 100$$
$$x = 11.1 \text{ ohms}$$

Therefore, the total circuit resistance, when the tube is normal, is 111.1 ohms; and, when the tube resistance is depreciated so that its effective internal resistance is doubled, the total circuit resistance is 211.1 ohms. After depreciation, the meter reading will be 52.6% of the normal reading of 77, or 40.5 in the "BAD" sector of the meter scale shown in Figure 43. The tube is correctly classified as being "BAD", and the error in the actual meter reading is negligible. With this arrangement of balanced ratio between internal tube and external circuit resistance values, the meter reading drops in proportion to tube depreciation, so that "BAD" tubes which test "GOOD" on the usual tube tester types are correctly indicated as being "BAD".

29—DESIGNING THE 1937 SUPREME TUBE TESTER CIRCUIT FOR THE DeLUXE SERIES

With the announcement of the cold cathode type tubes, such as OZ3 and OZ4, which require 250 v. as a striking potential, another problem arose in test design We needed a variable anode potential to apply to these and possibly other types of tubes not as yet announced.

You will remember that with a fixed 30 volt potential, we required a certain amount of meter protection in case we attempt to test an accidentally shorted tube. Inasmuch as we may apply more than one value of cathode potential, we must have a different meter multiplier for each potential applied. The meter multipliers should be ganged with the Cathode potential taps on one multi-gang switch, so that when we apply a certain cathode potential, the proper meter multiplier is also included in the meter circuit.

As a result of this new design, our previous variable value of 0 to 1000 ohms for the meter shunt resistor must be expanded to some higher value.

and a variable Load Resistor included in series with the main testing circuit to comply with the Radio Manufacturing Association's suggestion as to Tube Testing loads.

The R. M. A. propose a standardization among tube tester manufacturers upon a single tube tester type and design, and, while there is nothing yet which may be construed as being definite, it is interesting to note that the **Emission Tester** was proposed as the basic tube tester **type.**

Among other proposals, the Radio Manufacturer's Association (which number among their members a majority of all manufacturers of radio apparatus, including tubes) proposes that study be given the inclusion of three standard tube tester load resistances.

1. 5000 ohms for diodes, exclusive of power rectifier tubes.
2. 1000 ohms for battery type tubes of limited emission.
3. 200 ohms for remaining types.

This may work out quite satisfactorily, and the natural progression in our tube tester design would be to include these three fixed values of resistance as loads in series with the tube testing circuit. But, let us suppose the R. M. A. finally decides that one or more additional loads are necessary, or even advisable. Where then would be our tube tester design?

Therefore, we have included a Variable Load resistance so that future changes may not render the tube tester obsolete.

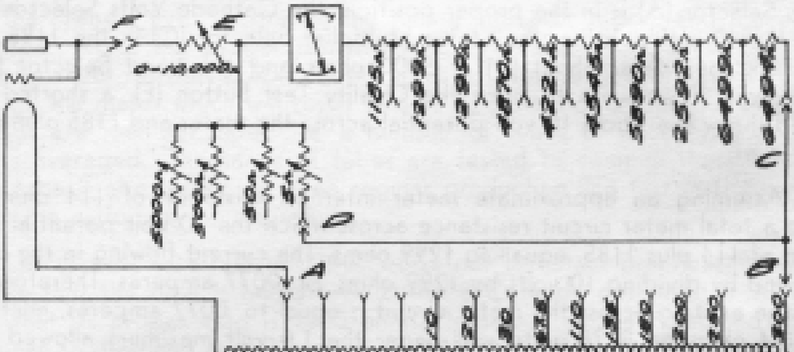


Fig. 47

Let us look at Figure 47 which is the result of this progressive step in tube tester design. The basic circuit seems quite familiar and is not, in basic design, unlike Figure 46. The Filament Volts Selector is shown at "A" and the Cathode Volts Selector is shown at "B". "C" is the variable meter multiplier selector, "D" the 4-gang potentiometer used as the variable meter shunt (called the "Quality Selector"), "E", the variable Load Selector, and "F", the switch which is to be closed to read the quality test.

