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SERVICING WITH SET ANALYZERS

**A Study of the Theory
and Proper Application
of Modern Set Analyzers
and Associated Apparatus**

by H. G. McEntee

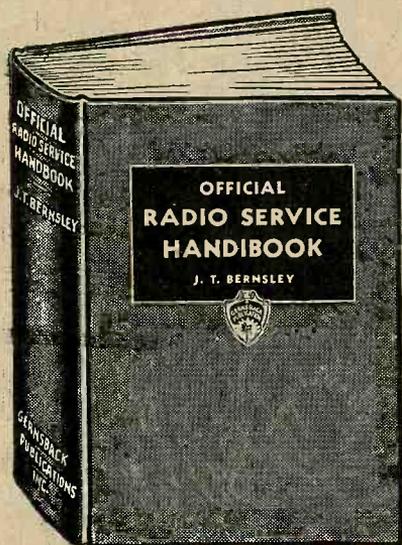


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By J. T. Bernsley



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SERVICING WITH SET ANALYZERS

CHAPTER I

Introduction

Year by year, as we progress in radio we find new equipment and new methods being developed and perfected for testing and servicing. Much of this new equipment is forced upon us by the engineering progress that is constantly being made in the field of radio receivers. The set which is now an open book to the well versed Service Man would have been a complete mystery to the repairman of not so long ago. We have progressed from the time when all sets used only one kind of tube, the triode (and not very many of these), to the point where we now use tubes, some of which have as many as *nine* separate elements in one bulb. We now have over two hundred tube types, and more are being added each month to this huge list. Only a very few of these may be used interchangeably, and most of them are suited for but a single purpose. Many of the tubes are able to perform more than one duty by virtue of their multiple element construction. Thus, the type 6Q7, is the equal of three tubes, since it has a triode and two diodes in its shell. Many sets are designed with several of these multi-function tubes in the line-up.

We find that, as a general rule, radio sets are designed according to their tube requirements. Hence, we should endeavor to test them and make our analysis from the same viewpoint. While it would be asking too much of any Service Man to expect him to memorize every tube with all its characteristics, it is possible and in fact imperative that the general classifications, such as converters, R.F. amplifiers, audio pentodes, and the like be understood. Also, the Service Man should be thoroughly familiar with the main arbitrary classification of all tubes, that is, by filament or heater voltage ratings. Thus we have the 2 volt line, the 2.5 volt line and

the 6.3 volt line, with several others which are not found very frequently and are of little importance today. An effort should be made to keep all the latest tube data of each manufacturer on hand, so that when a new tube is encountered, no time will be lost in searching for its characteristics. When a set is to be analyzed, then, and the proper readings are not obtained at any one tube socket, an understanding of that tube and its associated circuits will lead to speedy correction of the trouble.

New wrinkles and methods are brought out from time to time in the line of servicing procedure. The most recent of these is the so-called "point-to-point" method. While it is not as rapid and is considerably more involved than employing a complete analyzer and checking voltages from the socket by means of a connector plug it is, however, more convenient for those who are not familiar with circuit design, and therefore cannot make an accurate deduction when the meter readings are not correct. Also, it is the only method whereby deep seated or obscure troubles can be located—and is generally employed by the efficient Service Man as a supplementary method of ascertaining the location of trouble after the analyzer is used. The equipment employed for "point-to-point" tests is, usually, a multi-calibrated sensitive meter having various D.C. voltage scales, in addition to an "ohms" scale for resistance measurements. Two test prods are employed, and voltage or resistance measurements are taken across various parts of the receiver until the trouble is found.

The new testing equipment has provision for limited point-to-point testing built into it in the form of the "free reference point" switch system. Former analyzers always measured voltages between the tube terminals and some common point, such as the tube cathode or ground. By means of the

new system, however, the reference or common point may be shifted, by means of the proper switches, so that the voltage (and in some cases the resistance) may be measured between any two tube terminals, this being done rapidly and right at the tester, without having to break into the receiver.

Since modern radio receivers are so vastly different from those which were constructed from 1923 to 1926—the precision and servicing care necessary now is also of a much higher order. The equipment, as described, is comparable to that of the laboratory in efficiency, and permits both rapid and accurate determinations of trouble.

The circuits used at present are infinitely more complex than those that were used even a few years back. The widespread use of multi-function tubes adds to the confusion also, for in the older sets a certain tube could safely be assumed to be doing one job only, while at present a single tube may be employed for three or more unrelated functions. A description of a relatively simple set will prove this point. We will take as our example a set of the so-called A.C.-D.C. classification which has a total of six tubes. This set is of the "all-wave" type so we are greeted at the start with a complex array of coils, thirteen in number, and a switch to select the required band. Next in line is a multi-function tube, the 6A7, which is both oscillator and mixer. This is followed by a 78 tube as the I.F. amplifier, then another multi-purpose tube, the 75. This one performs three distinct operations. It is the second detector, the first A.F. amplifier, and the generator of A.V.C. voltage. The second A.F. tube is a 43, a pentode amplifier. The power supply is quite simple in this type of set, since there is no power transformer. However, this fact immediately leads to more complications, for the designer has used the 25Z5 rectifier tube as a voltage doubler in order to secure a higher voltage. The final tube, also made necessary by the lack of a power transformer, is a "ballast" tube, which is nothing more than a resistor enclosed in a bulb. So here we have a "simple" set in which three of the six tubes perform multiple functions. How is the Service Man to "shoot trouble" in such equipment, and do the job in such time that he will make a reasonable profit for his pains? The only possible answer is through the use of the

latest and most efficient type of analyzing equipment.

While we will not attempt to discuss the theoretical design of receivers here, it will be apparent to all that the removal of any tube or tubes from their sockets will disturb the voltage distribution to all other tubes in the receiver. In the older types of receivers it was almost the invariable custom of designers to include in the power supply circuit a fairly heavy wire-wound resistor, called the "bleeder", from which the various voltages needed for the tube elements were obtained by means of taps. This stabilized the circuit to a certain extent, since the current through the bleeder was fairly high, so that if a tube was removed, the overall voltage change in the circuit was not very great. The present tendency seems to be to eliminate the bleeder resistor, and to supply all voltage needs by means of series resistors directly from the high voltage lead. This newer method of voltage distribution has the advantage that each individual tube element may be supplied with exactly the correct voltage, but it also introduces difficulties in measuring these voltages. When an analyzer is applied to the tube terminal supplied by a series resistor, the current drain of the meter in the analyzer causes an additional voltage drop in the resistor, which must always be taken into consideration. Where the resistors are of a high value, such as those used in the plate circuits of audio amplifiers, the drop is so high that the readings are not to be trusted in most cases, and we must turn to other means of measuring the functioning of that particular circuit. This is one of the limitations of present analyzers, but as long as it is thoroughly understood, no harm will be done.

The value of an analyzer depends upon the fact that nearly every form of trouble in a radio set manifests itself in irregular voltages or currents.

When a Service Man arrives on the job after receiving a call, he should first satisfy himself that the trouble lies in the receiver itself. If the symptoms seem to indicate that tubes are bad, they should be tested first; merely because that is the easiest operation to perform and, usually, indicates the greatest source of trouble. If defective tubes are found, they should be immediately replaced by good ones before any other tests are made.

Plate, screen-grid and control-grid volt-

ages should then be measured, and the value checked by reference to manufacturers' data or tube charts. (The Service Man should make it a point to always have such information with him for reference purposes.) If it is found, for instance, that only one tube has no plate voltage, then reference should be made to the circuit diagram, to determine what can possibly cause the lack of voltage on the particular tube in question. Do not jump at conclusions; but conduct a systematic test from the tube's plate through every single piece of apparatus in that plate circuit, right down to the power unit. In this manner the defective piece of apparatus is bound to be checked.

On the other hand, if, to take another instance, three tubes that should have the same voltage have none, then the trouble lies either in the power unit, or else in a piece of equipment that is common to those three tubes; and the attention of the repair man should be directed accordingly.

Abnormally high plate or screen voltages usually mean that the grid bias or "C" supply for the affected tube has failed. This is especially noticeable in any tube whose plate supply circuit does not include a high resistance. A tube that is resistance coupled to the following tube will not show this high plate current because the increased current causes a large voltage drop through the resistor. In this case, however, other symptoms are readily apparent, for the resistor will probably show signs of overheating.

Often a thorough check of the tube voltages and currents shows that everything is correct. It is then necessary to trace through the set until the defective stage is found, and to test every piece of equipment in this stage until the poor unit is isolated.

This general analysis, which will be discussed in detail in another chapter, illustrates the absolute necessity of a device which will facilitate the measurement of tube voltages and currents and permit the testing of individual pieces of equipment. These fundamental essentials are to be found in modern analyzers. With modern competition in the field, rapid accurate service is not only desirable but absolutely essential, if a Service Man is to get a livelihood out of his business. A modern radio set analyzer is the only piece of equipment that affords the necessary ease and rapidity of operation.

From the above it may seem that all that one has to do is to plug in his analyzer, manipulate a few buttons, and the trials and tribulations of the receiver will be laid bare. This is not so. The only thing that can be expected of any analyzer is that it shall be a means for conveniently measuring the various voltages and currents at any tube socket with the tube connected to the socket. The interpretation of the readings is left to the Service Man himself. However, by proper reference to tube charts and circuit diagrams, coupled with a little knowledge and common sense, the average Service Man can locate trouble in a relatively short time.

There is often confusion in the minds of some as to just 'what is an analyzer?' In the strictest sense we might say that an analyzer is an instrument for testing voltages and currents at the tube sockets of a receiver. However, common usage has expanded the term to include various supplementary equipment, so that the modern analyzer often contains a tube tester, capacity and resistance (and often inductance) tester, a service oscillator, and other such equipment. This is a measure of economy, since the most expensive part of the analyzer, the meter, is used in the other circuits as well. It also makes for compactness, a feature that the Service Man greatly appreciates after lugging the usual heavy equipment around on his daily calls.

One of the most desirable advantages of an analyzer, aside from its primary function, is its ability to test tubes. The correct method of tube testing has long been a question of dispute. In this connection, the Service Man is usually not in a position to expend large sums of money on elaborate bridges which accurately measure such characteristics as mutual conductance (incidentally now, by the recent ruling of the I. R. E. "mutual conductance" has been changed to "transconductance", S_m), A.C. plate resistance, amplification constant, etc. The Service Man is, usually, only interested, so far as tube checking is concerned, to know whether the emission is normal. For a transconductance test, the same instruments are usually employed but a calculation is necessary. (This will be explained in a succeeding chapter.) As an added feature, most analyzers have arrangements which permit the use of each instrument, independently of the analyzer. This is a very useful device; especially if

tests are to be made on the bench aside from regular receiver work.

A small 3.0 to 4.5 volt "C" battery is housed in most analyzers, in order to permit the use of one of the voltmeters as an ohmmeter; the scale of the meter is then directly calibrated in ohms. This feature is a distinct advantage, where resistor replacement is necessary. Some manufacturers have even gone so far as to include calibration charts for inductance and capacity measurements on the A.C. milliammeter scale when such a meter is included in the analyzer.

It is in the nature of things, that different manufacturers should include various incidental refinements which they believe valuable (some of which have already been mentioned and will be discussed in detail later) with the result that the Service Man is usually at a loss to determine just what kind of an analyzer to secure for his purpose. Unfortunately, another man's advice usually does not apply to a particular case, and the Service Man is usually left to choose for himself. His choice will probably be determined first by the amount of money he has available to spend, and then by his requirements.

A few of the more costly instruments include an all-wave test oscillator which is built right in. Most active Service Men, however, prefer to have this instrument separate, as it adds considerable weight and bulk to the already unavoidably large analyzer. It goes without saying that it is

absolutely necessary for the Service Man to possess a test oscillator, since the servicing of superheterodynes, which are greatly in the majority now, demands the use of such equipment.

There are other pieces of apparatus which are often included in the larger commercial set analyzers, and which for that reason we must mention here. For example, when a test oscillator is used to align a receiver, some sort of meter must be used to note the results of the aligning operations. The human ear is a very poor judge of sound intensity, therefore some sort of instrument is needed to record accurately the changes in adjustments as they are made. The so-called "output meter", which is nothing more than a low current drain A.C. volt-meter which records the output of the set resulting from the use of a tone modulated test oscillator. In most cases the D.C. meter in the analyzer is used in conjunction with a small copper-oxide rectifier, as this combination draws very little current, and obviates the necessity of a special meter for the purpose.

Other supplementary equipment which is used to test receivers, in conjunction with the analyzer will be described briefly in another chapter, as it is felt that the Service Man should have at least a general understanding of equipment such as the V.T. voltmeter, the oscilloscope, the test oscillator and such apparatus.



CHAPTER 2

Analyzer Fundamentals

The modern analyzer must be designed with several fundamentals in mind. First, it must be capable of performing every task that the Service Man will require of it in his daily rounds. Since it must be carried by hand a great deal of the time it should be as light and compact as it is possible to make it, without sacrificing any of the necessary features. It is usual to provide a small space in the instrument case itself for carrying the associated cable and all the adapters that go with it, as well as test leads and any other equipment required. It used to be the practice to carry tools as well in the analyzer case, but the instruments have so expanded in size and complexity that there is now little room for such accessories. Indeed, the worry of the designer is to make the apparatus small enough to be called portable, and yet be capable of doing everything the present day Service Man wishes.

The final point to consider is that the circuits should be made as near foolproof as possible, that is, it should not be possible to ruin any of the apparatus by operating the wrong switch. This can be carried only to a certain point, of course, since no matter how perfect the circuits are worked out, if the user has the voltmeter set to the 10 V. scale, and the meter is inadvertently connected across a 500 V. supply, some damage is sure to be done. In this connection, low current fuses are sometimes used and are quite effective in preventing meter damage.

The Switches

Analyzer switches have to perform without failure a multitude of functions. They must be very carefully constructed, since all action of equipment is dependent upon them. The contacts must close positively and the contact resistance must be very low, and as nearly uniform as possible.

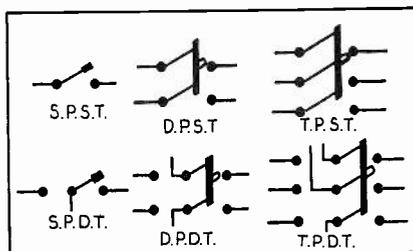


Fig. 1. Types of switches used in analyzers. These are knife switches.

All the better switches now used have either solid or plated contacts of some metal such as silver.

There are so many kinds of switches used that it is an impossibility to describe them all. An attempt will be made to discuss some of the more commonly used types, so that the reader may become familiar with the methods used in switching.

Diagrams of some of the more widely used knife switches are shown in Fig. 1. The abbreviations used are standard and are listed below for convenience.

- S.P.S.T.—Single-Pole, Single-Throw.
- S.P.D.T.—Single-Pole, Double-Throw.
- D.P.S.T.—Double-Pole, Single-Throw.
- D.P.D.T.—Double-Pole, Double-Throw.
- T.P.S.T.—Triple-Pole, Single-Throw.
- T.P.D.T.—Triple-Pole, Double-Throw.

Knife switches are rarely used in analyzer construction; not because they are inefficient, but because of the great deal of space required to house and manipulate them. The basic principle of switching is the same, regardless of the mechanical arrangement of the switch.

The type most commonly used in analyzers is shown in Fig. 2A; this switch, known as a push-button type, is composed of four blades a, b, c and d. Blades a and c are tied together by a bakelite strip k. When the button S is pushed in, the

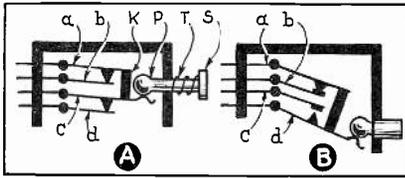


Fig. 2. Push buttons operate these switches. They are quite compact.

plug P pushes down blades a and c; so that blade a makes contact with blade b, and blade c with blade d. When the finger is released from S, the spring T removes P from the blades, and both circuits are open. It is seen that this switch is similar in action to the D.P.S.T. knife switch of Fig. 1. This type of switch (sometimes called a Jack Switch) is very small, rapid of operation and quite fool-proof.

This jack or push-button switch may, by simple mechanical changes, be made to perform a variety of purposes. For instance, Fig. 2B shows a push-button switch which opens one circuit at the same instant that it closes another. It may sometimes be desirable to open one circuit a little before the second circuit closes; this can easily be accomplished by making the contact on blade d of Fig. 2B slightly shorter than that on blade a. By having a sufficient number of blades, it is possible to switch a multiplicity of circuits simultaneously.

Another type of switch that is widely used is the so-called rotary type. Several variations of this are shown in Fig. 3. The first shown at Fig. 3A is the simple tap switch which, in this case, enables us to connect one lead to any of 5 others. This is not as flexible as is required in some circuits so the scheme at Fig. 3B is used. Here either side of the circuit may be connected to any of 5 other leads, enabling a much wider range of use. As the switches are shown, it is necessary to

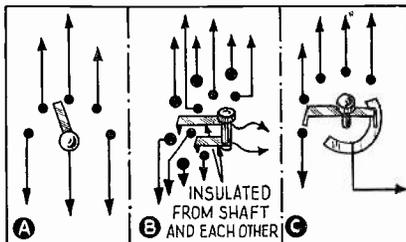


Fig. 3. A few of the simpler types of rotary switches. Several arms may be used.

make connection to the arm by means of a flexible lead. This is very undesirable, as such leads cannot be used for long without breaking. Therefore, connection is made as at Fig. 3C, the end of the arm opposite the taps being shaped so that it rubs on a semi-circular plate, the connection to the circuit coming from this plate.

To enable still wider application, the switches are arranged in "decks", one switch and set of taps to a deck. These decks are piled up one above another, so that all the switches may be operated by one common shaft. This arrangement is used in most present day equipment, as it enables the greatest variety of circuit changes for the least space.

We have heard it truthfully said that switching is one of the most interesting problems that the layman can find in electrical work. It taxes the ingenuity of the mind, without requiring detailed technical knowledge. No better examples of switching technique can be given than those employed in the modern set analyzer. At this time we

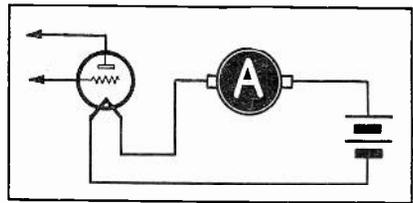


Fig. 4. Measuring filament current.

will not enter into a detailed account of the possible switching arrangements which are obtained with the types of switches described heretofore; as that will be treated at the end of this chapter, when we show how a simple analyzer is to be designed.

Suffice to say that it is possible to design a switch for almost any imaginable circuit arrangement. Some of these will be presented from time to time as the occasion arises.

The Milliammeter

The milliammeter is the basis of virtually all measuring equipment used in the set analyzer and associated equipment. For this reason, we will try to detail the actual theory of operation as much as possible in the limited space available.

Stated fundamentally, every kind of electrical instrument (whether it be a voltmeter, ammeter, wattmeter, etc.) works

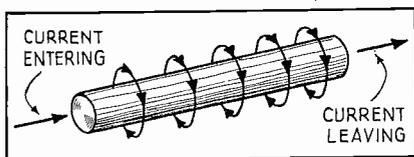


Fig. 5. Current passing through any coil of wire produces a magnetic field.

simply because an electric current is flowing through it. As an example, assume the battery of Fig. 4 to be lighting the tube connected to the battery. If it is now desired to measure the current passing through the filament of the tube, an instrument called an ammeter is inserted, in either leg of the line, as shown at A. Now it does not matter in which leg of the line the meter is inserted; since it will read the same in either case, because the current coming out of the battery into the filament must be exactly the same as the current coming out of the filament at the other end, into the battery. Stated in another manner, the filament and the meter are connected in series across the battery terminals. Furthermore, it is a universal law that the value of the current in a series circuit is the same throughout each and every part of the circuit. Since that is the case, it does not matter in which leg the meter is inserted; the same amount of current flows through the instrument. It should be particularly noted that, with the instrument connected as shown in Fig. 4, the current that flows through the filament must of necessity flow through the meter.

We come now to the question of what makes the meter read. The problem is very simple when considered in the light of elementary magnetism. Whenever a current flows through a wire a magnetic field is generated. The intensity of the field is dependent upon the length of the wire and the strength of the current. The field flows in a direction as indicated in

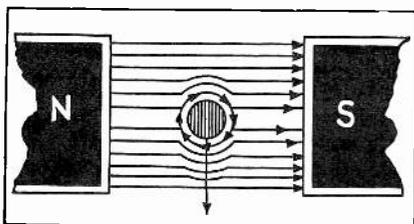


Fig. 6. Two fields produce a motion.

Fig. 5.

When the wire is placed between the poles of a magnet, as shown in Fig. 6, a force will be exerted upon the wire and if it is free to move, it will do so in the direction of the arrow. If the wire is wound into the form of a coil, the field will be as shown in Fig. 7. When such a coil is placed in the magnetic field, we have the elements of a moving coil meter, as shown in Fig. 8. Since like poles repel and unlike poles attract one another, the coil will tend to turn in a direction indicated by the arrow. The turning tendency is opposed by the hair spring, and the amount of turning is directly proportional to the amount of current flowing in the coil. The needle is fastened to the coil, and as the latter turns, the needle moves over the scale, which upon proper calibration, will indicate directly the amount of current flowing.

Now if the meter is connected in the cir-

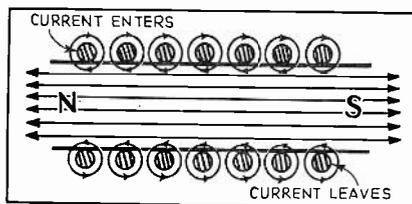


Fig. 7. Determining field polarity.

cuit shown in Fig. 4, the 2 leads of the moving coil are connected into the circuit. If the meter is rated at 100 milliamperes, and more than this flows in the circuit, the meter will probably be damaged. It would seem necessary then to connect a meter of higher-range in the circuit. However, it is possible to use the original instrument by placing a shunt across it. The following paragraphs will describe the construction and use of a shunt.