It will be noted that the majority of the cathode potential taps (B) are standard voltages and vary from 10 volts up to 300 volts, so that any future required potential may be instantly available, although the R. M. A. suggests that, at present, the majority of tubes should be tested at a 30 volt potential.

As stated previously, meters in general are able to withstand overloads, which are 10 times normal full scale loads, so that we can safely assume that a 1 m. a. meter will withstand a 10 m. a. load, or stated in another way, a meter having an internal resistance of 100 ohms and a sensitivity of 1000 ohms per volt, will fully deflect when a 0.1 volt potential is applied across it and can, therefore, withstand a 1.0 volt potential. It follows, therefore, that we should include sufficient series resistance to drop the applied cathode potential, in case of a shorted tube, to a safe value of 1.0 volt across the meter.

We also found that the maximum degree of accuracy is obtainable when the total external load resistance is considerably less than the effective internal tube resistance value of every tube, and that the ratio between internal tube resistance values and external circuit resistance values should be as constant as possible for all types of tubes. Stated in terms of voltage, a circuit is most accurate when the potential across the external tube circuit is the largest value possible with reference to that which is applied across the internal meter circuit and when this voltage ratio remains as constant as possible for all tubes.

Let us analyze Supreme's newest tube tester circuit as included in the Models 500, 505 and 585, to ascertain whether these theoretical points have been included.

Assuming that a shorted tube is being tested, and that the Filament Volts Selector (A) is in the proper position, the Cathode Volts Selector ("B") is in the 10 volt position, the Meter Multiplier Selector (C) in the 1185 ohms position, the Meter Shunt (D) at 5000 ohms and the Load Selector (E) at zero ohms, if we were to press the Quality Test Button (F), a shorted tube would throw the whole 10 volt potential across the meter and 1185 ohm meter multiplier.

Assuming an approximate meter internal resistance of 114 ohms, we have a total meter circuit resistance across which the 10 volt potential is applied of 114 plus 1185, equalling 1299 ohms. The current flowing in the circuit is found by dividing 10 volts by 1299 ohms, or .0077 amperes. Therefore, the voltage existing across the meter circuit is equal to .0077 amperes, multiplied by 114 ohms or .8778 volts, well under the 1.0 volt maximum allowed overload potential. As a check, the voltage existing across the multiplier resistor is equal to .0077 multiplied by its resistance, 1185 ohms, or 9.1245, which is close enough to check as correct.

Now let us move the Cathode Volts Selector to the 20 volt tap which automatically moves the meter multiplier selector to the next tap as the switches are ganged. We now have a total meter circuit series resistance of 114 ohms plus 1185 ohms plus 1299 ohms, or 2598 ohms, by checking we will find that the same current still flows on this circuit and the drop across the meter is still .8778 volts. The balance of the meter multiplier ranges are calculated in the same manner.

Since the new circuit is calibrated (as were the previous circuits) for normal tube readings at the center of the "Good" sector of the meter scale (Figure 43) which is 77% of the full scale deflection, the meter current load would be 77% of 1 m. a., or 770 microamperes (0.00077 ampere). A current load of 0.00077 ampere multiplied through the total meter circuit resistance value of 1299 ohms (in the case of an applied potential of 10 volts) results in a potential drop of 1.0 volt across the metering circuit, regardless of the setting required for the particular meter shunt potentiometer to produce a 77% meter scale reading. Therefore, a 9 volt potential results which may be applied across the tube and load selector (E), and the ratio of the tube and Load Selector voltage to the meter voltage (i. e., of the internal tube and external "Load Selector" resistance to the external circuit resistance) is constantly 9 to 1. It will be found that this ratio holds true for all settings where the meter is adjusted to 77% full scale deflection, regardless of the Cathode volts, meter multiplier selector, load, or meter shunt selector settings. For the 20 volt Cathode potential setting, the potential applied across the meter is 2 volts, and for the 30 volt setting it is 3 volts, etc.

The Load Selector, as explained previously, was included in the circuit so that specific loads could be applied to each tube to obviate the possibility of damaging the tube by allowing it to draw excessive currents.

The actual settings for tube types are ascertained in our laboratory in the following manner:

First, the tube is inserted in the proper socket after adjusting the tube tester to the line and adjusting the Filament Volts Selector to the proper filament potential. Then, the "Test Circuit Selector" switch, combining the Cathode Volts Selector and the meter multiplier contacts, is set to the proper voltage, (30 volts for all tubes with the exception of the cold cathode types and the "Magic Eye" section of the tuning indicator tubes), and the "Load Selector" set to the proper resistive load. A value of "Quality Selector" (a meter shunt resistor) is now chosen so as to allow sufficient current to flow through the meter which will result in a 77% deflection of the meter. These settings are then tabulated for a number of tubes of each type and the results averaged. Thousands of tubes are tested to compile these lists and each tube is also tested on three regular production line test instruments to check the uniformity of the results.

Let us now ascertain how this works out in actual practice. We shall assume that the tube is being tested with a Cathode potential of 30 volts, and, that its proper load is 1000 ohms. Inasmuch as the combined circuit has been so designed as to allow only 1/10 of the total potential drop across the metering circuit proper at 77% full scale deflection, 9/10 of the applied voltage, or 27 volts, is applied across the tube and external load resistor under these conditions. By reference to Figure 48 we see the various meter shunt settings from 0 to 5000 ohms, which will allow a constant 3 volt potential drop across the meter circuit at 77% deflection, regardless of the amount of current flowing through the main circuit.

The effective internal resistance of the tube plus such external load as might be added is also given in Figure 28 against the current such a circuit would pass, being connected across a potential of 27 volts.

Lastly, Figure 28 lists the proper ohmic meter shunt setting to deflect the meter 77% of full scale for each effective internal tube and external load resistance value from 45 ohms to 20,000 ohms, using a 30 volt total applied potential.

Let us assume that this tube which we are testing has an internal resist-

METER SHUNT SETTINGS FOR EACH TUBE AND LOAD RESISTANCE

Total Current	Tube and Load "R"	Total Meter Circuit "R"	Meter Shunt "R"
1.3	20770	2307	5660
1.4	19286	2143	4762
1.5	18000	2000	4109
1.6	16875	1875	3614
1.7	15882	1764	3225
1.8	15000	1666	2912
1.9	14210	1579	2655
2.0	13500	1500	2440
3.0	9000	1000	1345
4.0	6750	750	929
5.0	5400	600	709
6.0	4500	500	573
7.0	3857	429	481
8.0	3375	375	415
9.0	3000	333	364
10.0	2700	300	325
20.0	1350	150	156
30.0	900	100	103
40.0	675	75	77
50.0	540	60	62
60.0	450	50	51
70.0	386	42.9	44
80.0	338	37.5	38
90.0	300	33.3	33
100.0	270	30.0	30
200.0	135	15.0	15
300.0	90	10.0	10
400.0	67.5	7.5	7.5
500.0	54.0	6.0	6.0
600.0	45.0	5.0	5.0

Fig. 48

ance of 13,500 ohms when good, which would allow 2 m. a. to pass through the total meter circuit. If this resistance doubles, the effective current through the total circuit will be 27,000 ohms, effective internal tube resistance plus 1500 total meter circuit resistance, or 28,500 ohms divided into 30 volts, or .00105 mils. This total current flowing through both the meter shunt and the meter will produce a voltage drop across the total meter circuit of 1.575 volts. The current flowing in the meter circuit proper (meter and meter multiplier) will be found by dividing this voltage of 1.575 volts by the 3897 ohm resistance of the meter circuit proper, resulting in a current flowing in this circuit of .000404 mils., resulting in a meter needle deflection in the bad portion of the meter scale. The various values of resistance have been so chosen as to result in a Bad Tube being checked as "Bad", and a Good Tube as "Good".