Since the moving coil is of extremely light construction, in order that it may rotate easily, it must be wound with very fine wire. Practically, this means that the amount of current that can safely flow through this coil is very small—only a few thousandths of an ampere. If the safe current-carrying capacity of the wire is, for example, ten one-thousandths of one ampere, (10 milliamperes or 10 mills.), how can the meter be safely placed in a circuit in which 2 amperes are flowing?

The meter is safe because not all of the

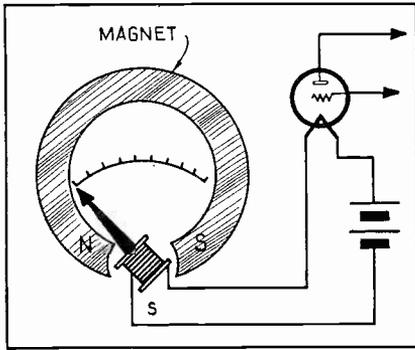


Fig. 8. The ammeter reads because the moving coil is twisted in the field of the permanent magnet, and turns on the axis.

current flowing in the circuit passes through the moving coil. As an example, let us assume that we have a meter with a moving coil so designed that, when ten one-thousandths of an ampere flow through it, the meter reads full-scale. This means that under no conditions can more than 10/1000 of an ampere safely flow through the coil. As the instrument is now, it is a 10-milliampere meter.

If a resistance which is equal to the resistance of the moving coil is placed in parallel with the moving coil of the meter, then one half the current in the circuit will flow through the moving coil, and the other half through the resistance.

To take an example, the resistance of our moving coil is, say, one ohm, and it requires 10/1000 of an ampere through it to give full-scale deflection. We now place a one-ohm resistor in parallel with it, giving the circuit of Fig. 9. If the current flowing in a circuit in which the meter is now connected is 10 mills., then 5 mills. will go through the meter, and 5 mills. through the resistance. The current through the meter being now one-half of what it was before the resistance was connected, the meter will, of course, only read half as much. If the current in the circuit be increased to 20 mills., 10 mills. will go through the moving coil of the meter, and the other 10 mills. through the resistance. The meter will now read full-scale.

It should now be noted that, without the external resistance, the actual current through the circuit goes through the moving coil and the meter reads the actual current in the circuit. With the resistance

connected across the moving coil, only one half of the current in the circuit will flow through the moving coil, and the meter will read only one-half the actual current in the entire circuit. To obtain the correct current, then, it is necessary to multiply the meter reading by the factor 2.

If, instead of the one-ohm resistor (which resistor is known as a shunt) a 1/2-ohm resistor was connected in, then only one-third of the total line current would pass through the moving coil, and the remaining two-thirds would pass through the shunt. The meter would then read only 1/3 of the actual current in the entire circuit; so that it would be necessary to multiply the meter reading by the factor 3, in order to obtain the actual current flowing.

The addition of these shunts, then, permits the extension of the amount of current that can be measured by an instrument. The same meter whose moving coil can safely carry but 10 mills., can, with the use of the proper shunt, be arranged to measure several amperes. For convenience a switch may be provided, to throw in any one of a number of different shunts; so that different ranges on the instrument are available. This is shown in Fig. 10. By setting the switch on the proper tap, any one of three ranges can be selected.

If the internal resistance of the meter is known, then the resistance of the shunt necessary to extend the range of the instrument may be calculated from the following formula,

$$R = \frac{r}{n-1}$$

The symbols are as follows:

R—resistance of the shunt

r—internal resistance of the meter

n—the number indicating how many times the meter range is to be multiplied.

The use of this formula may be illus-

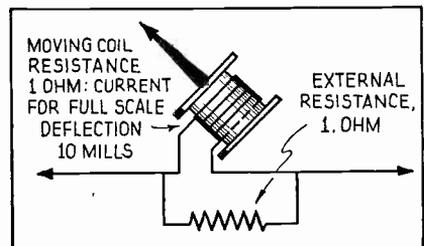


Fig. 9. A shunt alters the meter range.

trated by this example: suppose we have a milliammeter with an internal resistance of .01-ohm and it has a scale range of 25 ma. The meter is to be made so that it will read up to 100 ma. Our factor, n, is then 4. If we substitute these values in the above equation it becomes,

$$R = \frac{.01}{4-1} = .00333\text{-ohm.}$$

The purchase of a resistor of this small value and one that is accurate to about 5% or less is rather a problem. However, it can be made quite easily. Suppose we take our 25 ma. meter and put a current of about 20 ma. through it. Let us say the exact reading is 22 ma. Then, when we have applied the correct shunt, the scale reading should be 22/4 or 5.5 ma. It is then a simple matter to connect a piece of low resistance wire across the meter terminals until the reading is exactly 5.5, with the same current as was previously used. We know then that the resistor is of the required value.

The D.C. Voltmeter

It has been stated that current must flow through an electrical measuring instrument in order that it may function. The voltmeter is no exception to this, and, though it is not always understood so, a voltmeter measures current, as will be shown.

Current flows in an electrical circuit only because a potential difference exists. If the resistance is constant the amount of current flowing is directly proportional to the voltage causing the current flow. Therefore, in a D.C. circuit, if the voltage is doubled, the current also doubles, and

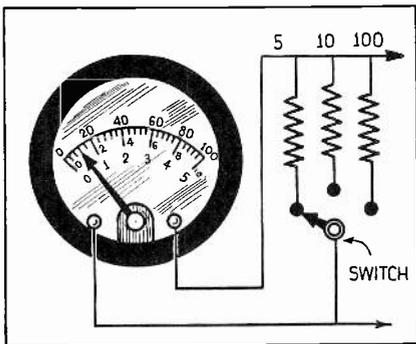


Fig. 10. Modern instruments have several shunts selected by a switch, with the meter scale calibrated in the various ranges.

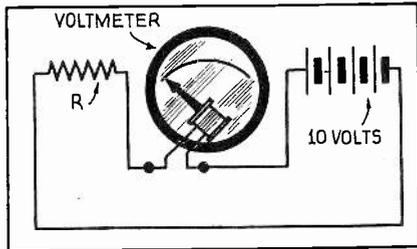


Fig. 11. The resistor limits the current flowing through the meter.

so on. This means, then, that if an instrument is connected ACROSS (in shunt with the circuit) the voltage to be measured, and if furthermore, the resistance of the instrument is constant (as it always is), then the current through the instrument will be directly proportional to the voltage across which the instrument is connected. In the formula of Ohm's Law, I (current Intensity) equals E (Electromotive force or voltage) divided by R (resistance). We may write this also $E=RI$, which comes to the same thing.

It is seen that a voltmeter, connected across a certain voltage has a current flowing through it; for the same reason that any resistance connected across a voltage has a current flowing through it. It is this current flowing through the meter that actuates it; the manner of its operation being identical with that of the ammeter discussed above (Fig. 8). Let it be stated at this time that exactly the same movement ("works") is used in the voltmeter as in the ammeter; the only difference being in the mode of connection. Let us examine the mode of connection more closely.

If we assume that we have the same milliammeter as before, that is, one with a scale reading of 25 ma. and an internal resistance of .01-ohm, a voltage of .0025 will be required to cause full scale reading. The formula is $E=IR$ or,

$$E = .01 \times \frac{25}{1000} = .00025\text{-V.}$$

Such a ridiculously small voltage reading would be useless to the Service Man, so we must find a means to use the instrument on higher voltages while still keeping the current through the moving coil below the maximum safe value (25 ma.). We can do this by placing a resistance in series with the meter as shown in Fig. 11. If we want a voltage range

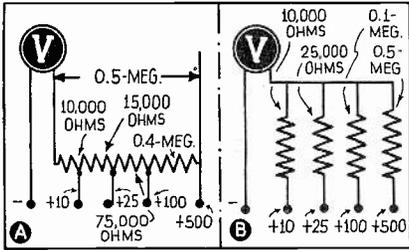


Fig. 12. Two methods of connecting the multipliers to a voltmeter.

of 10 V. and we know the current must be 25 ma., Ohms law gives the resistance as follows:

$$R = \frac{E}{I} = \frac{10}{0.025} = 400 \text{ ohms.}$$

The resistance of the moving coil is too low to need consideration in this case, so the series resistor should be 400 ohms. This resistor is usually called a multiplier.

It must be understood that the resistance of the meter cannot change, as it is determined solely by the resistance of the wire on the moving coil. Thus, for a full scale reading of 10 V. we need a resistance of 400 ohms, or 40 ohms for every volt of the meter scale. It may be said that the voltmeter has a resistance of 40 ohms per volt. This is the common method of rating voltmeters.

This method of expression is also useful in determining how much additional resistance must be used to increase the range of voltage reading of the meter. If we wish to raise the same meter to read 100 V., it will require a total of 4000 ohms,

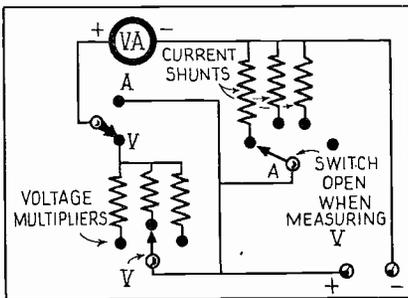


Fig. 13. A meter circuit arranged so that both voltage and current ranges may be selected simply by operating the proper switches.

or 3600 ohms more in addition to the first multiplier.

A current consumption of 25 ma. is sufficient to make the meter useless for reading the voltages ordinarily found in radio sets, since the current drawn by the meter is higher than that in most of the circuits to be measured. For example, if the screen grid of a tube is fed through a series resistor and the meter is connected from cathode to the screen grid socket prong, the current drawn by the meter will be many times that drawn by the screen, and the voltage reading will be entirely erroneous.

In order to obviate this trouble it is common practice to use a meter which has a much higher ohms-per-volt rating, or in other words, a higher sensitivity. The commonly accepted value is a meter of 1 ma. current drain, or one which will require a series resistance of 1000 ohms-per-volt. For a voltage range of 100 V. such a meter will have a resistance of 100,000 ohms.

It is quite possible to use several multipliers with a single meter to have the advantage of several voltage ranges. Two circuits for accomplishing this are shown in Fig. 12. At A, the multiplier is in the form of a tapped voltage divider. At B separate resistors are used for each range. The first method has the advantage of low cost and simplicity, while the second has the advantage that a burned out resistor will not make several of the ranges useless. It is also more flexible in design and construction.

A simple circuit is shown at Fig. 13 for the use of one meter as a multi-range voltmeter and milliammeter (or ammeter). Any number of ranges is possible by the addition of the required resistors and switch taps.

The A.C. Voltmeter

A study of the operation of the D.C. meter will show us that if the direction of current flow through the meter is reversed, then the pointer of the meter will move to the left instead of to the right. This means that, if A.C. is sent through the meter, then during one half of the cycle the meter will tend to move in one direction and during the other half of the cycle it will tend to move in the opposite direction. The result is that, at 60 cycles (commercial power frequencies), the needle does not move at all. To be able to read A.C.,

it is necessary to have a device that will move in the same direction regardless of the direction of the current through the meter. This is what the A.C. meter does.

There are numerous types of A.C. meters, but only one of them will be described, since the A.C. voltmeters used in analyzers are of this type. This is designated as the Soft-Iron, or Iron-Vane, type of meter. A sketch showing its internal construction is given as Fig. 14.

A small strip of soft iron *M*, bent into a cylindrical form, is mounted axially on a spindle *S* which is free to turn. Another similar strip *F*, which is more or less wedge-shaped, and which is larger than *M*, is fixed inside a cylindrical coil; this coil *C* is wound with fine wire and connected in series with a high resistance, (the multiplier). When current flows through the coil, both iron vanes become magnetized. The upper edges of *F* and *M* both have the same magnetic polarity—for instance, both “north” poles; and the lower edges have the same magnetic polarity—both “south” poles. The two upper edges repel each other, and so do the two lower edges; with the result that the free vane *M* moves. The pointer therefore moves with it. When the cycle reverses, the magnetic polarity reverses (the upper edges become south poles and the lower edges north poles), but the repulsive force is still there; consequently the meter moves in one direction only. The multiplier calculations for the A.C. meter are exactly the same as for the D.C. meters described above.

While this type of A.C. meter is quite rugged and inexpensive, it is not widely used in modern equipment because it is not very sensitive. In other words, it is a type that makes rather high current to operate it.

For this reason, and also as a measure of economy, modern test equipment almost exclusively uses the rectifier type of A.C. meter. This is simply a D.C. milliammeter, of the low drain type, connected to a small copper oxide rectifier. The circuit is shown at Fig. 15, and is a diagram for an A.C. voltmeter. It will be seen that the usual series resistors should be used, to enable various voltage ranges to be had.

To offset the obvious advantages of low current drain and the economy of being able to use the same D.C. meter for all purposes, the rectifier type has a few disadvantages as well. The rectifier itself is

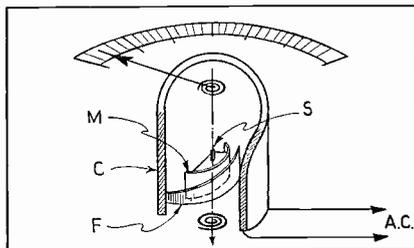


Fig. 14. The “works” of the iron vane meter.

somewhat sensitive to temperature changes, and also its characteristics change with age, with the amount of current through it, etc. Also the scale of a rectifier type meter is crowded at the low end as in other A.C. meters. However some of these faults can be sufficiently compensated for, so that a very usable instrument results and this type of meter is almost in universal use at the present time.

An Elementary Analyzer

In developing a simple analyzer, the reader should bear in mind that the finished product is not suitable for home con-

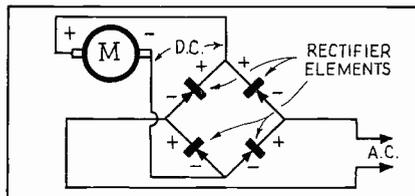


Fig. 15. Connections of a meter rectifier.

struction; since no mechanical or electrical constants will be given. By describing such a theoretical analyzer, the author hopes to accomplish but one purpose: to present the fundamental principles behind all analyzers. By doing this, thus illustrating the methods of design, the more complicated commercial types will be more

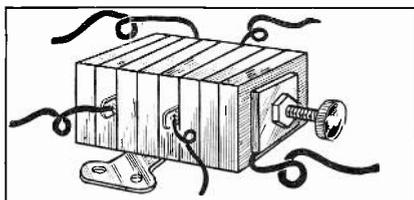


Fig. 16. One type of meter rectifier.

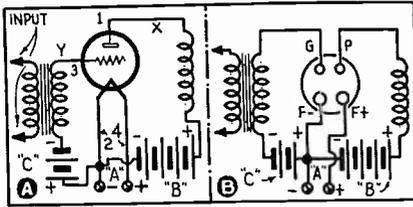


Fig. 17. An amplifier with and without tube.

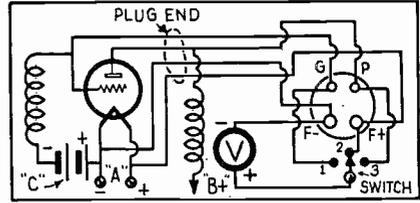


Fig. 19. Checking voltage at extension socket.

fully appreciated than if this mode of approach were not used.

Suppose a stage of A.F. amplification, such as that shown at A in Fig. 17, is to be examined. For a very complete test it would be necessary to know the following constants:

- (1) Filament voltages;
- (2) Plate voltage;
- (3) Grid voltage;
- (4) Plate current;
- (5) Grid current.

Let it also be assumed that we wish to measure each of these with as few instruments as possible. To measure the constants listed above, a single meter would have to be inserted at X to measure plate current; at Y for grid current, between points 1 and 2 for plate voltage; between 2 and 3 for grid voltage; and between 2 and 4 for filament voltage. Let it be further assumed that we cannot break any leads in the set to insert these instruments.

If the tube at A of Fig. 17 be removed, then the connections to the socket remain as in B. Suppose now, we take the base of an old tube and solder leads from the prongs of the tube base to a socket outside the set. The set will function exactly the same, whether a tube is inserted in the original tube socket, or in the one outside the set with the tube base plugged into the original socket, to complete the connections. This is depicted in Fig. 18. It is

now possible to break any leads or insert meters between any two points in the external socket *and, at the same time, keep a tube connected in the circuit.* This, it will be recalled, is a necessary precaution in all tube service work.

Now that we have devised a scheme to get at the tube socket prongs without breaking into the receiver wiring, we are ready to tackle the problem of measuring all required operating characteristics of the tube with a single meter. This is simply a problem of switching. A point to be remembered here is that it is standard practice to measure all grid and plate voltages with respect to the negative end of the filament or the cathode depending upon which type of tube is under test.

The circuit in Fig. 19 shows a simple means of switching a single meter so that it may be used to measure plate, filament and grid voltages. However several additions to this circuit are needed. In the first place, the filament voltage is almost invariably much lower than that of the plate. If a range of the meter were used that would measure the plate voltage satisfactorily, it would undoubtedly, be too high a scale on the meter to enable an accurate reading to be made of the filament voltage. So we need to add a switch and several series multipliers to enable the meter to be used at the widely different voltages we have already encountered.

The next difficulty we encounter in using

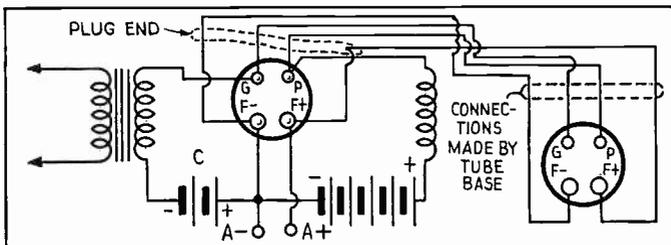


Fig. 18. The use of an analyzer plug to extend socket leads.

Fig. 18. The use of an analyzer plug to extend socket leads so that tests may be made without disassembling the receiver.

the simplified circuit of Fig. 19 is that the grid voltage will cause the meter to read backwards, which is not of much help to the busy Service Man. Therefore a switch must be added to reverse the polarity of the meter so that it may be used without changing any of the external connections. Fig. 20 shows this addition, which is usually a simple DPDT toggle switch in most commercial instruments. Since it is located next to the meter in all circuits it may be operated to change the polarity of the meter no matter to what use or on what scale the meter is being used. This reversal of the meter connections may be accomplished automatically in the rotary switch by the circuit of Fig. 21. However, the DPDT switch is usually included as this feature is useful in other connections as well.

We still have no provision to measure any of the current operating of the tube. To measure any current value, it is necessary to break a lead, so that the meter may be inserted in series with the circuit of that particular lead. This may be accomplished by the addition of more contacts on the rotary switch and connections as shown in dotted lines on Fig. 22. It will be necessary to close the break at points X and Y when the meter is not in use for current readings on that element. An easier method is to have a single push button switch for each circuit in which it is desired to read current. This method is shown in Fig. 23.

Many commercial analyzers use push buttons to select the various meter ranges, both for voltage and current measurements. The circuit for voltage change by push buttons is shown at A of Fig. 24, while B shows the same system as applied to current changes.

Free Reference Point Testing

The latest and most widely used style of switching from one tube element to another is the "free reference point" system. It will

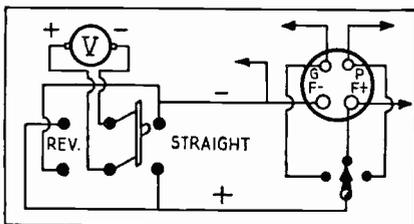


Fig. 20. Polarity reversing switch.

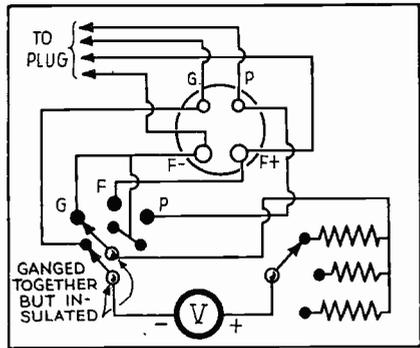


Fig. 21. Rotary switch to shift meter leads.

be remembered that we said all testing was to be done from the negative leg of the filament or from the cathode. These tube elements serving as the reference point for all voltage measurements. In the free reference point system, we can use any tube element as the reference point rather than being forced to use the filament or cathode. This is accomplished as shown in Fig. 25, by the use of 2 rotary switches. The switch points are numbered according to the standard RMA numbering system. This numbering system, by the way, has been made necessary by the wide variety of tubes now used. As an example, the type 76 tube has the control grid connected to the No. 3 prong, while the 36 tube has the screen grid connected to the corresponding terminal on its base. Therefore we cannot always call the No. 3 terminal the control grid, or any other element, and a universal numbering system became necessary.

If we wish to measure the voltage between the grid and plate of our 4 prong

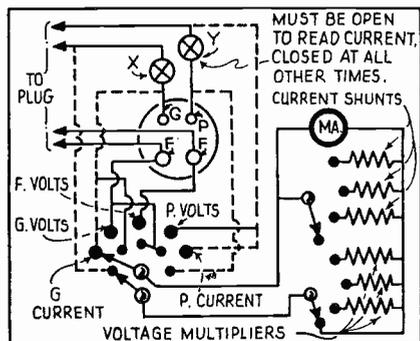


Fig. 22. Current reading leads are dotted.

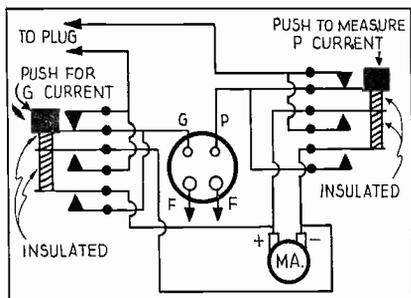


Fig. 23. Reading current by push switches.

tube, we need only turn the selector switches to the proper positions and the connection is easily made. This sort of measurement would have been impossible with the circuit of Fig. 22.

The completed circuit of the simple analyzer for 4 prong triodes is shown in Fig. 26. If the fundamentals underlying the selection of this circuit are clearly understood, it will be a comparatively simple matter for the builder to figure out the circuit for an analyzer incorporating any number of ranges and for any tubes required. In this circuit, provision is made for external use of the meter with any of the voltage or current ranges available, and for A.C. or D.C. measurements on the tube terminals.

A few words as to the action of the various switches may be of help to the prospective instrument builder.