30—DESIGN OF THE 1937 SUPREME TUBE TESTER CIRCUIT FOR THE STANDARD SERIES.

The 400 Series tube testers vary from the 500 series tube testers more in mechanical than electrical design. Their basic circuit is given in Figure 49

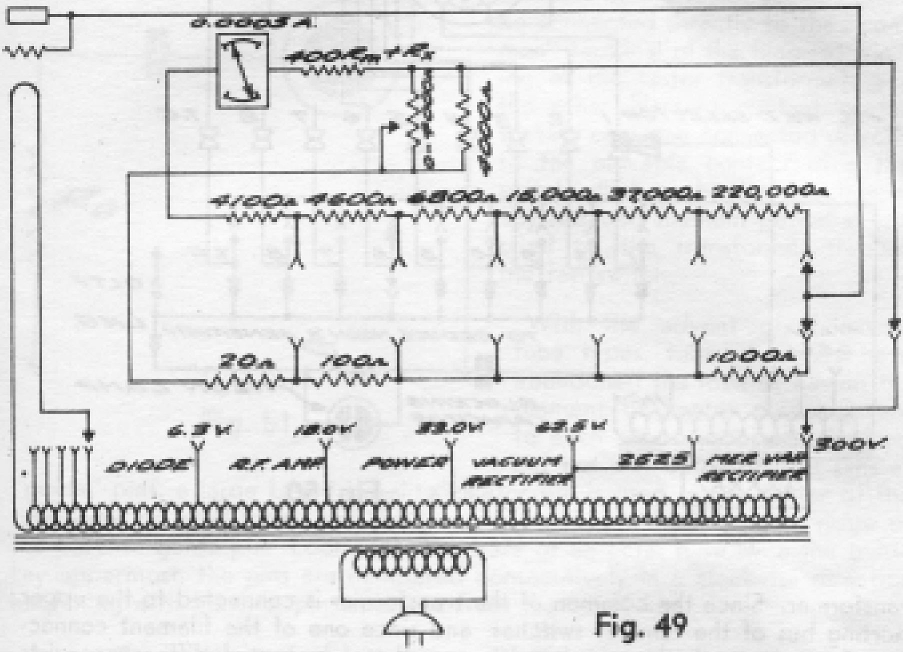


Fig. 49

and it will be noted that, aside from certain changes in potentiometer values and available potentials, the circuit is much the same. Mechanically, the Fan-Shape Meter is used in place of the quadrimeter, throw toggle switches are used instead of slide toggles, and a bakelite panel is used in the place of a metal panel.

31—DESIGNING THE TUBE LEAKAGE TEST CIRCUIT

Figure 50 is a simplified diagram of the "leakage" circuit of the 500 series, and it will be seen that the neon lamp is shunted by a resistor, the purpose of which is to limit the sensitivity of the lamp in order that permissible tube leakages over 100,000 ohms will not be indicated. The circuit also includes a capacitor in series with the lamp to make it responsive only to leakage potentials through the tube under test, and to prevent it responding to rectified potentials.

Under operating conditions, with a tube in the socket (Figure 50), we have the "Filament Return Selector" switch set in the No. 1 position which is one of the filament terminals, and tumbler switch No. 6 set in the "UP" position—connecting the filament to the transformer as explained in Section 33. The other elements of the tube are connected together by virtue of the fact that all the other tumbler switches are in the "DOWN" or normal position, and are connected by the shorting bus to the neon lamp—which is, in turn, connected through its blocking capacitor to the 110 volt tap of the

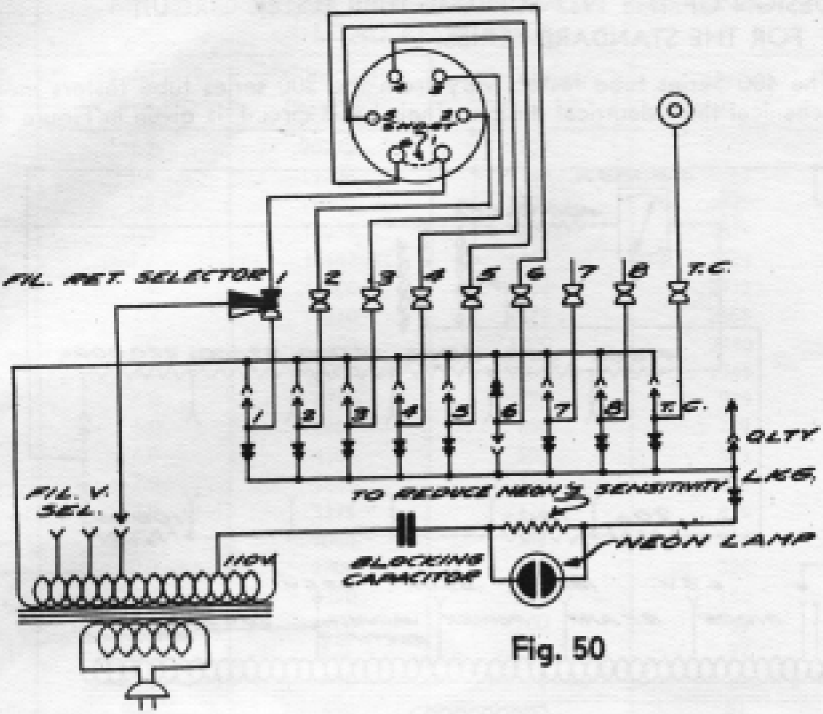


Fig. 50

transformer. Since the common of the transformer is connected to the upper shorting bus of the tumbler switches, and since one of the filament connections is made to that bus, it will be seen that a potential difference exists between the filament and all other elements, the neon lamp being in series with that potential, and any short circuit or high resistance leakage between the filament and any element will cause both plates of the neon lamp to glow. Similarly, if a short circuit or leakage exists between any other two or more elements, it is only necessary to place the tumbler switch, corresponding to either of the elements involved in the "UP" position and the glow of the neon will reveal it.

For example, assuming that a short exists between elements No. 2 and No. 5 in Figure 50, the neon lamp will glow when No. 2 tumbler is "UP", and again when No. 5 tumbler is up, but will not glow when both No. 2 and No. 5 are in the same position—namely both "UP"—or both "DOWN".

In the Supreme 400 series, a similar switching circuit is used, but instead of a 2 watt neon lamp, a 1/10 watt neon lamp is used as shown in Figure 51. The additional Resistance (R_o) is used to drop the sensitivity of the smaller neon lamp so that it will not register tube leakages over 100,000 ohms.

32—THE "FILAMENT RETURN SELECTOR SWITCH"—EARLY TYPE

For a number of years, the design of tube testing apparatuses presented no serious problems insofar as the application of filament or heater potentials was concerned. This was because the filament pins of all popular types of

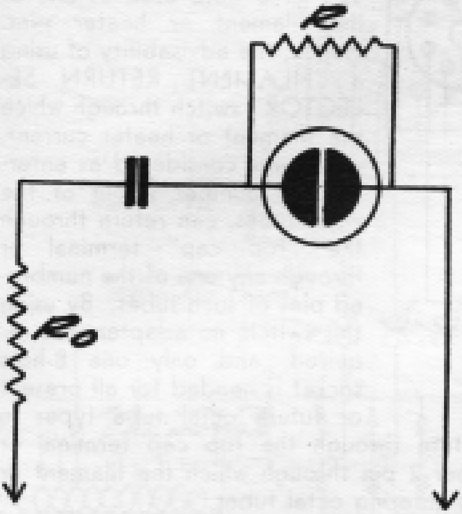


Fig. 51

tubes, prior to the advent of the new octal tubes, were adjacent to each other, usually larger than the other pins, and served as "guide" pins, so that one of the filament contacts of the tester sockets could be connected directly to the "common" terminal of the filament winding of the tester transformer, and the other filament contact of the sockets could be connected directly to the movable contact of a tap switch which enabled a selection of any required filament potential supplied by the transformer through the tap switch.