We have discarded the rotary switch idea of Fig. 22 entirely, and have used push button switches wherever possible. This makes for the utmost flexibility throughout, much more so than the scheme of Fig. 21, for example. The free reference point selectors, SW1 and SW2 enable voltage measurement

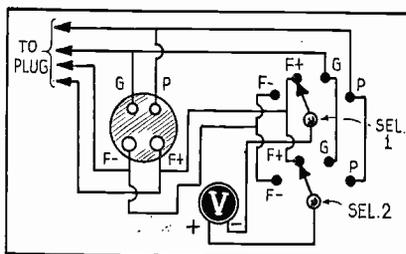


Fig. 25. Free reference point switching.

between any 2 base prongs. When these switches are on the "EXT" contact points, the voltmeter is connected to the external voltage terminals. For any voltage measurements the toggle switch, SW10 must be on the voltage side. Also the meter will not read unless one of the voltage range switches is depressed. These are SW7, SW8, and SW9.

For any current measurements, whether internal or external through the terminals, EXT CURRENT, SW10 must be in the left position. As a measure of meter protection, the highest range current shunt, R1 is always in the circuit until SW11 or SW12 are depressed, each of the latter being of lower range. When making a current measurement, try the circuit first without depressing SW11 or SW12. If the reading is too low on the meter to be of value, then one of the switches may be operated to lower the range.

The current buttons for reading plate and grid current are connected exactly as in Fig. 24 and should be operated one at a time.

Although the meter is marked as a milliammeter, it is to be understood that it will have several scales, and may be calibrated and read directly in milliamperes or volts.

Provision is made in the meter circuit for reversing and for change from D.C. to A.C. readings. Although A.C. current readings are very seldom made, and many meters are not provided with the correct scales for this use, the rectifier is usually placed in the

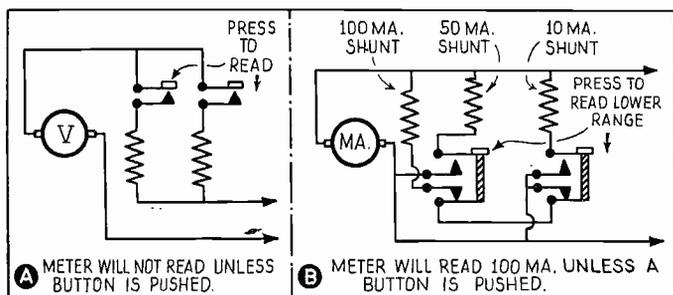


Fig. 24. Voltage and current ranges may be shifted by push switches.

A METER WILL NOT READ UNLESS BUTTON IS PUSHED.

B METER WILL READ 100 MA. UNLESS A BUTTON IS PUSHED.

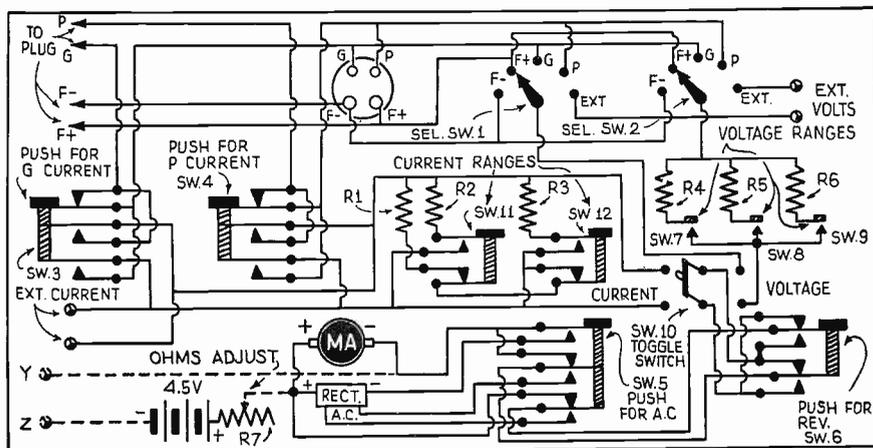


Fig. 26. An analyzer for checking 4 prong tubes only. It may easily be expanded.

circuit as shown. The voltage dropping resistors for the A.C. voltage ranges should always be placed between the rectifier and the external circuit. In this way, the current through the rectifier will always be kept to a very low value, a most desirable feature.

It should be noted that although all switches in this circuit except three are shown as push button types, they may be

of the locking variety, so that when the button is depressed, a slight twist will cause it to stay operated.

To expand this circuit for use with tubes of any number of prongs or elements, it is simply necessary to add current measuring buttons and extra points on the selector switches. Also of course, the plug connecting cable, and analyzer socket must be capable of accommodating the required tubes.

CHAPTER 3

Use of the Analyzer

Although this is a book on the technique and use of the set analyzer, we should spend a little time on consideration of the factors which can make the use of the analyzer a great deal more profitable and enjoyable.

Firstly, we must recognize that radio set trouble can come from several sources which may be grouped into two headings, those inside the receiver and those outside. A surprising number of "defective" receivers are so only because of some outside source of interference, which has no connection with the set.

A great deal can often be learned from the owner of the set as to what happened when it ceased to function. Certain fundamental questions may be asked, the answers to which will often give a lead as to just where to look for the trouble, and thus much time is saved and the job is made more profitable in the long run.

Some points upon which to question the owner are as follows:

- 1—Does the receiver work at all?
- 2—Did it stop playing suddenly or has it been getting worse for some time?
- 3—Does any time element enter into the trouble? In other words, will the set work for a certain length of time, before going bad?
- 4—Does it make any queer noise before it stops working?

These and many others can be asked depending upon the circumstances, and in general, the answers will be of material help. In most cases the customer is only too glad to help and those few isolated cases where the opposite is the case must simply be taken as they come.

If the receiver is workable but an interfering noise is heard, remove the antenna and ground leads and short the terminals to see if the sound is coming in over the aerial. If the sound disappears or is greatly reduced it is in all probability outside the receiver.

Other than natural fading, almost all trouble from the outside is in the form of noise, so that it is quite a simple task to exonerate the receiver and set about tracing down the trouble in house wiring and other likely causes.

If it is quite apparent that the trouble is in the receiver, it may be either of two types, mechanical or electrical. The first type is usually quite easy to locate, although unfortunately, not always so easy to repair. Broken or worn out dials, poor insulation on wiring, bent or broken shafts and such faults come in this category. The analyzer is of little use in such cases and the finding and fixing of the trouble is dependent upon the mechanical ability of the Service Man.

A list of the electrical troubles encountered in receiver would be of little use to the Service Man and in addition, it would lead to considerable confusion. However, the methods to be used for various troubles are the same for most any make of receiver so that an analysis of the more general methods of testing will be most helpful.

The first angle of attack on a faulty receiver is through the tubes. One method of proving whether or not the trouble comes from this source is to substitute a complete new set of tested tubes for those that are in the set. This is not very practical however, since to carry a complete set of all the hundreds of tubes now on the open market, to say nothing of carrying several of each type for sets using

more than one, is obviously ridiculous. Furthermore such a substitution would not show just which tube was bad, if more than one of the originals was at fault. If the receiver itself is at fault, then the Service Man will still not know for sure whether any of the tubes are useless. Another disadvantage of the substitution method is that one never knows just what is the matter with any particular tube that is supposedly defective. And as a final argument, it is quite possible for one or more of the replacement tubes to go bad, which would, to say the least, be extremely misleading.

So we come to the generally accepted method, that of testing the tubes themselves, and right on the job. This will result in finding out for sure just which, if any, of the tubes are poor, whether any of them are doubtful or apt to go bad soon, and exactly what is the matter with each bad tube, a valuable point when one is confronted by a sceptical set owner who has to foot the bills!

Having decided that an actual test of the tubes is required, we come now to the problem of what tests are needed and how they are to be made. Several are needed, the most important as far as the Service Man is concerned being the tests of emission and that of transconductance (or mutual conductance). Also, it is quite usual nowadays to test a tube thoroughly for shorts between any and all elements. In addition, a "gas test" is sometimes used.

The emission test is one of the simplest and consists of connecting the plate and the various grids together and applying a voltage as shown in Fig. 1. A plate current will flow and if the tube is in good condition this will have a certain value which will be much higher than when the tube has been used for some time. A table is usually prepared showing the correct values of emission for various types of tubes, and if one is tested and has a considerably lower value it is rejected. A tube which is just on the border line will probably work quite well in most cases, but will probably go bad in a relatively short time. Although the circuit in Fig. 1 is shown with batteries, it is quite possible and in fact more practical to use unrectified A.C. for all the required voltages, when this type of test is used in a regular tube tester. The tube itself acts as a

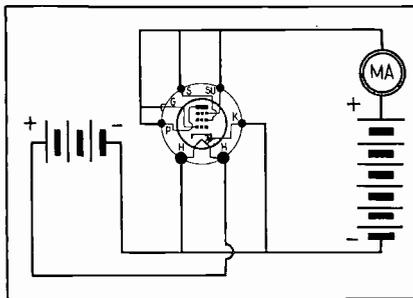


Fig. 1. A simple set-up for tube emission tests.

rectifier and plate current flows in the regular way.

The emission test is of some value but it is not sufficient to really show the worth of a tube, for the reason that even if the emission of a tube is quite normal, it is possible that the grid or some other element is bent or displaced so that proper action is not possible. It is necessary therefore to make a transconductance test.

Any tube will function in a radio set because the signal voltage on the grid causes the plate current to increase and decrease alternately. The greater this increase or decrease for a given signal voltage, the louder the signal. The amount of increase or decrease of plate current, per volt of increase or decrease of grid voltage, is called the Transconductance of the tube, and is measured in MHOS (or micromhos, as explained below).

Transconductance is therefore a measure of the "goodness" of a tube. Stated in another way,

$$\frac{\text{Change in plate current}}{\text{Change in grid voltage}} = \text{transconductance}$$

To measure transconductance then, all that need be done is to apply the normal grid, filament and plate voltages to a tube, and then change the grid voltage by a certain known amount. The plate current will change, in response to this change in grid voltage. This change in plate current, divided by the change in grid voltage, gives the transconductance.

For example, suppose a tube be connected as shown in Fig. 2, with the switch S on tap 1; and that, at this position, the tube has 3 volts (negative) on the grid,

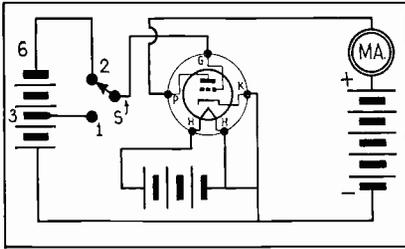


Fig. 2. Arrangement for transconductance test. An A.C. supply may be used for the heater.

and a plate current of 15 milliamperes flows. The switch is then thrown on tap 2; which places 6 volts (negative) on the grid. The plate current consequently drops to, say, 5 milliamperes. We know, now, that a 3-volt change in grid voltage causes a 10-milliampere change in plate current. The transconductance is then

$$\frac{.01}{3} = .00333 \text{ mhos}$$

The use of such small numbers as .00333 is rather unwieldy; so that, in practice, the micromho is used as the unit. One micromho is one millionth of a mho. To obtain micromhos from mhos, then, multiply the fraction by 1,000,000. Performing this operation in the case above, we get .00333 (mho) \times 1,000,000 = 3,330 micromhos.

Most analyzers have provision for the transconductance test, but few if any allow for the emission test. The necessary voltage for the grid shift is obtained from a small battery which is also used for continuity tests as will be explained later. Of course, the other voltages must be obtained from a receiver, which makes this method of testing inapplicable in many cases where the receiver is not in working condition when the tubes are to be tested. For this reason, it is usually desirable to carry a tube tester which will run from the A.C. line and thus have its own power supply independent of the receiver. Another reason for this is that the voltages in receivers vary widely even on tubes of the same type which may however be used for different purposes. This makes it impossible to draw up a table which will define what is a bad tube and what is a good one since the test conditions change within such wide limits, and the busy Ser-

vice Man has no time to stop for calculations. About the only use, then, that a transconductance test made with a set Analyzer will be is that it will show up a tube that is totally unworkable. Because of this limited use, many manufacturers of the latest test equipment are leaving this feature out of their new models, as they feel that it is not of enough value to offset the added expense and circuit complication.

Although never found in an instrument that may be called solely an analyzer, the short test and the gas test are included here in the interests of completeness, as they should be understood by the Service Man.

The short test may be made by a simple circuit as shown in Fig. 3. The two switches are connected so that each prong of the tube socket has a tap on each switch, similar to the arrangement used in free reference point testing. A neon tube which draws very little current may be connected in series with a voltage source between any two elements. A short will cause the tube to light. Also a leakage between elements will cause a light although of less intensity.

The gas test is required because a small amount of gas in the tube will sometimes cause the plate current to rise, when the transconductance test is made and fool the Service Man into believing that the tube is a good one. It is made simply by applying to the elements a voltage sufficiently high to cause the gas to ionize, when it may be seen as a blue glow. The voltage must be variable, as the same value cannot be applied to all tubes. For example, a type 6A3 tube must be tested at a

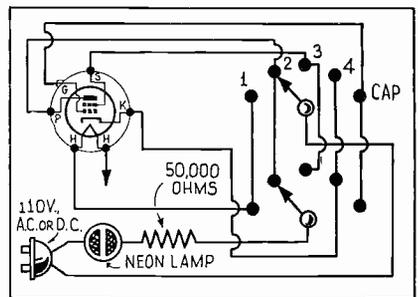


Fig. 3. A simple tube short tester. Contacts are needed for each tube element.

much higher voltage than a type 30. In all cases, however, the test voltage will be somewhat higher than that at which the tube normally is operated.

In most cases, the Service Man will find it sufficient to make an operating emission test of the tube in question. If the various element voltages are correct, and it is found that the plate current is quite near that specified by the maker, the tube may be quite safely assumed to be normal.

After the tubes have been found to be good and any poor ones replaced, the Service Man is ready to proceed with the balance of the tests on the receiver. The job now is to localize the trouble to as small a portion of the set as possible. The set may be considered to be divided into certain sections which we may designate as: the R.F. section (including the I.F. circuits if the set is a superhet); the A.F. section; and the power supply. We can begin by localizing the trouble in one of these sections, which will make it much easier to track the fault to its exact location.

The experienced trouble shooter knows from his past work that certain troubles reoccur in certain sets, so that when he has found in which section of the receiver the fault lies, he can quickly spot the actual defect and remedy it.

With a certain amount of experience, troubles in the audio end of the set can be separated from those in the radio-frequency end by a few simple tests. For instance, if the detector or any of the audio tubes is tapped with the fingers a musical sound, not unlike that of a clear bell, will be heard from the loud speaker. If this occurs, then—as a first approximation—the audio part of the set can be assumed to be normal; if not, then this part of the set should be suspected and tested thoroughly.

For the moment, let us assume that the audio-frequency end is normal. If the set uses a grid condenser-and-leak detector, then placing the finger on the grid condenser will usually result in a loud whistle. If this does not happen, then the detector should be suspected and also tested.

If everything seems normal so far, then the radio-frequency part of the set should be given a finger test. If the forefinger is slightly moistened, and the grid connection of each tube tapped, a dull thud should be heard before and after each tap.

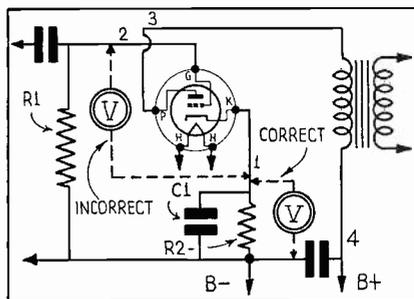


Fig. 4. A common set-up of an amplifier.

If tapping the grid of a certain tube does not produce any sound then that tube should be suspected. This latter test can also be used, with the same results, in the audio end of the set.

The above mentioned finger-grid tests are based on the assumption that the grid prongs are easily accessible. This is not always so; with the result that a set analyzer must be resorted to in order to localize and locate the trouble.

Remove the first R.F. tube from the socket, and plug it into the analyzer. Put the plug of the analyzer in the same socket of the set from which the tube was removed. By manipulating the proper switches and buttons, measure the filament voltage, plate voltage, plate current and grid bias. Compare these values with what the manufacturer says they should be. (If you do not know what the manufacturer's specifications are, then compare the results of the tube measurements with a tube chart.) In any case, they should check very closely. This process should be repeated for every tube in the radio set. If a grid leak and grid condenser are used, very little, or no grid-voltage reading will be obtained in the detector stage.

The greatest of care must be taken to properly interpret the readings of the analyzer, and these readings depend upon the design of the receiver, and upon what type of circuit is being tested. This is extremely important and emphasizes the fact that the Service Man should have a knowledge of the receiver under test and just what types of circuits are used in it. If this is not obtainable and no information of any kind can be found on the set, the circuit should be traced out before trying to analyze it, since otherwise there can be no

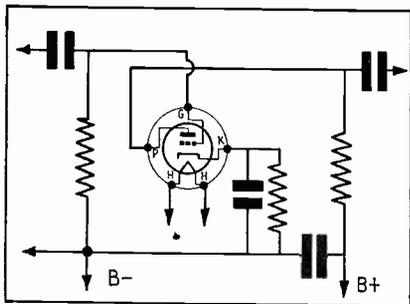


Fig. 5. Here the coupling medium is resistive.

certainty of just what any particular reading may mean.

Some of the more common methods of tube coupling will be discussed, so that we can see just what effect they have upon the analyzer readings obtained.

Fig. 4 shows an amplifier stage, in which the input circuit is resistive and the output circuit is inductive. This circuit would commonly be used in A.F. work between two stages. A voltmeter connected between the cathode and the control grid should theoretically measure the grid voltage. However, as we have already seen, any meter of this type draws current, so this current must also flow through the resistor R2. This current causes a voltage drop which is so large that the meter will probably hardly move at all. The Service Man would then be led to believe that there was no voltage on the grid, which is not so. A tube which is operating as a Class A audio amplifier has sufficient negative voltage on the grid to practically preclude any flow of grid current through the leak. Thus the full voltage will be applied to the grid. When the voltmeter is connected in however the

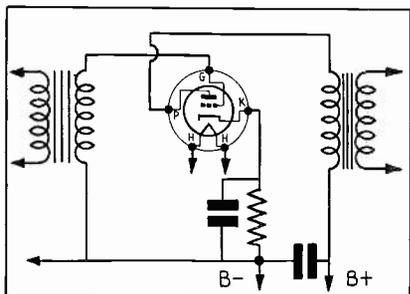


Fig. 6. An inductively coupled amplifier.

circuit is upset and the proper voltage cannot possibly be measured at the grid.

A typical example will show how large this error can be. A type 76 tube has a cathode resistor of about 2700 ohms, R2, to obtain a bias of about 13.5 V. Suppose we choose the 10 V. scale of a 1000 ohms-per-volt meter to measure the grid voltage. If we attempt to measure the voltage from grid to cathode, we will simply be measuring the drop in the cathode resistor which serves as the grid bias. Since the grid leak is of 0.5-meg., the total resistance in the circuit will be 512,700 ohms, including the resistance of the meter. The grid bias voltage is 13.5 V., so the current flowing in the circuit may be shown by the simple equation:

$$I = \frac{E}{R} = \frac{13.5}{512,700} = .000024\text{-A.}$$

The combined drop across the grid leak and the cathode resistor is shown by:

$$E = RI = 502,700 \times .000024 = 12.06 \text{ V.}$$

This leaves 1.4 V. to be read by the meter, which is obviously highly misleading.

When it is known that the input circuit is composed of a resistance load, either short this resistance or measure the grid voltage across the cathode resistor (or other source) which produces the voltage. The latter method naturally gives no assurance that the voltage is actually reaching the grid, so that this point must be carefully checked, and the Service Man should assure himself that the grid to cathode or filament circuit is intact.

The same precautions should be observed when measuring the voltage in the plate circuit. Many receivers nowadays, in fact the majority, have detector and audio tubes with a resistive plate load. Although the plate voltage is higher than the grid voltage, the same conditions are to be found and it is impossible to read the exact voltage at the plate of the tube with any degree of accuracy. In the case of a circuit similar to Fig. 5, where both grid and plate circuits include a resistive load, the precautions must be doubly observed. This situation is mainly encountered in resistance coupled A.F. amplifiers.

Another combination is shown in Fig. 6, where both grid and plate loads are inductive. The inductances may be either

air core as in R.F. coupling transformers, or iron core as in A.F. units. In the former case, the resistance seldom is over 100 ohms, while even the resistance of audio transformers is usually below 5000 ohms, and so in both cases the resistance may be neglected and a fairly accurate reading will be obtained at the tube element.

The only other possible coupling combination is shown at Fig. 7, and is that where the plate load is resistive while an inductance appears in the grid circuit. It will be quite apparent which of the foregoing precautions must be followed in this case.

Of course, it is possible for the Service Man to make allowances for the low readings obtained when working on a tube with a resistive load. In fact, many of the manufacturers have presented with their service data, voltages charts taken with a 1000 ohms-per-volt meter, as this value is more or less standard. This is a great help to the Service Man, since he is primarily interested in what voltage readings will be obtained under practical working conditions, and not in the theoretical values. Here again, a precaution must be given. Some of the newer service equipment is built around measuring instruments which have a sensitivity of 2000 ohms-per-volt or even higher. Although these new meters are a move in the right direction, the Service Man who owns one should use care when he is following a manufacturer's data sheet, to be sure what type of meter was used to measure the voltages given.

Let us suppose that, during the course of our tube measurements, it is found that the plate voltage is nearly normal, while the plate current is either too low or too high (either plate current condition may result), and there is no grid bias. Assume the circuit is similar to that shown in Fig. 4. The fact that plate voltage exists indicates that the grid-bias resistor R2 (which is in the plate return circuit to "B-") is not open. It may be shorted; the condenser C1 may be shorted; or the tube's input circuit may be open.

Short-circuited condensers are not uncommon; so that the first place to look for the trouble is in the condenser. This should be removed from the circuit and tested. (Methods of testing condensers and coils are given near the close of this chapter.) If the condenser is shorted,

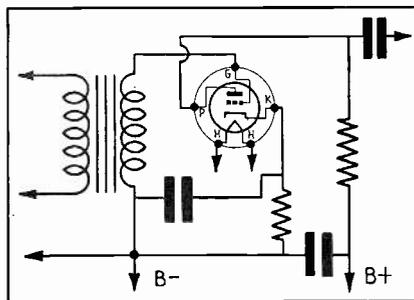


Fig. 7. Combination coupling system.

then its removal should restore normal bias to the tube. If this does not restore the bias then C1 is not shorted. The input device to the tube's grid whether it be a resistance (as R1) a choke, or the secondary of a transformer, should then be tested for an open. Finally the grid-bias resistor should be tested for a short.

In many circuits a single grid-bias resistor is used for several tubes. If this (corresponding to R2) is shorted then none of the tubes getting their bias from the same resistor will have grid voltage.

In testing a piece of apparatus, it should be completely isolated from the circuit electrically before any tests are made.

Suppose our analyzer shows no plate voltage on a tube. Our next procedure is to test for voltage between points 1 and 4 (see Fig. 4). If voltage is present between these points, then—obviously—the plate coupling device (choke or primary of A.F. transformer) is open and should be replaced. If no voltage exists between 1 and 4, then the condenser C2 should be removed; if its removal restores voltage to the tube, then C2 should be replaced with a good condenser. If the removal of C2 does not restore plate voltage, then the grid-bias resistor R2 should be tested for an open, since the plate current of the tube passes through this resistor. If this resistor also proves to be good, then the trouble lies somewhere in the power unit.

The circuit of a conventional power supply is shown in Fig. 8. All power connections to the tubes are shown but the various coils and other circuit elements have been omitted for the sake of clarity. Assuming that the circuit is of the T.R.F. type, tubes V1 and V2 are the R.F. amplifiers, V3 is a bias type detector, V4 is an A.F. amplifier, and V5 is the output A.F. amplifier. Grid bias for tubes V1

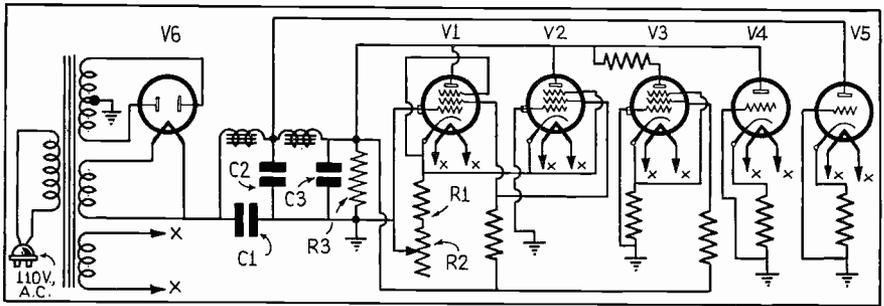


Fig. 8. The power supply circuits of a typical T.R.F. receiver showing essentials only.

and V2 is obtained by the drop through resistor R1 in the cathode leads of these tubes. In addition, R2 is a variable control used to vary the volume. It does this by changing the grid bias on the R.F. tubes, so the grid bias should always be measured with this control in the same position. It is standard practice to make all measurements with the volume control on full and the antenna and ground posts shorted, unless otherwise specifically stated.

With zero voltage on the plate of a tube (assume the one we are measuring is V2) then it is obvious that V1 should also have zero plate voltage. In other words, if several tubes obtain their plate voltages from the same point in the power supply, and one of these tubes has no plate voltage, then the others cannot have any (that is, if the coils, resistors and condensers in the set are good). We have now localized our trouble down to the power unit.

The next test is across the bleeder resistor, R3, where the full voltage of the power supply should be available. This voltage will be more or less independent of R3, although it will be a little higher if R3 is open. If no voltage is found across R3 all the elements of the filter system will have to be tested starting at R3 and working back to the rectifier tube, V6.

If C1, C2 or C3 is shorted, very little or no voltage will be obtained anywhere. If this condition is found, then the filter condenser should be tested first, since a shorted filter condenser is about the only piece of apparatus that can be bad and affect the voltage on all the tubes. Another indication of a shorted filter condenser is the white heat of the plates of the rectifier tubes. With C1 shorted, the rectifier plates become white-hot, with no

voltage on the bleeder resistance. With C2 shorted, both the rectifier plates and L1 become very hot, and there is no voltage on the bleeder. With C3 shorted, the rectifier tube, V6, becomes very hot, with no voltage on the bleeder.

With the filter unit testing normal, and the voltages on the bleeder still low or zero, the voltages on the plates of the rectifier tube should be measured. By proceeding in this manner, defective apparatus is bound to be found.

The problem of trouble shooting finally resolves itself down to the testing of individual units. For this purpose the analyzer is indispensable. Fortunately there are only three properties used in radio sets, namely, inductance, capacity and resistance: and they are supplied, respectively, by coils, condensers and resistors. We will take these up in their order.

The Continuity Tester

Now most analyzers have, as an integral part of the device, a continuity tester or ohmmeter. This is nothing more or less in its essentials than a voltmeter V connected in series with a small battery, as shown in Fig. 9. With terminals 1 and 2 shorted, the voltmeter reads the battery voltage; which is the same as the full-scale deflection of the meter. If a resistance R is inserted between terminals 1 and 2, the voltmeter reads less than the battery voltage, because of the drop in voltage caused by current passing through R. The more resistance between points 1 and 2, the less the voltmeter reads. This makes it possible to mark or calibrate the scale of the voltmeter directly in ohms, so that, when a resistor is connected to points 1 and 2, the meter reads a certain figure which is

the value of the resistance in ohms so connected.

Since this continuity tester or ohmmeter is one of the most important pieces of apparatus for the Service Man, we should perhaps devote a little more space to a description of the more usual types. In the circuit of Fig. 9, when the battery starts to run down, the meter cannot be made to read full scale. For this reason a variable resistor is usually included in the instrument (as in Fig. 10) so that a full scale reading will be easy to obtain. When used only for continuity, this is not so important, but it is absolutely necessary, when the apparatus is used as an ohmmeter, because full scale in this case means zero resistance. In practice, the test leads are shorted, and the resistor adjusted until the needle reads exactly full scale. The apparatus is then ready for use.

The higher the voltage of the battery, the higher the resistance must be to compensate for it and the higher the ohmmeter will read on its scale. This circuit can and should be incorporated in the simple test set shown on page 17, since as has been mentioned before, it will be found the most used of any of the associated equipment in the analyzer. The dotted lines connected to the terminals marked YZ are for this purpose. To use the ohmmeter, simply plug into the XY terminals, and make sure that SW10 is on the Voltage side.

Another type of ohmmeter that is becoming increasingly popular is the so-called shunt circuit shown in Fig. 11. This type is especially good for measuring voltages below about 300 ohms or so, and this is just where the series type of ohmmeter circuit is of least use. The shunt circuit can be read to about $\frac{1}{2}$ ohm with quite good accuracy. This low range accuracy is of great importance when testing R.F. and I.F. coils.

It will be seen that the meter reads full

scale at all times until a resistance is connected to the test leads. Since these are directly across the meter, the less resistance there is in the external circuit, the farther the meter pointer will move to the left or zero end of the scale. With zero resistance, there will be a direct short across the meter, consequently it cannot read at all and the pointer will be all the way to the left. If this circuit is incorporated in an analyzer, a switch should be provided to open the battery circuit when the instrument is not in use, otherwise the battery will have a very short life.

Point to Point Testing

This type of testing simply means the use of the ohmmeter to trace out individual components of a circuit, and to find those at fault. This method of attack is a necessity when the Service Man has no data on a certain set at hand, and has no knowledge of the circuit or the operating voltages. It then becomes necessary to trace out the circuit from point to point. Many Service Men prefer this method to any other.

Coil Testing

If a certain coil is suspected, it should be tested first with the high resistance circuit of Fig. 10. The reading to be obtained with a good coil depends upon the type. As has been mentioned before, most R.F. coils have a resistance below 100 ohms, and when we get to the high frequency coils of the all-wave receivers, the resistance is often less than an ohm! A test of such a unit would show such little resistance that it might be suspected that the coil was shorted. However, most R.F. or I.F. coils have at least a few ohms resistance, and can be tested quite accurately on the shunt type of ohmmeter. At any rate, the test will show if the coil is open or not.

Iron core coils of the type now quite

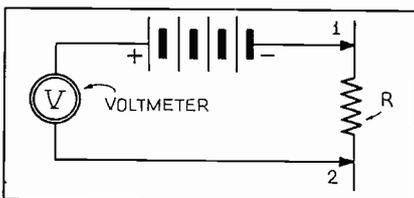


Fig. 9. Measuring resistance with a voltmeter.

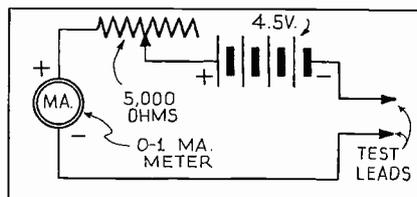


Fig. 10. The usual simple ohmmeter circuit.

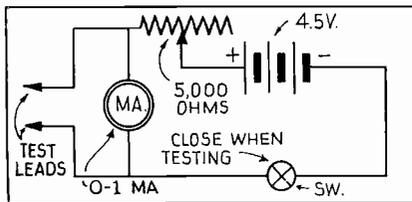


Fig. 11. The low range shunt ohmmeter hook-up.

widely used for I.F. and R.F. purposes, as a rule have a lower resistance than the corresponding air core units. However, iron core coils as used for A.F. work and power supply equipment have, in most cases, a reasonable resistance and may be easily tested. Some of the exceptions are filament windings, voice coils of speakers and their associated transformer windings, and the primary windings of some of the larger power transformers. In these and similar cases, it is necessary to resort to the shunt type of ohmmeter, if anything other than a simple continuity reading is desired. All coils should also be tested for shorts to ground and shorts between the windings if there are more than one. Most iron cores are grounded to the chassis and a short to the core would therefore make the coil useless.

Most of the service notes now available have the resistance of the various coils marked right on the diagram or in accompanying tables. When this is not so, and there is some doubt as to the correct value, it is sometimes possible to test a similar unit on another set of the same type to find an approximate resistance value.

Needless to say, great care should be exercised when testing coils or any other component of a receiver, to be certain that none of the other circuit elements are affecting the test. For example, if two coils are connected in parallel, one of these may be open, yet a continuity test will show it to be OK since the current will flow through the other coil. Naturally the best procedure is to remove all components from the circuit before testing them, but this is entirely impractical to the busy Service Man. In many cases it will be quite obvious from the circuit that a coil may be tested while still connected, while in others it will be quite sufficient to disconnect one end of it from the circuit.

As a rule when a coil is defective, it is either open or has a dead short. One of

the few exceptions is that of A.F. transformers, which sometimes develop a partial open. This is usually easy to observe on the ohmmeter, as the pointer will jump back and forth over the scale. Such a unit will always be noisy in service.

Condenser Tests

A good condenser under test should do two things: (1) it should not allow D.C. (direct current) to pass through it; and (2) it should therefore accumulate and hold a charge, when its rated D.C. voltage is applied. When a condenser is leaky it allows D.C. to pass; so that, to test for a leak in a condenser, all that is necessary is to connect the terminals of the condenser to the ohmmeter. The needle of the ohmmeter should move a little (with the flow of current into the condenser to charge it, if its capacity is large); and then return to its normal position and stay there. If it does not return to its normal position, but stays somewhere on the scale, the condenser is leaky and should be discarded.

It is perfectly possible for a condenser to test O.K. on the small voltage used in the ohmmeter, but break down completely when normal voltage is applied. To completely test a condenser, the rated D.C. voltage should be applied for a few moments, and then removed. The condenser should be allowed to stand charged for several minutes, and then discharged. If a spark occurs during discharge, the condenser is good; if there is a weak spark or none at all, the condenser is defective.

The above statement applies only to condensers of large capacity; about $\frac{1}{4}$ to $\frac{1}{2}$ mf. and over. For the smaller sizes, the continuity test described above is sufficient; it being merely sufficient to determine whether or not the condenser is shorted.

It is perfectly possible for a condenser to be open, even though it is a rare occurrence; an open condenser is one which passes neither D.C. nor A.C. This is due usually to broken or unsoldered leads from the condenser plates to its terminals. To locate an open in a condenser of small capacity, without taking it apart, is practically impossible. In the larger sizes, an open may be easily found by connecting the condenser to the ohmmeter of the analyzer. If the needle of the meter does not move and return to its original posi-

tion, then the condenser is probably open.

It is very useful to be able to measure condenser capacity. Some analyzers, which use a high-resistance A.C. meter (which is nothing more than a sensitive D.C. meter with a copper-oxide rectifier in series) are calibrated in microfarads; to enable the user to measure capacities from about 0.25 to 15 microfarads, with an A.C. line-voltage of 115 volts at 60 cycles.

Testing Resistors

Testing resistors really involves only the measurement of the value of the resistance. If the result of the measurement is within 10% of the rated value of the resistance, then it may be assumed to be good. If it is far from the 10% tolerance, then it should be discarded. For all practical purposes, resistors may be measured with the ohmmeter included in the analyzer.



CHAPTER 4

Associate Test Equipment

There are several supplementary pieces of equipment, some of which are contained in the more expensive analyzers with which the Service Man should be acquainted. Even if they are not in his analyzer, they should be included in his equipment, as the day of the "single-meter Service Man" is at an end, and the present-day expert must have all the very latest equipment to do a good job and do it in a space of time that will allow him to compete profitably with others.

The V.T. Voltmeter

The vacuum tube voltmeter is an instrument that will measure voltages and yet take no appreciable current from the circuit under test. It will be remembered that the usual voltmeter, even the so-called sensitive 1000 ohms-per-volt variety takes a good deal of current to operate it, so much so that it is of little use when measuring voltages in, for example, the grid circuit of a resistance coupled amplifier. The V.T. voltmeter will do this without disturbing the operating voltages and currents of the circuit in any way. This is

because it is entirely a voltage-operated instrument, while the meter requires power (even though it may be only a tiny fraction of a watt).

Naturally we cannot get this action without getting power from somewhere, so a source of power in the form of batteries or the usual rectifier system is needed.

A circuit of a simple V.T. voltmeter is shown in Fig. 1. It will be seen that the input from the test prods is connected across the grid and cathode circuit of a vacuum tube. The bias of the tube is adjusted by means of the potentiometer, R2, to any desired value as read on the meter, M. The test leads are then connected to the voltage to be measured which will cause a change in the reading of meter M. Resistor R2 is then adjusted to bring the meter M back to its original reading. The difference between the readings of meter V, as originally set and at the new setting of R2 will be the actual voltage at the input. The actual range of voltage that can be read depends upon the constants in the circuit, such as R2, battery C, and the plate voltage battery, B.

It should be noted that as the battery C is connected in Fig. 1, it is necessary to connect the positive of the voltage under test to test lead number 1. When the potentiometer is originally set, the meter M will drop in reading, and the positive voltage on the grid of the tube will tend to neutralize the bias supplied from battery C, thus causing the meter to increase in reading. Further operation of R2 will now again raise the bias on the grid and bring M back to the original reading.

When reading D.C., the condenser C1 should always be shorted by SW2. When reading A.C., however, SW2 may be open, and it should always be so when measuring the A.C. component where D.C. is also present. Such a case would be the

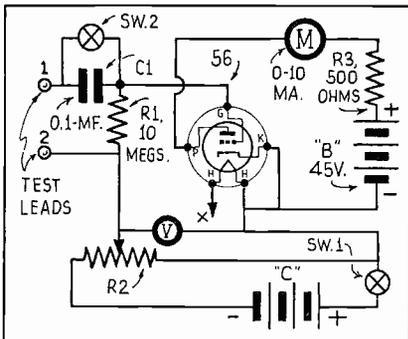


Fig. 1. A simple V.T. voltmeter. Almost any type of tube may be used.

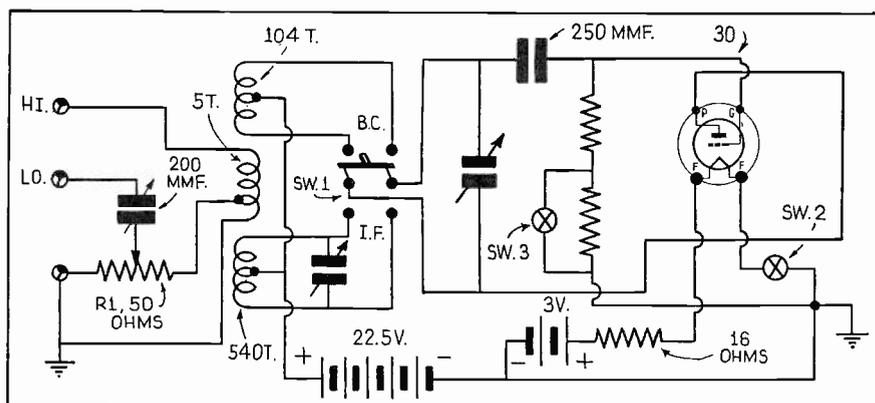


Fig. 2. A dual range service oscillator. This is a simple type of limited use.

measurement of the A.C. at the plate of a tube where the plate voltage would also be found.

SW1 is used simply to open the circuit of battery C so that the battery will not run down when the apparatus is not in use. This switch should be ganged with whatever switch is used to turn the apparatus on and off. R3 is used mainly as a protection to meter M. Of course, meter V should be chosen to correspond with the voltage of battery C.

The tube need not be a type 56 as shown, since almost any type will do. A pentode, such as the 77, 57, or 6J7, with all the grids tied together will give even greater sensitivity than the 56.

These V.T. voltmeters are made in many different forms and with many circuits, but all work on the principle that a vacuum tube is very sensitive to changes in grid voltage, and since no power is taken by the grid in this sort of service, there is absolutely no drain upon the equipment under test, as there would be in the case of an ordinary voltmeter, as described in previous chapters.

The Test Oscillator

When a radio receiver is to be lined up, that is, when the various tuned circuits are to be tuned to resonance, it is necessary that a signal be supplied to the receiver. It is quite possible to use the incoming signal from a broadcast station in some cases, but this is never entirely satisfactory. In the case of a TRF receiver, a broadcast signal may be used with fair results, if a local station is chosen. A distant station is out of the question due

to the fading usually experienced. When we have a superhet that is badly out of adjustment, or one that has just been built and never tried, it is virtually impossible to get the proper alignment through the use of a broadcast signal, since the I.F. amplifier is running at a frequency much different from the tuning frequency of the set.

The Service Man should always have at hand a service oscillator or signal generator as it is sometimes known. A circuit of such an instrument is shown in Fig. 2. This is a very simple type that is to be used with battery power supply and can thus be carried in a compact shielded case for portable work. A single type 30 tube is used, and by the use of SW1, the output frequency may be made to cover both the broadcast and the I.F. bands. There are 2 output posts, other than the ground post, the maximum which is used for a large signal output, and the minimum, which gives a variable signal through the use of resistor R1. Operation of SW3 changes the value of grid leak and causes an audio tone to be emitted with the R.F. This is necessary when it is desired to use an output meter.

It must be emphasized that the circuit shown is that of a very simple unit. Most test oscillators now in use, both battery and power line operated types, have provision for servicing all-wave receivers. This means that they must cover wave bands from about 150 kc. all the way to around 20 mc. without any skips. It is quite common to have a separate tube for the production of A.F. modulation of the output signal, since better frequency

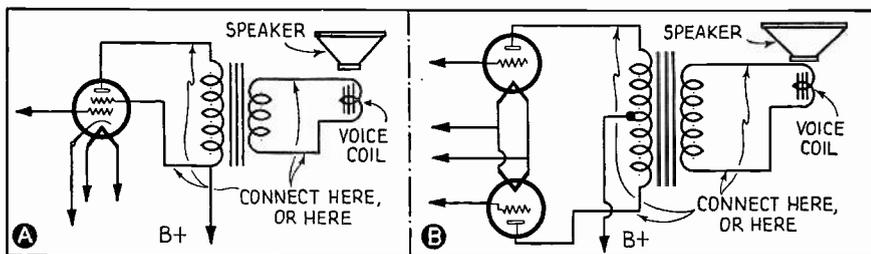


Fig. 3. Connection of output meter. The A.C. voltage at the voice coil is low.

stability, and greater flexibility may be had in this manner.

Some of large test analyzers include an oscillator in the same container, while in other cases it is used as a separate unit. At any rate, the use of such an instrument is very necessary today.

The Output Meter

The use of a service oscillator enables the Service Man to align a receiver to peak operation. However, it is necessary to use some form of indicator to tell when the best adjustment has been reached. The ear is notoriously poor when it comes to judging the volume of sound coming from a receiver, so trust must be placed in an output meter. This is simply an A.C. voltmeter of the rectifier type, as described in Chap. 2. It is usually connected to receiver as shown in Fig. 3. It is best connected somewhere in the plate circuit of the output tube, as the A.F. voltage is highest here. It is quite possible to connect the meter across the voice coil of the speaker as shown. Whenever the meter is connected to the plate circuit, a condenser should always be in the circuit as this prevents the D.C. in the circuit from entering the rectifier, where it would surely do damage. It is safest to connect such a condenser in the meter circuit whenever it is to be used for output measurements, no matter where the meter is to be connected.

It is necessary to have several voltage ranges for this use, since the voltage may change as much 100 V. or more during adjustments.

It is interesting to note that in sets equipped with any sort of tuning indicator, be it a "magic eye", a tuning meter, a "shadowgraph", or any other, there is no need for the use of an output meter. The tuning indicator on the receiver will serve perfectly in this capacity.

The Oscilloscope

This piece of apparatus is one of the most complicated that the Service Man can use, and it also is about the most widely useful. While it is absolutely impossible to go into the theory of the oscilloscope in the limited space at our disposal, we can point out some of the uses of this invaluable instrument.

So far as the Service Man is concerned, the foremost use is that of providing a graphic and clear picture of the results of any alignment attempts made upon the receiver. If the results are not what they should be, the picture on the screen of the oscilloscope immediately shows this, and shows just what results any further adjustments have.

There has recently been placed upon the market a small oscilloscope tube which may be operated from voltages of a value such as found in most radio receivers. This is quite an advance, since in the past the voltages were usually over 1,000 V., thus necessitating very expensive power supply equipment. The new small tube costs only about $\frac{1}{3}$ what the older and larger ones do, and this fact, together with the lowered cost of the power supply, has brought the cost of a complete oscilloscope within the reach of most Service Men, something that certainly could not be said of the larger equipment. While the screen of the new tube is only 1 in. in diameter, this is entirely adequate for any needs of the average Service Man, the larger tubes being needed only in laboratory and research work. Furthermore, the small size of this equipment makes it quite practical to carry the oscilloscope on Service calls where it might be needed, something that would be very impractical with the larger equipment.