With the advent of the octal tube types, tube engineers have abandoned the idea of having the filament or heater pins adjacent to each other, and instead of using the filament or heater pins as "guide" pins, a large keyed bakelite locator pin is used in the center of the tube base of octal tubes and the pins are numbered from the key ridge of the bakelite guide pin. Looking at the base of an octal tube, with the guide key uppermost, the pins are numbered consecutively in a clockwise direction beginning with the first pin clockwise from the guide key.

For the better part of last season, the established practice was to use the No. 1 pin to terminate the metal shield and the No. 2 pin as one of the filament or heater pins. The other filament connection might then terminate at any pin from No. 3 to No. 8 inclusive, or even terminate at the top cap position. This meant that, if a single 8-hole socket was to be used in which to test all elements of all octal tubes, it would be necessary to select the contact of the octal tube to which the "roving side" of the filament potentials may be applied, in addition to selecting the filament or heater potential to be applied; otherwise, a separate 8-hole socket or adapter would have to be added for each new pin combination.

The filament or heater circuits terminate at what are known as the pins numbered 2 and 7 on the octal tubes which were included in the preliminary announcements of metal tubes. Subsequently, the metal tube type 5Z4 was announced with a filament circuit term terminated by pins numbered 2 and 8, and a later type (6P7) was announced with a heater circuit terminated by pins numbered 2 and 3, so that a tester socket in which the filament or heater potentials are applied to the contacts numbered 2 and 7, only, cannot be used for testing the later types in which the filament is terminated by pins numbered 2 and 3 or 2 and 8.

If the "Filament Return Selector" circuit as shown in Figure 52, or its equivalent, were not used, three 8-hole sockets would have been required to enable a test of all of the elements of this group of octal tubes, and the tester would be partially obsolete in the event a metal tube were announced

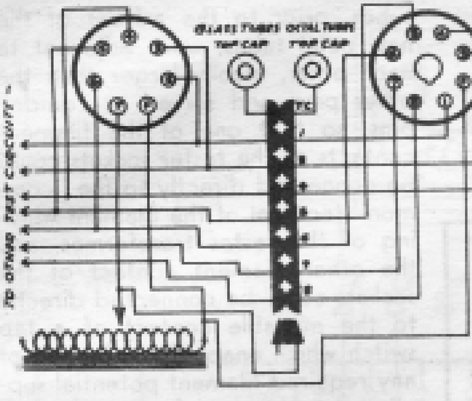


Fig. 52

in which neither pin numbered 3, 7 or 8 were used as one of the filament or heater pins. Hence, the advisability of using a "FILAMENT RETURN SELECTOR" switch through which the filament or heater current, which was considered as entering the number 2 pin of the octal tubes, can return through the "top cap" terminal or through any one of the numbered pins of such tubes. By using this switch, no adapters are required, and only one 8-hole socket is needed for all present or future octal tube types in which the filament currents may return through the top cap terminal or through any pin other than the number 2 pin through which the filament or heater currents may be considered as entering octal tubes.

Subsequently, the type 5X4 and the type 5Y4 were announced on which the filament connections were made to the No. 7 and No. 8 pins. With remarkable foresight, Supreme Engineers had so arranged this previous circuit, that it was only necessary to depress an extra tube test button on the panel together with the push button to be depressed for the Quality Test and these tubes can also be tested on last year's models of tube testers. This previous tube test circuit was so arranged that all elements were permanently connected to the "plus" side of the "quality test" supply circuit, through the top contacts of separable push buttons for each element. By depressing any one or more push buttons, connection was broken from the "plus" side and connected to the minus side of the "Quality Test" supply through bottom contacts of these push buttons. Therefore, to test 5X4 and 5Y4 tube types, it was only necessary to set the "Filament Return Selector" switch to the No. 7 position and depress the regular cathode push button **and the No. 8 push button!** Thus, these tube checkers are still able to check **every hot cathode emitting type** receiving tube on the market today, a remarkable proof of Supreme's ability to ward off that perennial buggaboo—obsolescence.