Besides its use in aligning receivers, the oscilloscope has many other uses that are

of great benefit to the Service Man. For example, it may be used for distortion and phase shift measurements in amplifiers, calibration of oscillators, voltage measurements, all kinds of transmitter tests, and many others.

When using the oscilloscope for alignment purposes, it is necessary to use with it a "frequency modulated" oscillator. This is merely a modification of the usual test oscillator, and many of the latter have the Frequency modulation feature built in so that it may be used when required. Such equipment "wobbles" or shifts the frequency of the oscillator back and forth about 10 kc. from the main frequency. In other words, the frequency shifts a total of about 20 kc. A circuit for an instru-

ment having this and other features will be found in the commercial equipment section, as will a companion oscilloscope unit, using the new small-size tube.

Other Equipment

There are, of course, other pieces of equipment that the Service Man will need for certain jobs, but they are not included in the Analyzer, are not usually used with it, and thus cannot be considered within the scope of this book. Such apparatus as the Resistance Bridge, Beat frequency oscillators, both R.F. and A.F., and the like come under this heading. The serious Service Man will be able to find considerable literature on such instruments, both in magazines and specialized books.



CHAPTER 5

Commercial Test Equipment

RCA Frequency Modulated Oscillator

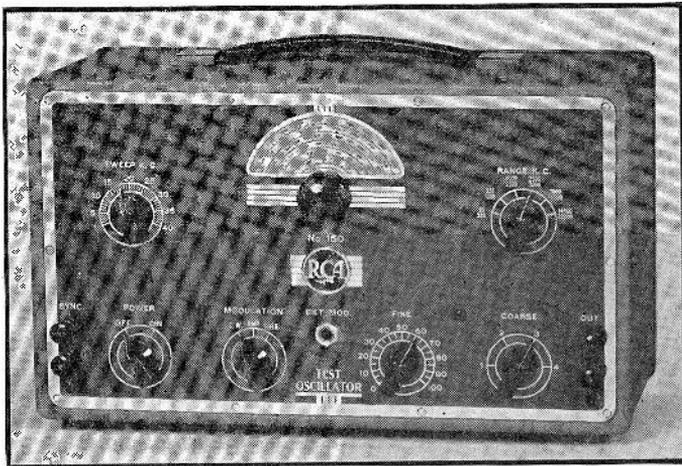


Fig. 1. The RCA No. 150 Frequency Modulated All-Wave Oscillator.

The equipment illustrated in Fig. 1 is known as a frequency modulated oscillator. It will supply an R.F. output of about 0.25 V. over the range of 90 to 32,000 kc., this range being covered in 6 bands. Approximately 30% A.F. modulation at 400 cycles is available.

The frequency modulation feature is used in conjunction with an oscilloscope for alignment work. The sweep width may be varied between ± 20 kc. at maximum and ± 0.5 kc. at minimum. This frequency modulation is accomplished without the use of any moving parts, since it is entirely electronic in nature. A synchronizing voltage for the oscilloscope is supplied by the instrument.

Complete control of the output is possi-

ble. The various coils are aligned by means of air trimmers which assures permanent calibration. The power supply is self-contained and the instrument requires about 30 W. The weight is 17 lbs.

The companion unit, a complete miniature oscilloscope, is illustrated in Fig. 4. This uses the new 1" cathode ray tube and the associated circuits include a linear sweep, synchronizing control, and vertical and horizontal amplifiers.

While these two units are designed to be used together, either may be used separately. The oscilloscope used alone will operate as a sensitive A.C. voltmeter, and may be used to check phase shift and distortion in amplifiers, modulation in transmitters, A.F. wave form and so on.

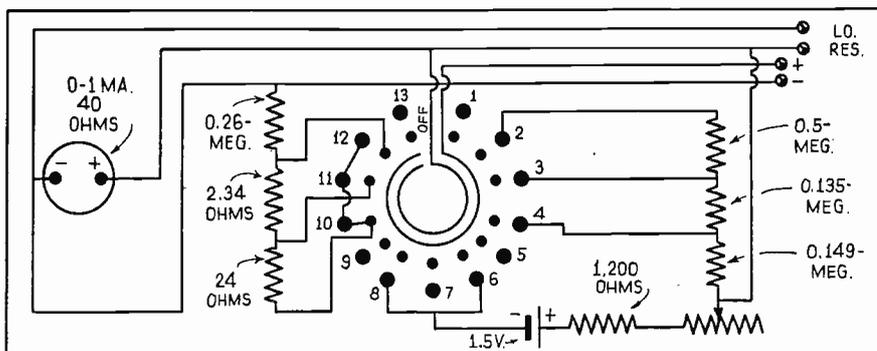


Fig. 5. The circuit of the Ranger Examiner Model 735 D.C. test meter. The small size makes this very handy, as it may be tucked in a pocket or in the service kit.

RANGER EXAMINER MODEL 735 D.C. VOLT-OHM-MILLIAMMETER

This compact instrument will be found of great utility to the Service Man. It will probably be used not so much as a main test unit as it will an auxiliary portable job which can be tucked in a corner of the tool kit or even in a large pocket.

It may be used for such purposes as: Check voltages, such as plate, grid, screen, suppressor, battery, D.C. filament, drop across resistors, chokes, connections, field coils, etc.

Check current such as: plate, grid,

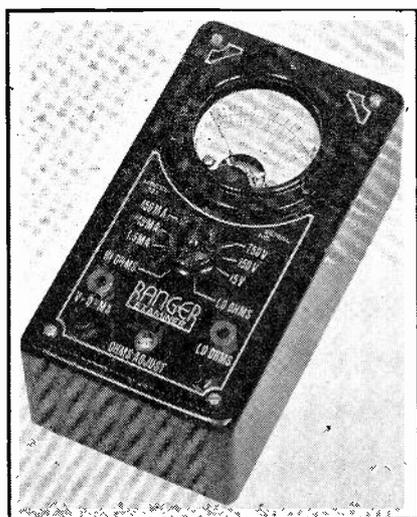


Fig. 6. Appearance of the tiny unit, the circuit of which is shown above. A 2-inch meter is used.

screen, bleeder, total rectifier, electrolytic condenser leakage, etc.

Check resistance and continuity such as: pure resistive circuit, chokes, coils, condenser leakage, shorted connections, opens, etc.

The meter has scales to read to 750 V., 100,000 ohms, and 150 Ma. The meter has a 0-1 ma. movement, thus giving a sensitivity of 1000 ohms-per-volts.

An ohms adjustment is provided, and the necessary 1.5 V. battery is included in the case.

READRITE 720-730A SET ANALYZER

These instruments are complete resistance and voltage continuity testers in compact form. They may be used on radio receivers, P.A. systems and for other similar work.

Although the set contains two meters, there is only a single pair of jack connections for measurement of voltage, current, or resistance. Therefore, once the test leads have been plugged into the jacks they need not be changed when shifting meter ranges or when testing from a receiver socket.

One meter is used for the A.C. voltage readings only and this does away with the complicated rectifier and switching circuits ordinarily needed for changing from A.C. to D.C. The other meter takes care of the D.C. voltage, D.C. current, and the ohms readings.

A simple arrangement of jack switches is employed to connect the milliammeter circuit into any of the leads from the tube socket for measuring element current. The

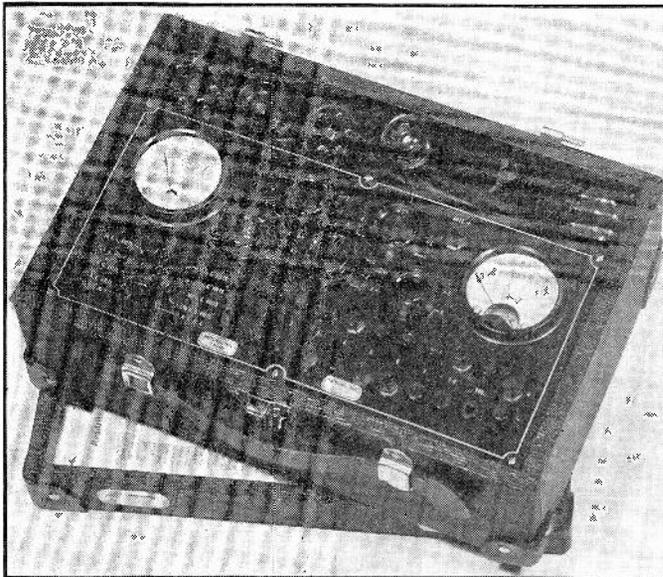
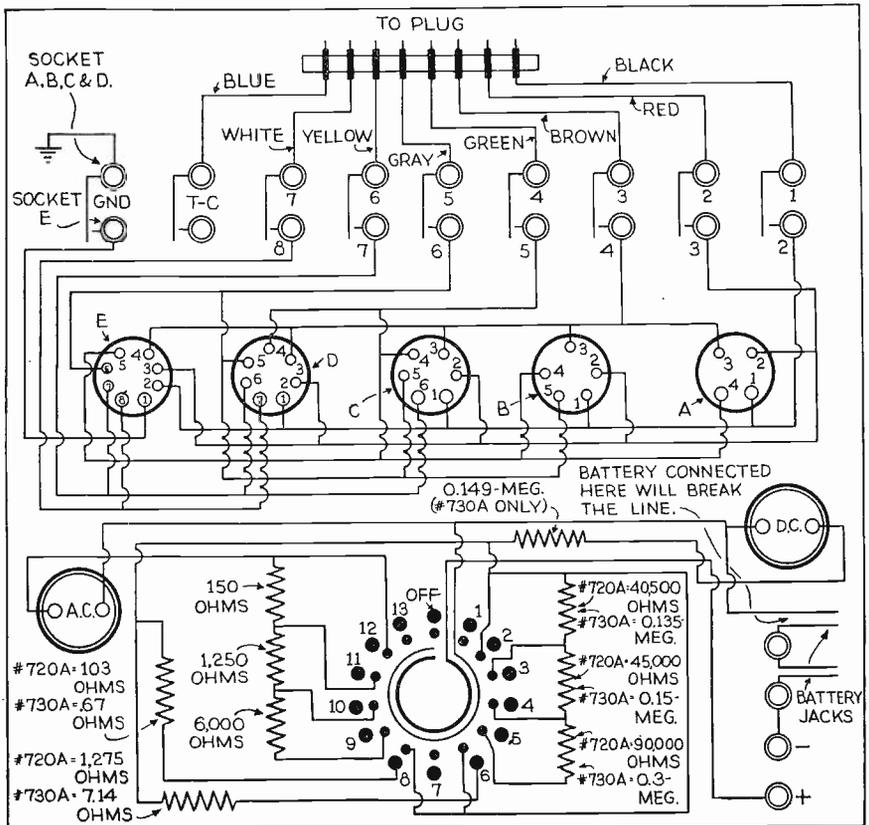


Fig. 7. The Readrite Model No. 730A Set Analyzer. Although this is a compact unit, space is provided for carrying the plug with its cord and adapters. The double row of jacks enables the user to connect the meter to any of the tube circuits.

Fig. 8, below. The diagram of the above unit. This makes it quite clear how the jacks are used for analyzing purposes. Note the connections to the meter.



test leads from the meter circuit are simply inserted into the proper jacks, and with the selector switch set on the proper scale, the current is quickly read.

OPERATION OF READRITE MODEL 720A-730A

The operation of the 720A-730A is very simple. Connect the pair of 31 cords which are furnished with the testers to the jacks marked "positive" and "negative". The selector switch is set on the desired position for the voltage or current to be measured and the free ends of the 31 cord are connected across the voltage source. Remember that to measure voltage, connect the free ends of the 31 cord across the voltage source, and to measure current connect the free end in series with one side of the circuit. To measure continuities and resistance connect the battery of the proper range as shown in the continuity and resistance chart across the battery—and the battery + jacks, observing the polarity. Have the 31 cords plugged into the positive and negative jacks, the selector switch set on the proper position as shown in continuity chart. Connect the free ends of the 31 cord across the continuity or resistance to be checked. To test Condensers use 60 cycle A.C. instead of batteries.

Furnished with the Model 720A-730A is an eight conductor cable, one single wire that has an alligator clip, the control grid wire, and five adapters.

Connect the 720A-730A to the radio set by removing the tube in the stage which is to be tested, place the tube in the proper socket on the Models 720A-730A. If the tube is other than a 7 prong place the proper adapter on the plug and insert plug in the radio set socket vacated by the tube.

Now turn the radio set on. Allow the tube to reach normal operating temperature and proceed to analyze the circuit, first by measuring the filament voltage by setting the selector switch on the proper position either 10 or 25 volts, depending upon the filament voltage of the tube. If the filament voltage is below 10 set the selector switch on 10 volts A.C. Be sure the type 31 cords are connected to the jacks marked positive and negative and the battery is not connected to the jacks marked battery— and battery+. The filament connections on a 4 base tube are No. 1 and No. 4. As it is desired to place the voltmeter across the filament, the free

ends of the 31 cord would be placed in jacks No. 1 and No. 4.

After the filament voltage is determined the next voltage to be measured would be the plate. Always be sure to refer to the tube base chart to determine the respective number for the different elements of the tube. In a 4 tube socket of the 201-A type the plate voltage would be measured from plate to filament. The volt meter would be connected from the jack (black) No. 1 to the jack (black) No. 2—No. 2 being the plate connection in this type tube. As No. 3 is the grid connection and grid is generally negative, it will be necessary to reverse the procedure here and connect the No. 31 cord, which is in the negative jack to the jack (black) No. 3, and the No. 31 cord which is in the positive jack to jack (black) No. 1.

By using this method the voltage between any two elements in the tube may be checked. However, bear in mind that voltage is generally measured from the cathode and in filament type tubes the heater is considered as the cathode.

The black lead wire, which has the alligator clip, is connected to chassis or ground. Voltages can then be measured through the cable connections from the radio chassis or ground to any element of the tube. Bear in mind that the jack marked positive should be connected to the most positive portion of the voltage which you are measuring. The jack marked negative should be connected to the most negative portion of the voltage which you are measuring. Do not forget to set the selector switch on the proper position for the voltages or current you are measuring.

To measure plate current it will be necessary to set the selector switch on the proper D.C. milliamper position, and as the No. 2 socket contact is the plate contact, it will be necessary to plug the 31 cords which are connected to the jacks marked positive and negative to the red and black jack No. 2. Connect same so that the meter will read forward.

READRITE TUBE TESTER—MODEL 430

Illustrated on next page are a front view and the circuit of this new tube tester. There are two meters in the instrument, one of which is shadow type used to read the line voltage, which must of course be set to a certain value every time the apparatus is used. The other meter is a

the sensitivity needed for this service. Since the elements are numbered according to the RMA standards it is a simple matter to find which is shorted, if the meter gives an indication.

Complete facilities are afforded for the checking of all tubes with more than one

plate, such as the 19, 6A6, and all the dual rectifier types.

A pilot light is used in the form of indirect illumination of the line voltage meter so that there is always a positive indication when the apparatus is turned on.

RANGER EXAMINER MODEL 740 VOLT-OHM-MILLIAMMETER

The instrument illustrated below is of the universal type and may be used on either A.C. or D.C. The ranges covered are as follows:

0-10 50-250-500-1,000 A.C. or D.C. volts; 0-10-50-250 D.C. Ma.; 0-300 and 0-250,000 ohms, with provision for extension of this range to 2.5 meg. The meter is of the

400 micro-ampere type, and is shunted to produce a sensitivity of 1,000 ohms-per-volt on the D.C. ranges. Through the use of a special compensating circuit the same sensitivity is available on the A.C. scales. A copper-oxide rectifier is used. A 1.5 V. battery is included in the instrument for the ohms scales, and should have exceptionally long life, as the current is only 2.5 ma. on the low ohms scale and 400 micro-A. on the high scale. The usual ohms adjusted is provided. The switching is greatly simplified through the use of panel jacks in which the test leads are plugged, for the various meter uses. Also a small toggle switch is provided to change from A.C. to D.C. measurements.

A novelty is provided in the form of a case with a small compartment for carrying the required test leads and with room also for a few small tools. Test leads and alligator clips are furnished.

TRIUMPH MODEL 77 OSCILLOGRAPH-WOBBULATOR

Since it is necessary to use a frequency modulated oscillator when aligning a re-

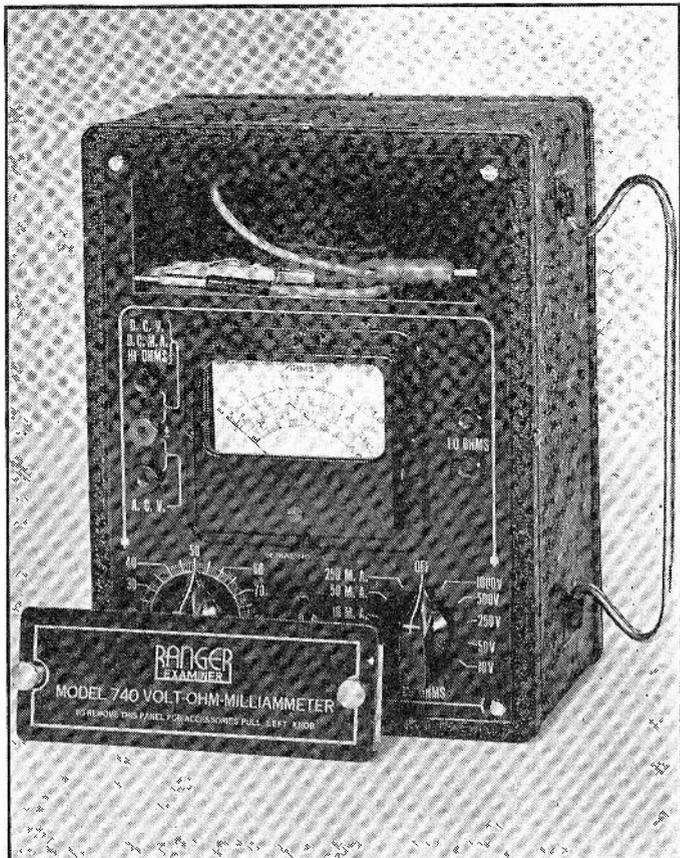
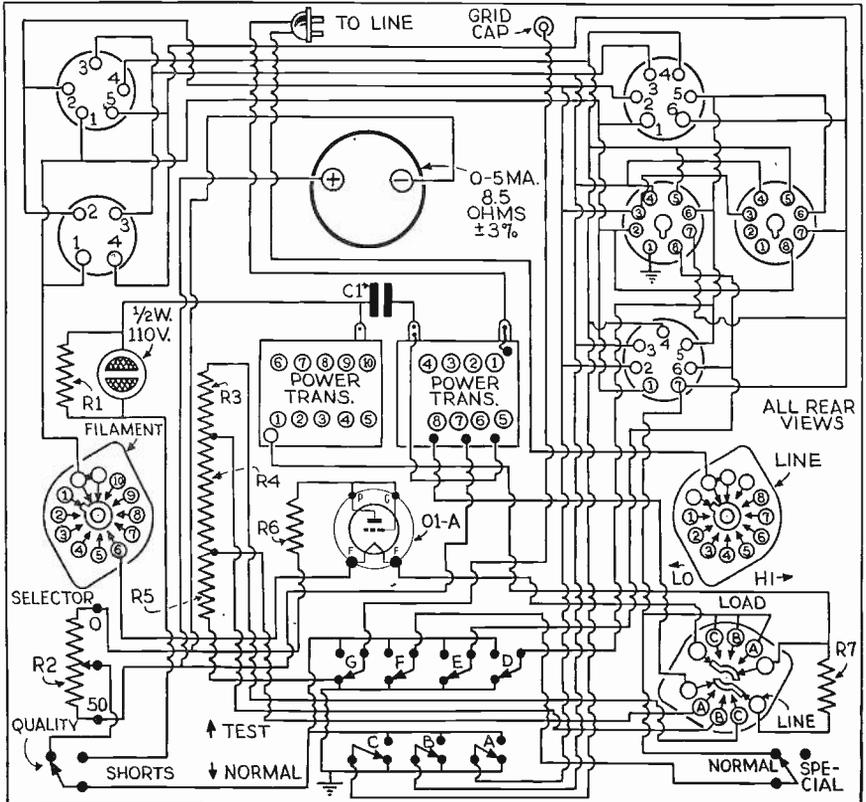


Fig. 11. The Ranger Model 740 Meter. Note the leads compartment.



Fig. 12, right. TRIUMPH MODEL 420 TUBE TESTER. This instrument is of the type mainly used for counter display test, since it is laid out with a sloping panel and may be had with an illuminated sign to fasten on the top. It is of the loaded circuit type, that is, a load switch must be set before the tube is tested. A neon bulb is used as a short indicator. The line voltage is observed on the single meter, and a line voltage regulator which operates to shift taps on the primary of the power transformer, is used to obtain the correct reading before testing.

Fig. 13, below shows the schematic circuit.