33—NEW FILAMENT RETURN SELECTOR CIRCUITS

Due to the probability that future vacuum tubes will be developed with their filament or heater connections terminating at **any** two pins on the tube base, it was considered advisable to provide in the design of this year's tube testers some switching arrangement whereby any two base pins may connect to the filament supply potential without the necessity of actually holding several buttons simultaneously in a depressed position. Such a unique switching arrangement is incorporated in the new Supreme tube testers, and it is interesting to note the change from the momentary push button type switches of previous models to the sliding toggle switch as used in the 1937 series of Supreme testers.

Figure 53 is a diagram of the filament switching circuit and it will be

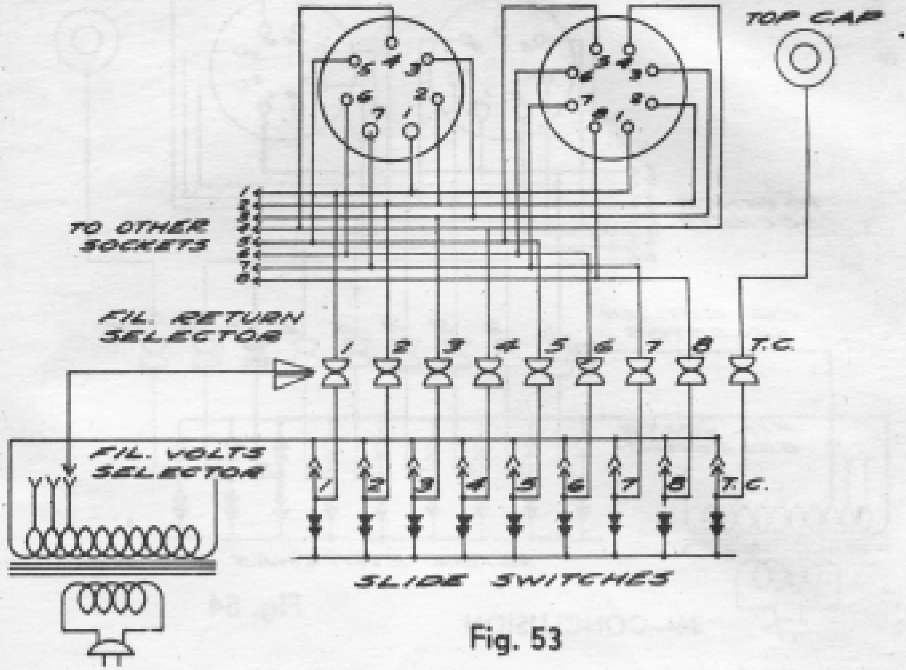


Fig. 53

noted that the sockets connections are all wired in parallel to the contacts on one side of the "Filament Return Selector" switch, all No. 1 pins connect to the No. 1 contact, No. 2 pins to the No. 2 contact, etc., the contacts on the other side of the "Filament Return Selector" switch are connected to the center arms of the tumbler switches—No. 1 to No. 1, No. 2 to No. 2, etc. One side of all the tumbler switches are connected together and wired to the common of the transformer secondary, while the various taps on the transformer are wired to the "Filament Volts Selector" switch, the common arm of this switch being, in turn, wired to the common of the "Filament Return Selector" switch on the side that carries the connections to the sockets.

Figure 54 is a diagramic representation of the circuit with the connections completed, by switching, for a tube with its filament terminating in pins No. 1 and No. 7. It will be seen that the "Filament Return Selector" switch has been placed in the No. 1 position, connecting the No. 1 pin through the "Filament Return Selector" common to the "Filament Volts Selector" common which has been placed on one of the taps of the transformer, the connection being completed through the transformer winding to the transformer common, and thence to the common bus of the tumbler switches to switch No. 7 which has been placed in the "UP" position, allowing the current to flow to the No. 7 pin of the socket through the No. 7 contacts of the "Filament Return Selector" switch.