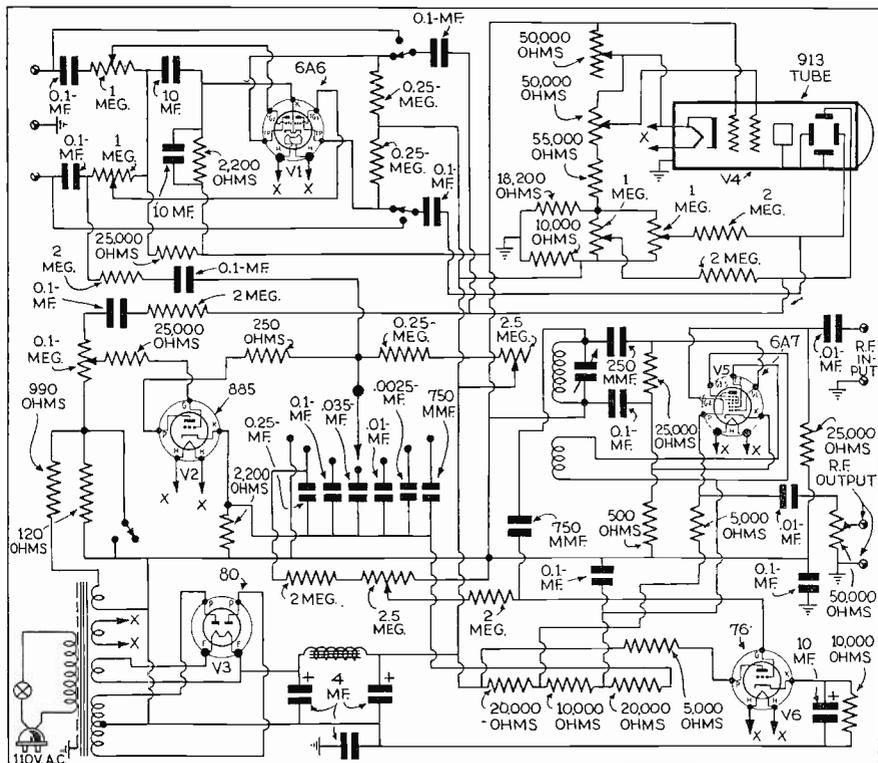


Fig. 14. Circuit of the combined oscillograph-wobbulator. The 76 tube is the wobbler oscillator.

strument is of great use to the Service Man since a frequency modulator is included in the unit. The apparatus may be used with any external all-wave oscillator and is entirely electronic in nature, with no moving parts. There are terminals provided for R.F. input from the oscillator, and output terminals for the frequency modulated output to the receiver under test. The necessary synchronizing connections to the cathode-ray tube sweep circuit is made within the unit. The modulated oscillator or wobbulator is fixed at a frequency of 840 kc. and is wobbled plus or minus 15 kc. Thus the desired frequency for receiver alignment purposes may be obtained by adding or subtracting this 840 kc. with the frequency provided by the external all-wave oscillator. As an example, to secure 456 kc. for aligning a receiver I.F. stage, the external oscillator may be set at either 1296 kc. or 384 kc.

The oscilloscope circuits may be used separately if desired. All the usual controls are provided. Either horizontal or

vertical amplifier may be used or may be cut out and each has its own amplitude control. Beam centering controls are provided, although as a rule the beam will be found correctly centered.

A wide range of sweep frequencies are had through the use of the coarse and fine controls. The use of the locking control is a great help in steadying the image on the screen. In practice, the locking control should never be advanced more than enough to steady the image.

Considering all the apparatus included, the case is very compact, measuring $13\frac{3}{4} \times 10 \times 8\frac{3}{4}$ ins. deep. The weight for shipping is 16 lbs.

TRIPLETT MODEL 1250 V.T. VOLTMETER

The measurement of low Alternating and Direct current voltages has become increasingly important in servicing the modern radio sets, as well as in many other applications. The ideal Voltmeter for measurement in any circuit is one

which requires minimum current for its operation. Such voltmeters operating under nil current condition are now available for the first time in a practical instrument of unquestioned accuracy. The Triplett Vacuum Tube Voltmeter is an instrument of comparative high torque and does not depend for its super sensitivity on high resistance, as does the ordinary type of instrument which consumes current in its operation. All current to operate the Triplett Vacuum Tube Voltmeter is cancelled out by the unique nil method. It is necessary in a Vacuum Tube Voltmeter to have an instrument that is not difficult to use and one in which the calibrations are not subject to change in the tube value. Tube characteristics will change and cause calibration changes which upset the circuit and brings about an uncertainty as to accuracy of the ordinary instrument. The cut-off adjustment is very critical, which will vary somewhat with different tubes. This characteristic also affects the calibration even when the tube is operated at low emission. The ranges of the conventional Vacuum Tube Voltmeter are limited, and if a meter shunt is used the saturation point of the tube is soon reached. The scales of the average Vacuum Tube Voltmeter are not linear, but are quite distorted, especially on ranges which cause the tube to work on a characteristic other than applies to the current squared scale. To overcome these deficiencies in calibrations which are dependent on the particular tube to which the circuit used in the Vacuum Tube Voltmeter of the conventional type is calibrated, the Model 1250 Bridge Type Vacuum Tube Voltmeter has been developed.

The Model 1250 employs an entirely new circuit of the Bridge Type in which the second tube is used along with a sensitive Galvanometer to balance out the current in the circuit, thereby making a calibration adjustment each time a reading is taken. In this way the input voltage of the first tube is under definite control, regardless of what the characteristics may be of the particular tube used in that circuit.

The type 76 vacuum tube forms the fourth arm of a Wheatstone Bridge along with two 6000 ohm and one 40,000 ohm resistor for the other arms. The resistance of the tube is controlled by the 10,000 ohm variable rheostat which in this way sets the bridge in balance and thus

eliminates tube calibration. When a signal is applied to the prods of the input leads the grid of the 6C6 tube goes positive upsetting the normal plate and cathode current of this tube and in turn upsetting the balance of the Bridge. A bucking out voltage can be applied to the Plate Cathode of the 6C6 tube by Control No. 1. When this equals the input voltage the current through the 6C6 tube will be normal and the Bridge will be in balance. Since the bucking out voltage is equal to the input voltage when the bridge is balanced, the D.C. Voltmeter placed in this circuit will give a measurement of the input voltage. Any other type of the so-called "Slide back" method of balancing out the current leads to inaccuracy and difficulty in obtaining zero adjustment compared with the bridge type used exclusively in the Triplett Vacuum Tube Voltmeter which permits adjustment to a very fine degree by the galvanometer method.

The conventional Vacuum Tube Voltmeter using an input voltage divider brings about a decided disadvantage in the discrimination of frequencies. In addition the voltage divider draws current from the source of voltage which is being measured. It is important that the current draw be kept to a minimum since a drain causes a large error, depending upon the circuit measured. The balancing out method in the Triplett Vacuum Tube Voltmeter makes unnecessary the use of an input voltage divider and, therefore, the circuit is undisturbed in relation to the frequencies, and the amount of current drawn can in no way upset the circuit.

The Model 1250 Bridge Type instrument assures accuracy in a Vacuum Tube Voltmeter which is entirely independent of tube error. Elimination of calibration and other errors in this newly developed circuit is an outstanding feature that every user will appreciate.

TRIPLETT MODEL 1260 A.F. OSCILLATOR

The purpose of an Audio Frequency Oscillator is to furnish an audible frequency to test Audio Amplifiers, speakers, P.A. systems, etc. The circuit used in the model 1260 is the familiar feed-back system which has the ability to generate a pure note, is very stable and can be made with an accuracy of frequency far beyond the needs of the service shop or Laboratory. This type of audio oscillator is generally

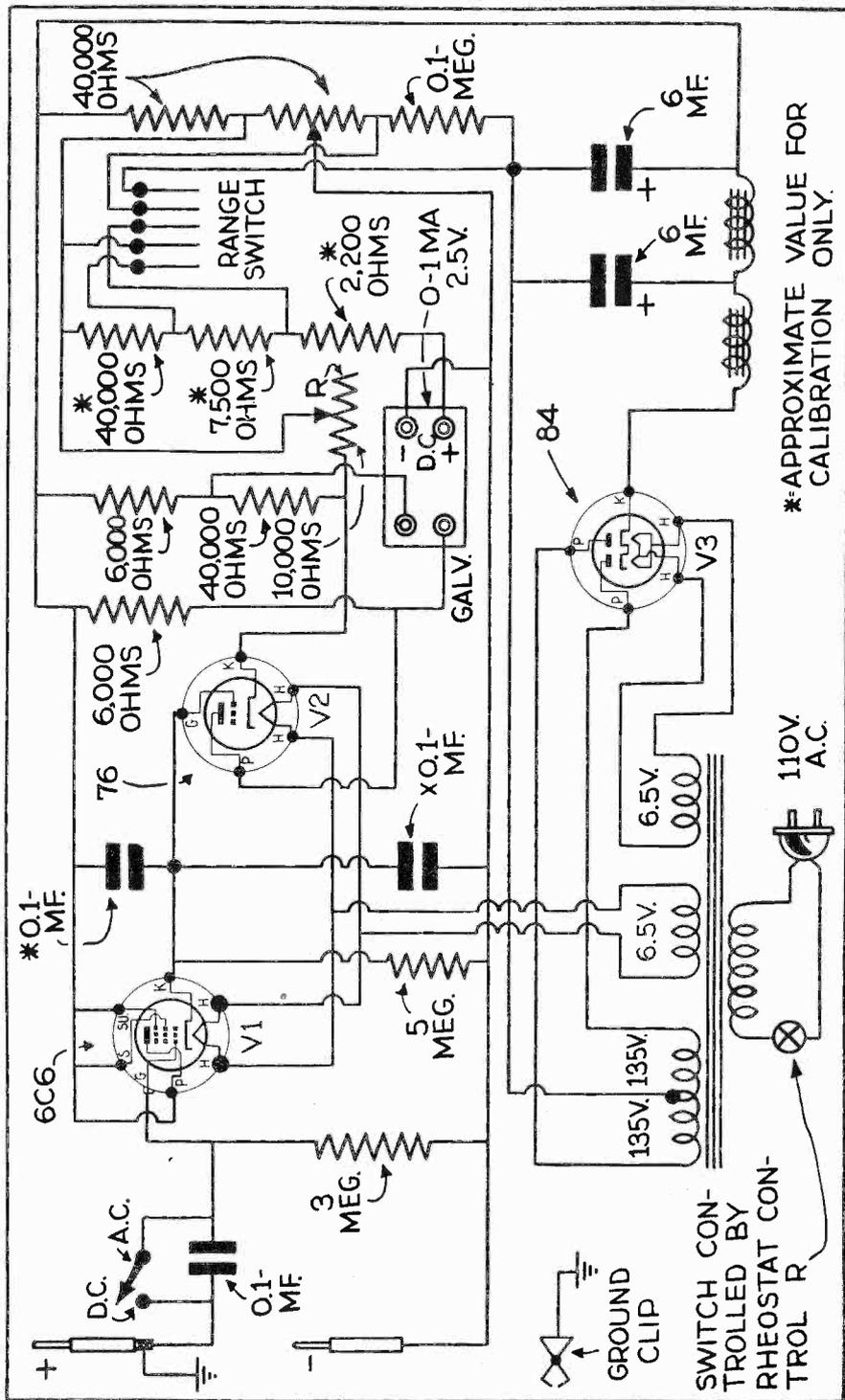


Fig. 15. The bridge-type circuit used here assures perfect calibration. The 76-tube is part of the bridge. This is an advanced "slide-back" V. T. voltmeter.

TRIPLE T 1250 V.T.M

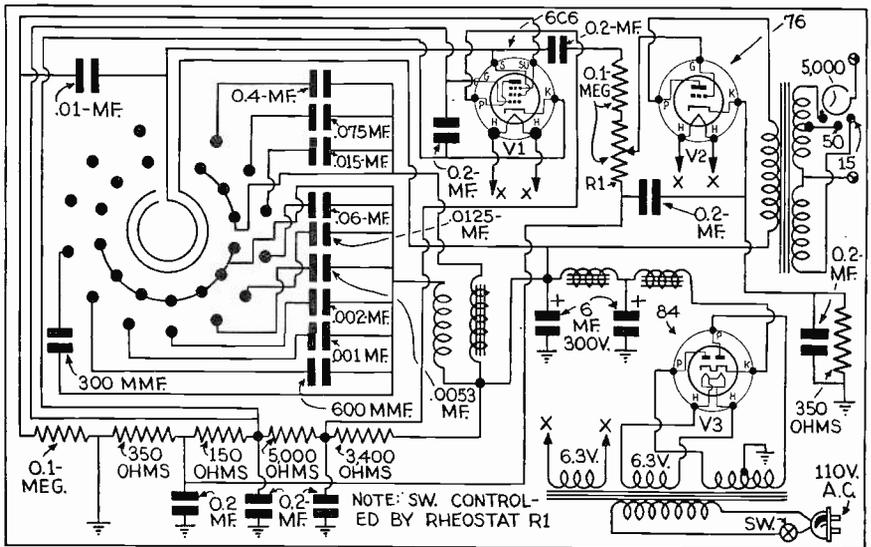


Fig. 16. Circuit of the Triplet Model 1260 A.F. Oscillator.

constructed on the same principle as radio frequency oscillators except that large inductances are used which are generally of the iron core type to improve the Q factor.

The Triplet Audio Oscillator makes use of the negative characteristics of the 6C6 Oscillator tube, as shown in Figure No. 1. This tube feeds the oscillation through a 100,000 Ohm Potentiometer to the grid of the 76 amplifier tube. In order that the wave form may be as pure as possible the oscillator tube operates with low amplitude and the wave is amplified in such a manner that the power taken off does not upset the frequency. The frequencies furnished are 100, 250, 500, 1000, 2000, 3000, 4000, 5000, 7500 and 10,000. As shown in Figure No. 2, the values are obtained by placing different capacities across the choke in the screen circuit of the 6C6 tube. The selector switch is used for this purpose and to change from the iron core choke for the first three frequencies to the air core type for the last seven frequencies.

After the oscillations are amplified they are passed to the universal Output Transformer with secondary impedances of 15,500 and 5000 ohms. The secondary impedances are connected to a switch and jacks. Two jacks are used for the output. The various secondary impedances are connected across these output jacks. The 15,500 and 5000 ohm impedances are de-

signed to match the input of various amplifying systems.

The power is furnished by an A.C. line supply fed to the power transformer which is operated by the gain control. The high voltage of the transformer is rectified by an 84 full-wave tube and this current is filtered by a conventional brute force filter.

The modulation is the tuned choke type using 30 henries and 275 millihenries chokes and nine condensers. The chokes are tuned by connecting the condensers across the chokes with the control marked "FREQUENCY SELECTOR". This control is marked with the fundamental frequencies available.

Operating Instructions

- 1—Connect tester to A.C. line of suitable voltage and frequency.
- 2—Connect tester to audio amplifier using the two jacks marked "OUTPUT". The connections to the amplifier will vary with the make of the amplifier or P.A. system. However, on P.A. systems this will generally be made to the phonograph pick-up jacks or the microphone terminals. On radios which have connections for phonograph pick-up the Oscillator will connect to the phonograph jacks. When phonograph jacks are not available, use the high

- impedance setting of the impedance switch and connect jacks across the audio grid input. In like manner each audio stage may be connected.
- 3—Set "OUTPUT IMPEDANCE" switch marked 15, 500 and 5,000 ohms to proper impedance for the input of the amplifier.
 - 4—Turn the Oscillator ON by rotating gain control from OFF position to the right.
 - 5—Turn the set audio amplifier volume control ON.
 - 6—Turn the set audio amplifier power switch ON.
 - 7—After allowing the tubes to warm up, select the frequency desired by rotating the "FREQUENCY SELECTOR" to the desired frequency.
 - 8—Attenuate the signal to the proper level by adjusting the gain control. Always have the amplifier control on full.
 - 9—While oral indications may be used, it is best to use visual means for indication of the amplifier output.
- 6—Adjust output to a point of about two-thirds of full scale. It may be necessary to rotate the gain control until this is accomplished. However, use the proper meter scale and the one which does not permit the Amplifier to overload.
 - 7—Plot the reading on graph paper.
 - 8—Rotate the frequency control to all the frequency positions marked on panel, plotting each reading of the output on the graph paper.
 - 9—When the last frequency is plotted the curve can be drawn and the characteristics of the Amplifier noted.
- In making this test do not move the gain control.

TRIPLETT MODEL 1200-C METER

The Triplet Model 1200-C Volt-Ohm-Milliammeter has been designed for simplicity of operation, extreme accuracy—both D.C. and A.C., assurance against obsolescence and a maximum of safety.

Fidelity Curves

- 1—Fidelity curves should be run on all high fidelity Audio Amplifiers. This can be done best with the Triplet Audio Oscillator in conjunction with Triplet Output meter.
- 2—Adjust Audio Oscillator, as before.
- 3—Connect output to voice coil of amplifier speaker.
- 4—Set "FREQUENCY SELECTOR" switch to 1000 cycles.
- 5—Adjust gain control so that the speaker does not overload.

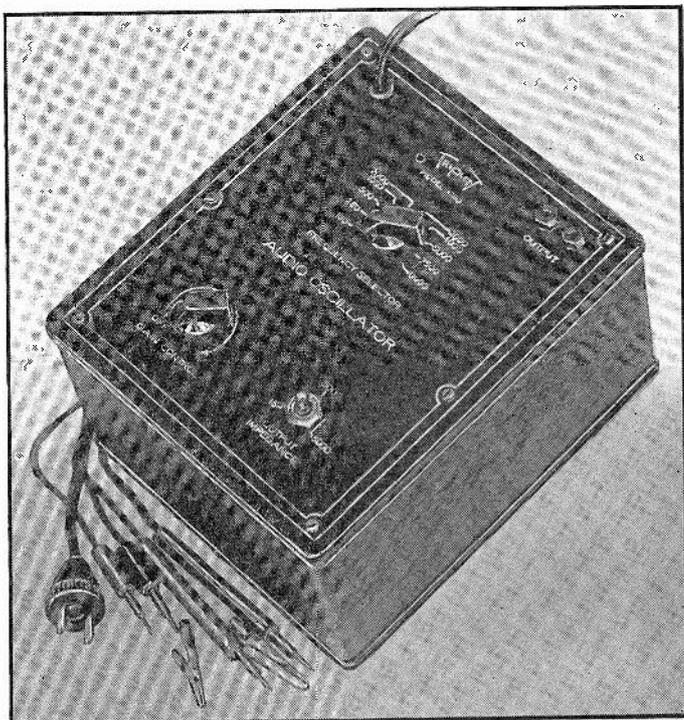


Fig. 17. Appearance of the Triplet Model 1260 A.F. Oscillator.

A most unique and practical arrangement is the separate A.C. and D.C. instruments combined in a single Bakelite case and fastened to the panel on two strong hinges. The purpose of this exclusive type of mounting is to give an accurate reading angle at any position the tester may be placed, thereby avoiding parallax, one of the most common errors in meter reading. Often the variations of readings due to parallax is greater than the difference between precision and non-precision instruments. By pulling forward on the knob at top of meter case the Bakelite case housing the two meters can be instantly tilted to any desired reading position, which will place the meter scale in direct vision with the operator's eyes.

The instrument scale readings are—0-10-50-250-500-1000 volts, both A.C. and D.C. The D.C. meter is used also for measuring 0-.25-1-10-50-250 milliamperes and resistances—on a low ohm scale from .5 to 500 ohms with approximately 13 ohms center scale and on 1500 ohms, 1.5 and 7.5 megohms scales with approximately 240, 24,000 and 120,000 ohms center of scale. All meter readings are obtainable by setting the selector switch to the proper position, marked to correspond with the scale numerals. The zero setting for ohms

readings is accomplished by adjusting the meter needle to full scale by using a small screw driver to turn any one of the three rheostats. The shafts of these rheostats have slotted heads projecting through the panel and marked "Ohms Adjustment". There is an individual rheostat adjustment for each of the megohm scale readings making it unnecessary to readjust each time the scale is changed. A single rheostat controls the zero adjustment for the LOW OHMS and 1500 ohm scales as the current consumed is the same, and one setting serves for both adjustments.

Two jacks are used for the measurement of A.C. and D.C. volts, D.C. milliamperes—1500, ohms 1.5 and 7.5 megohms. A third jack is used for the measurement of output voltages when the meter is used in conjunction with an oscillator, and another jack is used when measurements are made in the low ohms scale. No. 32 cords with prods and tips are used in conjunction with these jacks. The output jack has a condenser in series with the meter movement to prevent the application of D.C. current to the A.C. output meter.

TRIPLETT MODELS 1231-1232 OSCILLATORS

An oscillator properly used is an aid to radio servicemen in the finding of radio set troubles. There is no need to limit the oscillator to a single function such as required in aligning tuning circuits of a radio receiver, as it has many useful applications not commonly known to servicemen or if known, not generally used.

An oscillator can be used for nearly all tests encountered by the radio serviceman, including locating and isolating actual defects; testing tubes in a receiver under actual operating conditions. To appreciate and learn the usefulness of an

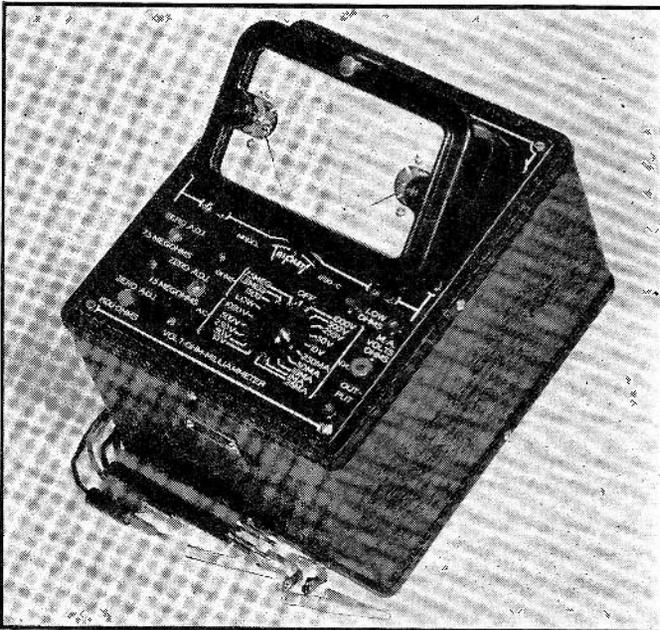


Fig. 18. Triplett Model 1200-C Volt-Ohm-Milliammeter.

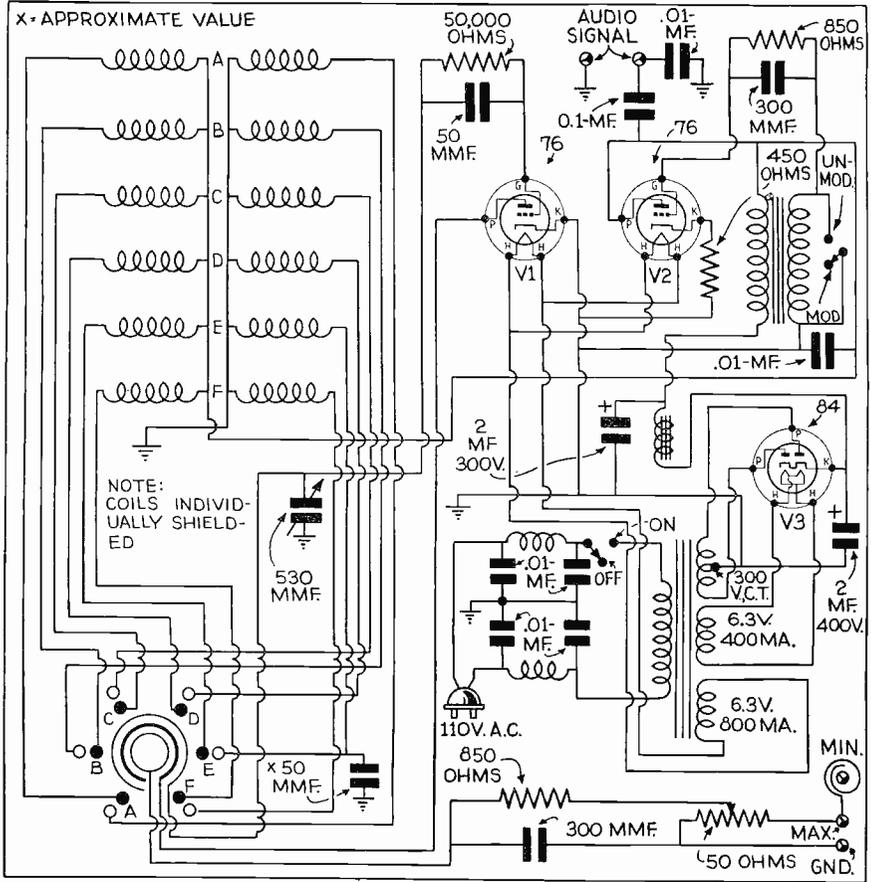


Fig. 20. Circuit of Triplett Model 1232 Signal Generator. The line input is well filtered.

oscillator the radio set circuit should be studied in order to understand how to feed the oscillator signal into various parts of the circuit. Radio engineers mutually agree upon one point of tube testing, *i.e.*, the best method of testing a radio tube for its worth is under actual operating conditions such as the tube is subjected to in the radio circuit, accomplished by an oscillator properly applied to the radio circuit.

Most tube testing apparatus which servicemen use comprises the so-called static test. It is commonly known that a tube which may test perfectly under a so-called static test will not perform under actual dynamic conditions. It is, therefore, highly desirable when a radio set is brought to the bench for repair not only to align the circuit, but also "Testing of Tubes" by means of the oscillator. To use the out-

put meter properly, connect the oscillator to the aerial and ground of the radio receiver, adjust the attenuator so that there is minimum signal voltage appearing across the loud speaker coil. Connect the meter between the plate of the output tube and chassis. This signal voltage shows up as an audible whistle, or when using the output meter, as a deflection of the meter needle.

All tubes should be in their respective sockets and the voltage characteristics of the radio receiver carefully checked previously to see that the proper operating voltages are being applied to the tubes.

In testing tubes by the oscillator method the A.C. signal is actually applied to the grid of the tube. Proceed by connecting the oscillator to the radio receiver and have the output meter connected as above. The

signal is then attenuated to a minimum value with all the receiver tubes in place. The logical place to begin a test is with the first stage. This may be the R. F. stage or it may be the first oscillator detector stage.

Secure a new tube of known performance having the same characteristics as the one removed from the circuit. Substitute the new tube for the tube which is in the set and note on the output meter the increase or decrease of amplification in comparison with the original tube in the radio set.

A decrease in the output meter reading indicates the tube should be replaced. A reading of the same magnitude would indicate the tube is performing satisfactorily. Proceed through the entire receiver stage by stage using the same method.

Since the rectifier tube does not amplify and is essentially a diode rectifying device, we are primarily interested in the amount of current this tube will put out at the proper voltage for actuating the radio receiver.

After testing all the stages of the radio set it is logical to test the rectifier tube by the oscillator method, although our preliminary check may have shown this tube to be putting out the proper voltage and the proper current. However, we can substitute a new rectifier tube for the one which is in the set and note if there is any increase in the indication of output meter.

The 1231 contains two type '30 tubes attached to the underside of the panel, which are accessible by removing the four screws holding the panel in the corners. The case also contains beneath the panel a 72 volt battery and 3 ordinary flashlight cells. The 1232 contains a power pack and 2-76, 1-84 tubes.

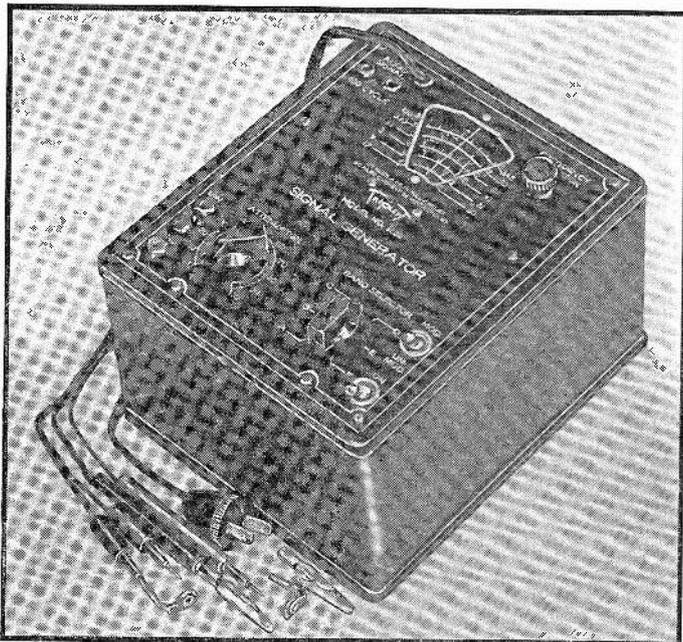


Fig. 21. Triplet Model 1232 Signal Generator. The Model 1231 is similar in appearance, but has set of batteries in the case.

The tubes and batteries should be replaced when tests show they have depreciated approximately 35%. The power pack is self contained in the 1232.

To connect the oscillator for use, connect the GND and MAX. jacks to the proper position in the radio set.

DEPENDABLE EQUIPMENT

Master Multitester Model 410

This instrument is shown on page 50. All D.C. measurements are made at a sensitivity of 2,000 ohms-per-volt, while A.C. readings are at 1,800 ohms-per-volt. An electronic rectifier is used for the A.C. readings. The apparatus is capable of measuring inductance, capacity and power in decibels, as well as the more usual volts, ohms, and milliamperes. Below at left on the same page is the Model 503, which, when used with a multimeter, provides a complete set tester. It will accommodate all present tubes, and has full provision for those with more elements which may be brought in the future.

The unit at the lower right is the Model 409 meter, which is quite similar to the 410, except that it is in a more compact

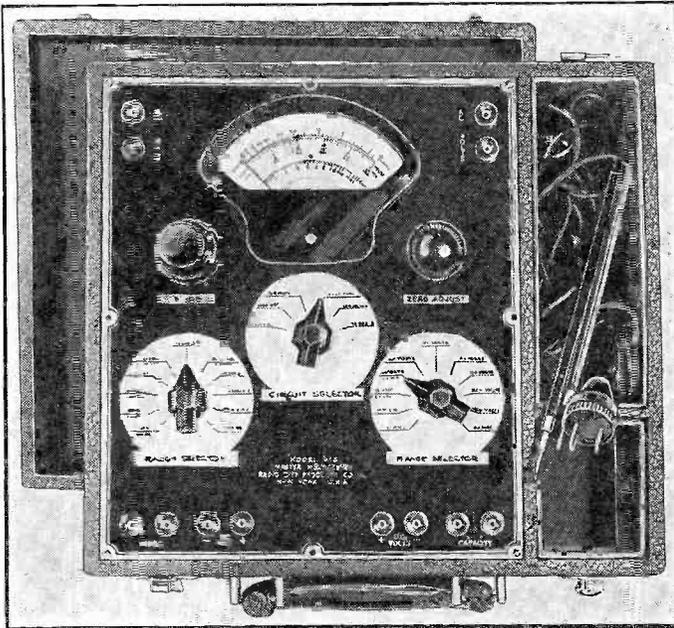


Fig. 22. Dependable Model 410 Multitester.

case and has no facilities for measuring capacity, inductance or power levels.

Both the 409 and the 410 feature a large fan-type meter which has a 0-500 micro-ampere movement. Both use the electronic rectifier, which does away with the disadvantages of the more usual copper oxide type.

meters, both of which are separately controlled from one shaft through the panel. The apparatus may be used with the minimum of switch setting, yet affords very fine results.

The instrument is housed in a Golden Oak case with a panel finished in antique bronze. A leather handle which lies flat

SUPREME MODEL 530 OSCILLOSCOPE

This unusual instrument uses a 2" tube, a radical departure from all the other popular priced units which have recently been brought out. This model has no linear sweep, but has provision for 60-cycle sweep. A vertical amplifier is available, and may be cut out if not needed. Another feature is the return sweep eliminator, which is very useful when using the 60-cycle sweep frequency. The spot may be positioned by means of two potentiometers, both of which are separately controlled from one shaft through the panel.

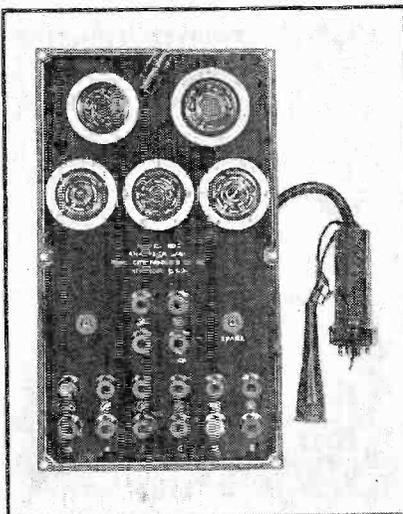


Fig. 23. The Dependable Model 503 Analyzer.



Fig. 24. Dependable Model 409 Multimeter.

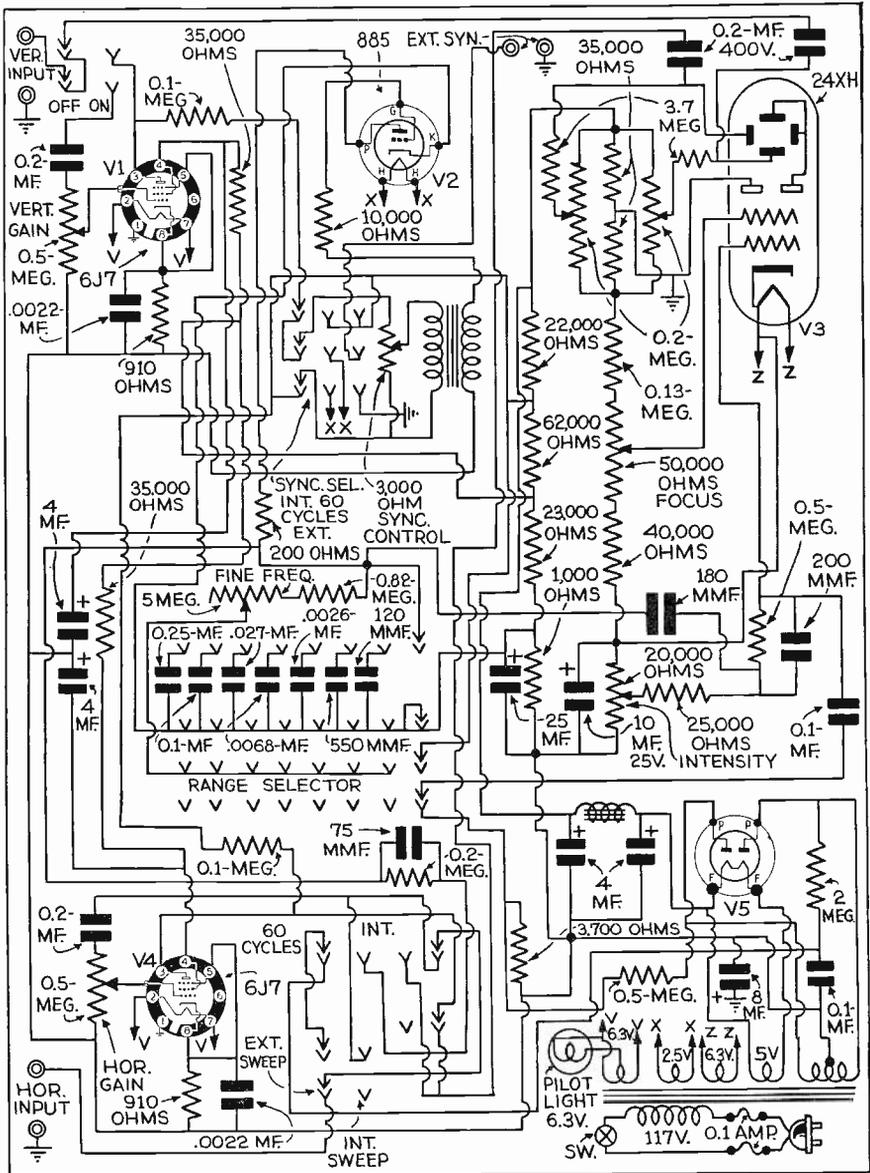


Fig. 26. Supreme Model 535 Oscilloscope with linear sweep circuit.

**SUPREME MODEL 550 DELUXE RADIO
TESTER**

One of the outstanding features of this new tester is the use of a radically new type of meter. Previous meters on test equipment needed so many scales that the readings were often difficult to interpret. The ohms scale in particular led to confusion, since it is so crowded at one end.

The so-called quadrimeter used on this tester has a double scale arrangement whereby one meter movement is made to serve for two separate sets of scales. Since the ohmmeter scale is one of the most confusing due to its non-linearity, this scale is placed separately from the others. All the scales are very long and easily read.

The panel of the apparatus is of etched antique bronze and the case is of Golden

Oak. The latter has an easily removable cover, and there is room in the case to carry all the necessary test leads and other connections.

Complete facilities are provided for testing tubes by the use of the grid shift test. This, of course, entails the use of power from the receiver being checked. All types of tubes including triodes and multigrid tubes may be checked in this manner (as was described in Chapter 3).

Resistance readings up to 200,000 ohms are made by the use of a 4.5 V. battery contained in the case. When higher ranges are required, use is made of a small built-in power pack, and readings may be made all the way up to 20 megs.

Electrostatic capacity leakage tests are easily made, and it is not necessary to observe polarity when connecting the condenser to the circuit.

The use of the copper-oxide meter rectifier circuit allows the use of the instrument for conducting output tests and for A.C. measurements. A.C. measurements are made on the same scales as the D.C. measurements, thus greatly simplifying the readings.

This apparatus is very useful for testing

in other fields than radio receivers. Since voltages up to 1,400 V. may be read, the equipment will be very useful to the transmitter engineer and the P.A. or theatre sound system Service Man. Special connection leads are made for the latter use.

The d.b. readings run from -10 to $+46$, and capacity ranges from .002 to 14 mfd. Currents may be read up to 14 A., in D.C. only.

CLOUGH-BRENGLE VACUUM TUBE VOLTMETER

This apparatus has been designed to have the widest possible range and yet always work on the linear part of the tube characteristic. There are three scale ranges, 0-1.2 V., 0-10 V., and 0-100 V. The circuit is such that both the square law and peak methods of measurements are applied in carefully chosen ranges.

Normally the equipment is used with the tube placed in clips inside the cabinet. This makes it very conveniently portable. Under these conditions of operation, the input circuit consists of 300 mmf. in parallel with 10 megs. However, if a lower input impedance is desired, or if it is desired to eliminate excessively long leads between the

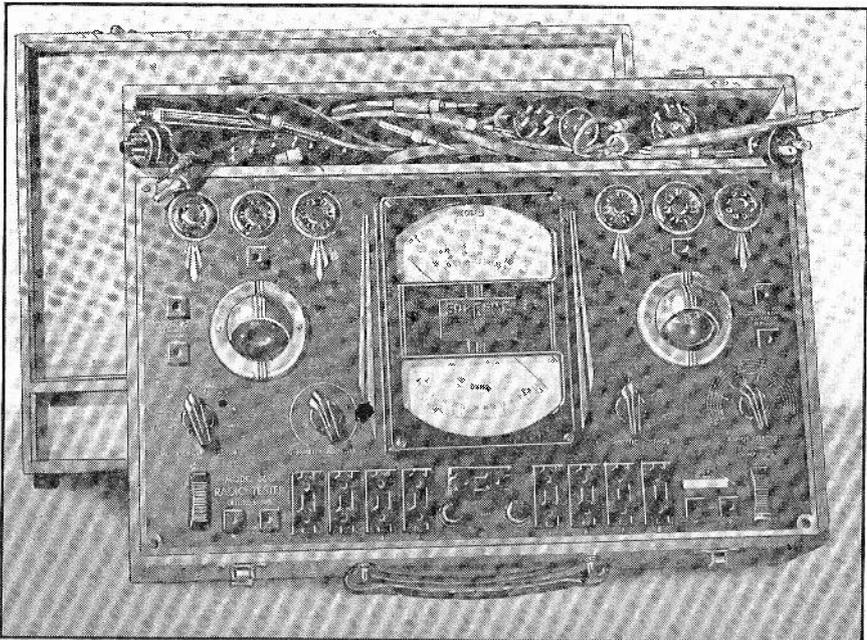


Fig. 27. The new Supreme Model 550 Set Analyzer. A special "quadrimeter" is used.

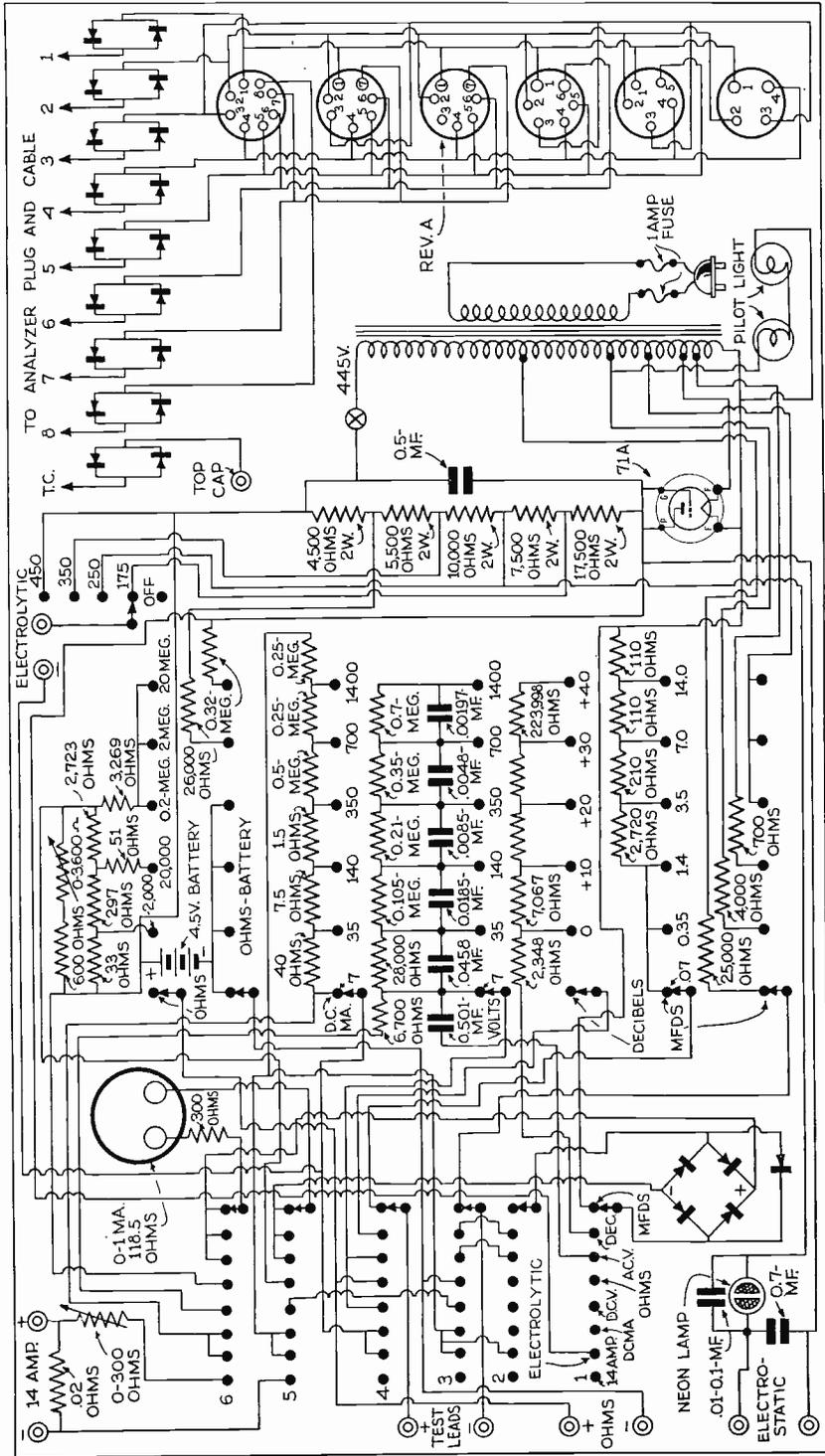


Fig. 28. Diagrammatic view of the Supreme Model 550 Deluxe Set Tester. A self-contained power supply allows very high resistances to be read, and makes possible complete condenser tests. The rows of dots represent decks on the selector switches.