From Figure 54 it will be seen that any two socket pins, or any one pin and the Top Cap, may be used as filament terminals by merely setting the "Filament Return Selector" switch to the position that corresponds to one of the pins, and moving to the "UP" position the tumbler switch that corresponds to the other pin, and applying the proper filament potential by means of the "Filament Volts Selector" switch.

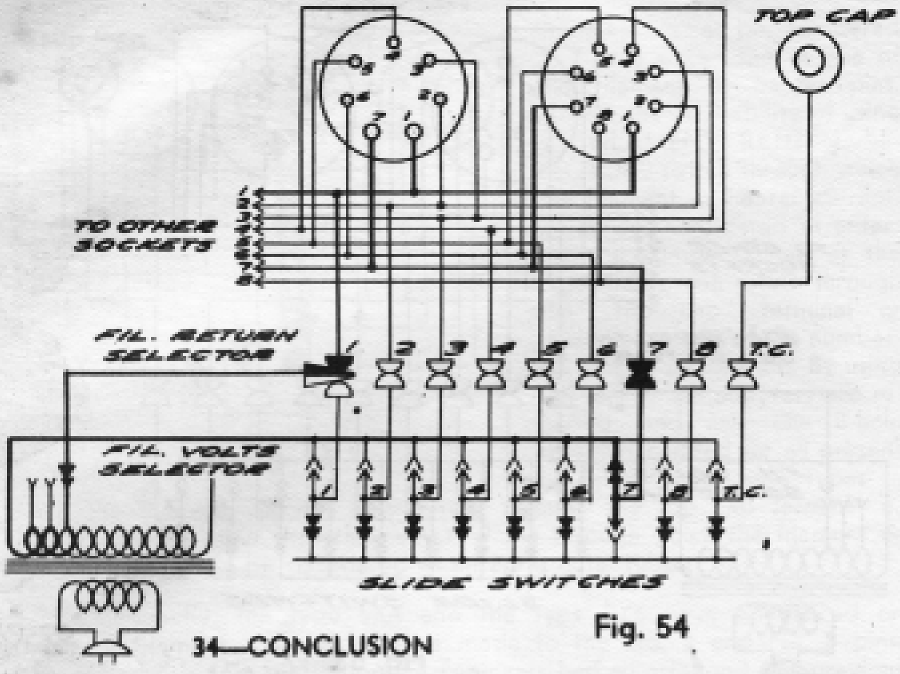


Fig. 54

34—CONCLUSION

In the foregoing chapters, we have attempted to give you a general idea of the enormous amount of time and effort necessary to correctly design only the electrical portion of a commercially satisfactory tube or radio tester. We have not mentioned the Mechanical Engineer's part in the solving of many perplexing problems dealing with size, weight, materials, etc. We have not mentioned the keen artistic ability necessary to design a tester panel and parts so arranged as to combine (1) Ease of operation, (2) Beauty through a harmonious balance of the parts on the panel and (3) Physical balance of the parts under the panel for ease in carrying. We have not mentioned the part played by the Purchasing Engineer who must purchase parts according to rigid specifications and yet purchase them at a price which will result in the biggest saving to the ultimate instrument user. Nor have we mentioned the keen-eyed inspectors who impartially test **every** incoming part and refuse to pass such parts as do not "measure up" to inflexible specifications—the Production Department which, with speed and precision, builds each instrument so that it is a mass production unit fabricated as if it were custom built—the Test Department where all finished testers are given complete tests by not one—but **two** and sometimes **three** men, before packing—the Shipping Department—the Stock Keepers—the Executive personnel—the Service Department—your Parts Jobber who stocks the finished instruments for your immediate call—the thousands of individual efforts, which, combined in a finished instrument—result in one mighty effort to give you the very best in quality for the very least in price.

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EXPORT DEPT., ASSOCIATED EXPORTERS CO., 145 WEST 45TH STREET, NEW YORK CITY, N. Y.
CABLE ADDRESS, LOPREH, N. Y.

Printed in U.S.A.