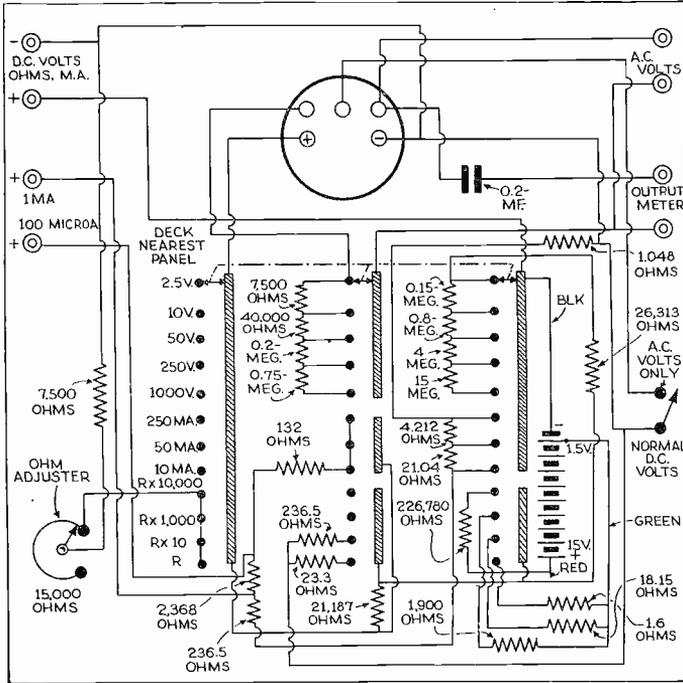


Fig. 32. Weston Model 772 high sensitivity analyzer.

scales, 1 Ma., and 100 microamperes, these being reached by separate jacks on the panel as a protection to the meter.

Output meter jacks are provided, and these differ from the A.C. jacks by the addition of a series condenser, which is usually needed for this purpose.

This instrument comes complete in a covered case which has a large pocket for carrying the test leads which are also supplied.

The panel is finished in black enamel with chromium and red trim, and the meter is of the bakelite cased type.

Both A.C. and D.C. voltage readings up to 1,000 V. may be made, the A.C. readings being at 1,000 ohms-per-volt, while the D.C. readings are at 20,000 ohms-per-volt. Current readings up to 250 Ma. are possible. There are two high sensitivity current

The appearance of the WESTON MODEL 669 VACUUM TUBE VOLT-METER may be seen in Fig. 35. The circuit is shown in Fig. 34. There are only two tubes used, one of which is the power supply rectifier. The power line connection cord is of the double fused type for positive protection against shorts. The apparatus is directly calibrated in 6 ranges up to 16 V. These readings may be easily multiplied by factors of 10 and 50 by means of a simple voltage divider system. The input capacity is only 4 mmf. and the grid cap of the tube projects through the panel so that it is an inch or more from any grounded surface.

The accuracy is within 3% from 40 cycles to 50 mc. Accuracy on the very low ranges is assured by the use of a neon tube across the power supply which tends to hold the grid and plate voltages steady regardless of line fluctuations. A simple control is provided to compensate for ageing of the type 78 measuring tube or for use when a new tube is to be inserted.

The WESTON MODEL 692 TEST OSCILLATOR is pictured in Fig. 36. This unit is particularly notable for its very

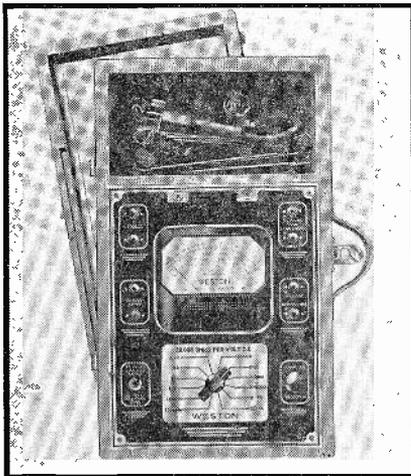


Fig. 33. Front view of the Weston 772.

careful and complete shielding. Triple shielding is used and this cuts the external field to a negligible amount.

The power supply is obtained from a $22\frac{1}{2}$ V. "B" battery and a $4\frac{1}{2}$ V. "A" battery. Both of these are entirely self-contained and well shielded. A separate tube is used for R.F. and A.F. oscillation and the A.F. tube may be cut out or its output may be separately used at will. A connection is provided for use of external A.F. modulation.

Also, for use when aligning receivers with a cathode ray oscilloscope, a jack is provided for the use of an external frequency modulator or wobbler.

The maximum R.F. output is 0.2 V., and this may be cut down to about 1 microvolt by the use of the R.F. attenuator. The A.F. output is 1 V. at 400 cycles.

A plug-in coil system is employed, this allowing complete freedom from inter-

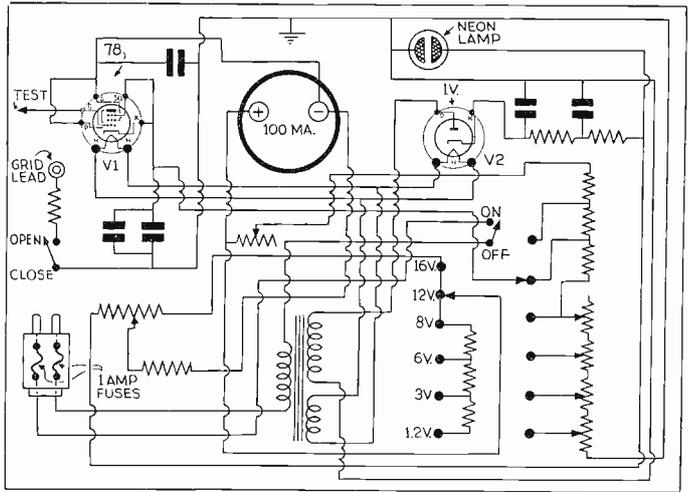


Fig. 34. Weston Model 669 V. T. Voltmeter. The meter is a 100-micro-ampere instrument, not 100 ma., as shown above.

action between coils of the various bands. The coils are carried in a handy holder, and plug into a cast aluminum compartment. The guaranteed accuracy over the entire frequency band is 1%. The various bands covered run as follows: 100 to 250 kc.; 250 to 550 kc.; 535 to 1,600 kc.; 1.5 to 4 mc.; 4 to 10 mc.; and 10 to 22mc.

The apparatus is supplied complete with all tubes and batteries, and a carrying case may be had if desired.

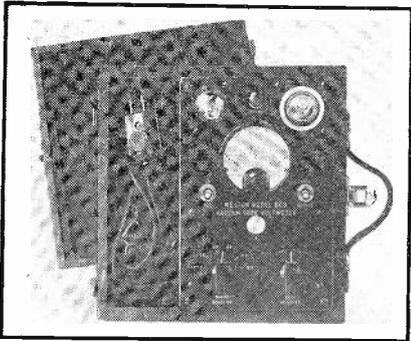


Fig. 35. Weston Model 669 V.T. Voltmeter.

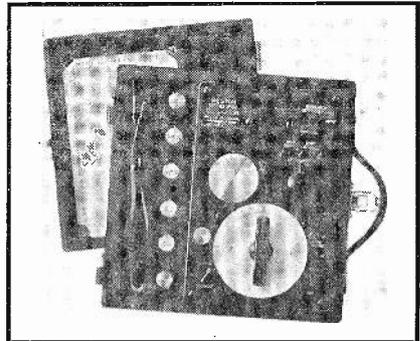


Fig. 36. Weston Model 692 Test Oscillator.

TUBE TYPES

and Base Diagram Numbers

Tube	Base	Tube	Base	Tube	Base	Tube	Base
01A	4D	5V4G	5-L	6L7G	7-T	35/51	5-E
1A1	4A	5W4	5-T	6N6G	7-W	35S/51S	5-E
1A4	4-K	5X4G	5-Q	6N7	8-B	36	5-E
1A4T	4-K	5Y3G	5-T	6N7G	8-B	37	5-A
1A6	6-L	5Y4G	5-Q	6P7G	7-U	38	5-F
1B1	4-A	5Z3	4-C	6Q7	7-V	39/44	5-F
1B4	4-K	5Z4	5-L	6Q7G	7-V	40	4-D
1B4T	4-K	6	4-A	6R7	7-V	41	6-B
1B5/25S	6-M	6A3	4-D	6R7G, 6S7G	7-R	42	6-B
1C1	4-A	6A4/LA	5-B	6T7G	7-V	43	6-B
1C6	6-L	6A5G	6-T	6U7G	7-R	45	4-D
1C7G	7-Z	6A6	7-B	6V6	7-AC	46	5-C
1D1	4-A	6A7, 6A7S	7-C	6V6G	7-AC	46A1	5-7
1D5G	5-R	6A8	8-A	6V7G	7-V	46B1	5-7
1D5GT	5-R	6A8G	8-A	6X5	6-S	47	5-B
1D7G	7-Z	6B4G	5-S	6X5G	6-S	48	6-A
1E1	4-A	6B5	6-D	6Y5	6-J	49	5-C
1E5G	5-R	6B7, 6B7S	7-D	6Y7G	8-B	50	4-D
1E5GT	5-R	6B8	8-E	6Z5	6-K	53	7-B
1E7G	8-C	6B8G	8-E	7	4-A	55, 55S	6-G
1F1	4-A	6C5	6-Q	8	4-A	56, 56S	5-A
1F4	5-K	6C5G	6-Q	9	4-A	56AS	5-A
1F5G	6-X	6C6	6-F	10	4-D	57, 57S	6-F
1F6	6-W	6C7	7-G	12A	4-D	57AS	6-F
1F7G	7-AD	6C8G	8-G	12A5	7-F	58, 58S	6-F
1G1	4-A	6D6	6-F	12A7	7-K	58AS	6-F
1G5G	6-X	6D7	7-H	12Z3	4-G	59	7-A
1H4G	5-S	6D8G	8-A	15	5-F	71A	4-D
1H6G	7-AA	6E5	6-R	18	6-B	75, 75S	6-G
1J6G	7-AB	6E6	7-B	19	6-C	76	5-A
1K1	4-A	6E7	7-H	20	4-D	77	6-F
1R1G	4-T	6F5	5-M	22	4-K	78	6-F
1T1G	4-T	6F5G	5-M	24A, 24S	5-E	79	6-H
1V	4-G	6F6	7-S	25A6	7-S	80	4-C
1Y1	4-A	6F6G	7-S	25A6G	7-S	81	4-B
1Z1	4-A	6F7, 6F7S	7-E	25B6G	7-S	82	4-C
2	4-A	6G5	6-R	25L6	7-AC	83	4-C
2A3	4-D	6H6	7-Q	25L6G	7-AC	83V	4-L
2A5	6-B	6H6G	7-Q	25S	6-M	84	5-D
2A6	6-G	6J5G	6-Q	25Z5	6-E	85	6-G
2A7, 2A7S	7-C	6J7	7-R	25Z6	7-Q	85AS	6-G
2B7, 2B7S	7-D	6J7G	7-R	25Z6G	7-Q	89	6-F
2E5	6-R	6K5G	5-U	26	4-D	V99	4-E
2S/4S	5-D	6K6G	7-S	27, 27S	5-A	X99	4-D
2Z2/G84	4-B	6K7G, 6K7	7-R	30	4-D	182B/482E	4-D
3	4-A	6L5G	6-Q	31	4-D	183/483	4-D
4	4-A	6L6	7-AC	32	4-K	210T	4-D
5	4-A	6L6G	7-AC	33	5-K	485	5-A
5U4G	5-T	6L7	7-T	34	4-M	864	4-D

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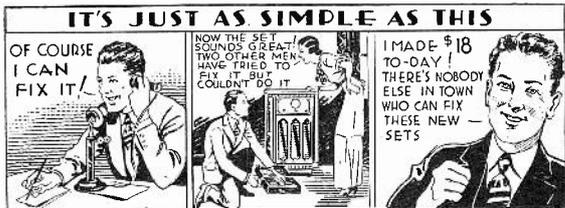
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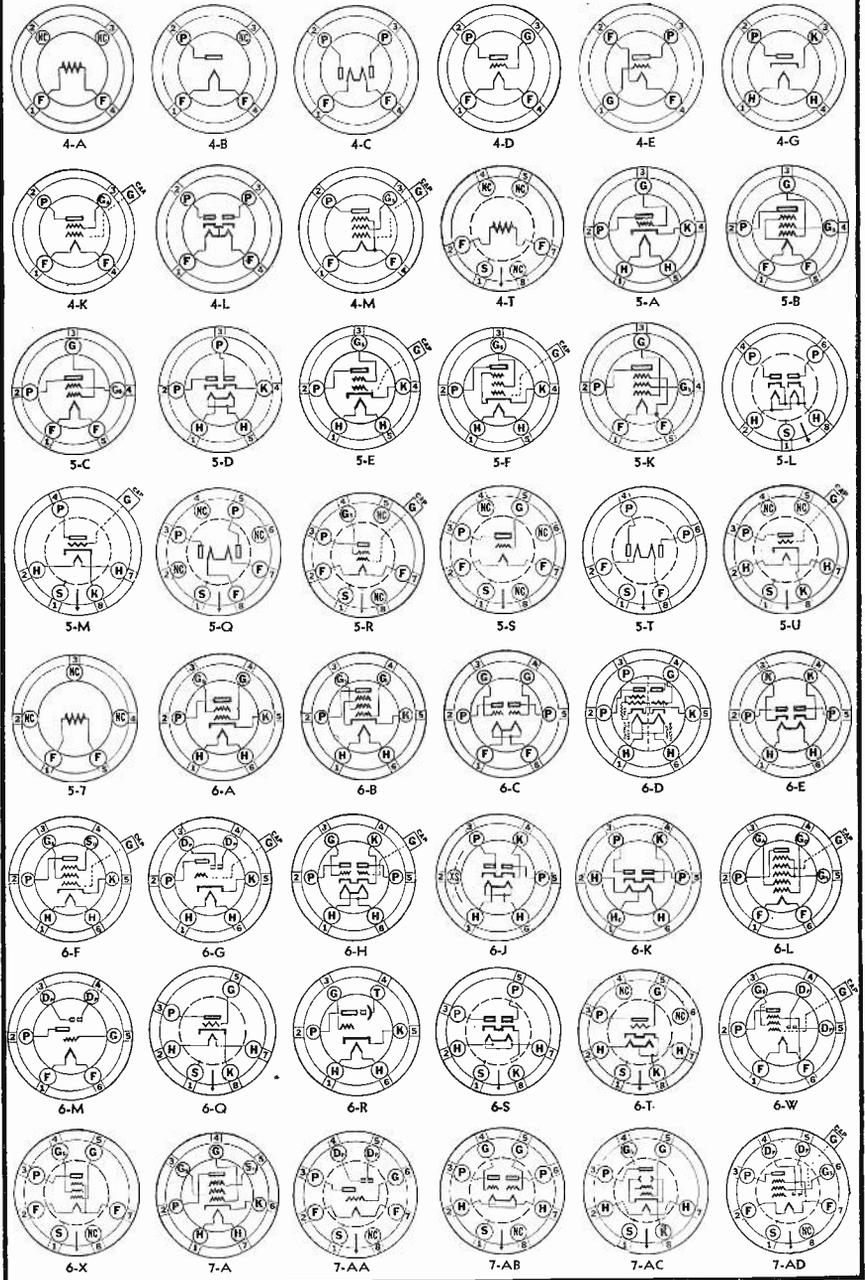
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TUBE AND BASE DIAGRAMS

(Viewed From Bottom of Base—RMA Numbering System)



Above and on page 60 are shown the bases of the latest types of tubes at the time this book was written. Others will doubtless soon follow.

Here Are the Other Titles

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PRESENTED on this page are the other books in the RADIO-CRAFT LIBRARY SERIES—the most complete and authentic set of volumes treating individually important divisions of radio, refrigeration and air conditioning. Each book has been written for the purpose of giving you the opportunity to specialize in one or more of the popular branches of the subjects mentioned. The

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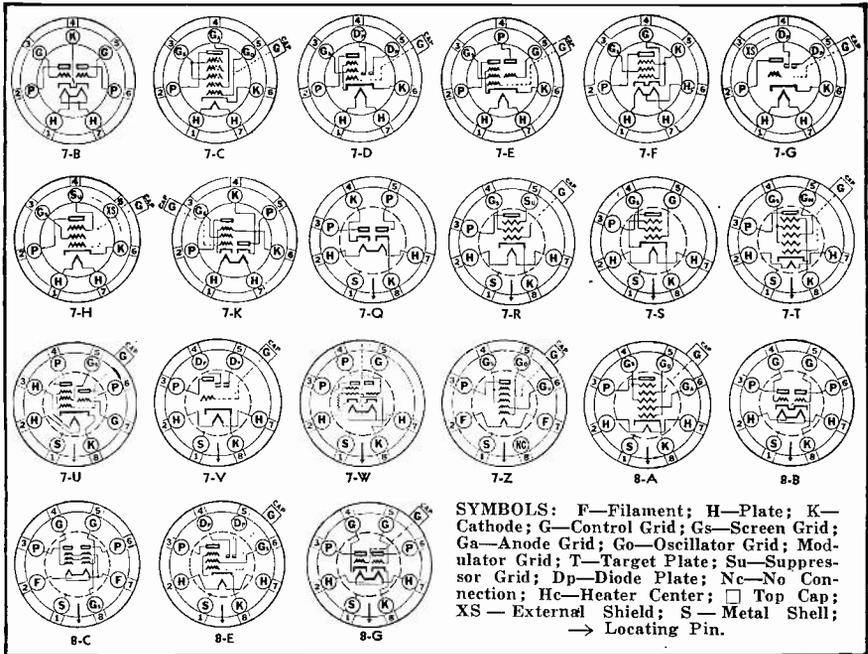
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“G” tubes and those with similar characteristics.

Type	Description	Similar to:	Type	Description	Similar to:
1C7G	Pentagrid Converter	1C6	6F6G	Power Output Pentode.....	42
1D5G	Super Tetrode Amplifier.....	1A4	6H6G	Double Diode	6H6†
1D5GT	Super Tetrode Amplifier.....	1A4	6J5G	Triode Amplifier	*
1D7G	Pentagrid Converter	1A6	6J7G	Amplifier and Detector.....	77
1E5G	Screen Grid R-F Amplifier....	1B4	6K5G	High Mu Triode Amplifier....	*
1E5GT	Screen Grid R-F Amplifier....	1B4	6K6G	Power Pentode	41
1E7G	Output Double Pentode.....	*	6K7G	Super Control Pentode.....	78
1F5G	Power Output Pentode.....	1F4	6L5G	Triode Amplifier	6C5G§
1F7G	Double Diode Pentode.....	1F6	6L6G	Power Amplifier	6L6
1G5G	Power Output Pentode.....	*	6L7G	Heptode Mixer	6L7†
1H4G	Amplifier and Detector.....	30	6N6G	Power Output Amplifier.....	6B5
1H6G	Double Diode Triode.....	1B5/25S	6N7G	Class B Power Amplifier.....	6A6
1J6G	Class B Twin Amplifier.....	19†	6P7G	Pentode Triode	6F7
1R1G	Battery Receiver Ballast.....	1Y1	6Q7G	Double Diode High Mu Triode	6Q7†
1T1G	Battery Receiver Ballast.....	*	6R7G	Double Diode Med. Mu Triode	6R7†
5U4G	Full Wave Rectifier.....	5Z3	6S7G	Super Control Pentode.....	6D6§
5V4G	Full Wave Rectifier.....	83V	6T7G	Double Diode High Mu Triode..	6Q7G§
5X4G	Full Wave Rectifier.....	5Z3	6U7G	Super Control Pentode.....	6D6
5Y3G	Full Wave Rectifier.....	80	6V6G	Power Amplifier	*
5Y4G	Full Wave Rectifier.....	80	6V7G	Double Diode High Mu Triode	85
6A5G	Power Output Triode.....	6A3§	6X5G	Full Wave Rectifier.....	84
6A8G	Pentagrid Converter	6A7	6Y7G	Double Triode Amplifier.....	79
6B4G	Triode Power Amplifier.....	6A3	25A6G	Power Pentode	43
6B8G	Double Diode Pentode.....	6B7	25B6G	Power Amplifier	43§
6C5G	Triode Amplifier	6C5†	25L6G	Power Amplifier	*
6C8G	Double Triode Amplifier.....	*	25Z6G	High Vacuum Rectifier and	
6D8G	Pentagrid Converter	6A7§		Voltage Doubler	25Z5
6F5G	High Mu Triode Amplifier....	6F5†			

* New Characteristics.

† Except filament current (240 Ma.).

§ Similar but not identical in characteristics.

† Similar except for capacitance.

COMMON FORMULAS

Ohms Law

Calculation of voltage, current and resistance.

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

I is the current in amperes;
E is the potential in volts;
R is the resistance in ohms.

The formula may also be written in two other forms:

$$E = IR \text{ and } R = \frac{E}{I}$$

Inductive Reactance of a Coil

This comes in handy when working out the value of choke coils and the like.

Reactance in ohms = $2\pi fL$ $\pi = 3.14$
f = frequency in cycles;
L = inductance in henries.

The capacitive reactance of a condenser may be figured from:

$$\text{Reactance} = \frac{10^6}{2\pi fC}$$

$\pi = 3.14$;
f = frequency in cycles;
C = capacity in mf.

Resistance Calculations

Resistances in parallel may be figured from this formula:

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

R = the total of all the resistances;
 R_1 and R_2 = the individual resistances.

For a series connection, it is simply necessary to add up the values;

$$R = R_1 + R_2 + R_3 + R_4$$

Calculating the Wavelength and Frequency

A simple formula for this is of great use to the Service Man. It is:

$$\lambda = 1,885 \sqrt{LC}$$

λ = wavelength in meters;
L = inductance in microhenries;
C = capacity in mf.

The formula for calculation of frequency is:

$$f = \frac{10^6}{2\pi \sqrt{LC}}$$

$\pi = 3.14$;
f = frequency in cycles;
I = inductance in henries;
C = capacity in mf.

A.C. Circuits Calculations

Ohms law may be used in this work as follows:

$$E = IZ \quad I = \frac{E}{Z} \quad Z = \frac{E}{I}$$

E = potential in volts;
I = current in amperes;
Z = impedance of circuit in ohms.

The impedance may be found from:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Z = impedance in ohms;
R = resistance in ohms;
 X_L = reactance of inductance in ohms;
 X_C = reactance of capacity in ohms.

Use of the Decibel

The decibels equal to a certain power ratio is 10 times the logarithm of that ratio.

$$N = 10 \text{ Log}_{10} \frac{P_2}{P_1}$$

N = decibels;
 $\frac{P_2}{P_1}$

$\frac{P_2}{P_1}$ = power ratio.

When voltage or current are being considered, the constant 20 is used in place of 10.



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tubes, repairs, etc. A few hundred \$30, \$50, \$75 a week jobs have grown to thousands in 20 years. And Radio is still a new industry—growing fast!

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