PRACTICAL
RADIO SERVICE METHODS
and
GENERAL SERVICE PROCEDURE
on
RECEIVERS AND TRANSMITTERS

TRAINING AND INSTALLATION DIVISION
PHILCO RADIO AND TELEVISION CORPORATION
PHILADELPHIA, PA.

FOREWORD

The purpose of this book is to clarify and correlate the approach to radio problems throughout the entire course of the Philco Training School.

It takes the form of a general theory of radio and service methods and provides a framework upon which a detailed method of attack may be constructed. This can then be applied to any specific piece of equipment.

It must be remembered that this book is a complement of detailed specific lectures and laboratory procedures as given in the course of training.

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TABLE OF CONTENTS

PART I

PRACTICAL RADIO SERVICE METHODS

PART II

GENERAL SERVICE PROCEDURE ON RECEIVERS AND TRANSMITTERS

PRACTICAL RADIO SERVICE METHODS

PART I

PHILCO TRAINING SCHOOL

INTRODUCTION

This text is intended to familiarize the student with troubles which may occur in radio parts, together with the symptoms of these troubles; and to enable him to discover defective parts in various circuits by the most dependable and most direct methods.

First, the student is taught how to identify parts by their physical appearance, their location in relation to other parts, and their circuit position in relation to certain common reference points such as: the power supply input terminals, the power supply output terminals, the signal input terminals, the signal output terminals, and the tube sockets. The basic ability to recognize parts by observation, and to associate them with their schematic representations, is essential to the intelligent testing of any unit.

Second, the student is shown how defective parts influence circuit conditions, by contrasting voltage, current, and resistance readings in circuits when all parts are normal, with similar readings when certain parts are defective. Also, audible indications of the signal are noted in both cases. It is shown that nearly all troubles may be resolved into varying degrees of open-circuits and short-circuits; therefore, most troubles are simulated by the introduction of certain values of resistance either in parallel or in series with the various parts. It is thus shown how an abnormal value of resistance in each component part of a circuit affects the voltage, current, and resistance readings in all related circuits, and how to interpret these readings accurately. With the previous training the student has received, he should know in general when readings are normal. By drawing upon this knowledge he is in a position to detect specific troubles more readily.

Third, the student is taught the most logical and effective methods of service procedure. He is shown how to simplify an apparently complicated circuit by breaking it down into a succession of different types of amplifier stages, through which a signal may be followed until a particular stage failure is noted. In this way the trouble is quickly localized, and much unnecessary testing is eliminated. Once the trouble is localized, further simplification of the problem is made, by considering any stage as being composed essentially of only a tube, resistors, coils, and condensers. Since most troubles in these parts are varying degrees of open-circuits and short-circuits, the possibilities of trouble are greatly limited. Such a viewpoint makes the student's thinking more definite, and increases his confidence.

The text is arranged in logical order for the best learning sequence, and each chapter is practical and important.

IDENTIFYING RECTIFIER SOCKETS AND "B" SUPPLY TERMINALS

Since the rectifier is the next link in the A-C power supply, it is important to know which tube and socket is the rectifier; also, which socket terminals connect to what elements of the rectifier tube.

The rectifier tube socket may be located visually by observing where the power transformer is located, and then tracing the high voltage leads. These leads will connect to the rectifier socket. The terminals to which they connect will be the plate terminals of the rectifier socket. In tracing the transformer leads, bear in mind that the filament leads as well as the high voltage leads will connect to the same socket. Also, the rectifier may be the half wave or the full wave type. In the former case, only one high voltage lead from the transformer will connect to the socket. The power supply may be of the full wave type using two separate half wave rectifier tubes such as is done in high voltage high power supplies. Again, only one high voltage lead from the transformer will connect to a socket. The other high voltage lead will connect to the other socket.

Naturally, a rectifier socket will not be found in equipment designed to receive plate supply voltage directly from a dynamotor, batteries, or from the power supply of another piece of equipment. A piece of equipment so designed will have at least four power input terminals; two for the low voltage filament power, and two for the high voltage plate supply. This is in contrast to the equipment with its own built-in power supply wherein only two terminals are used. An exception to this last statement will be equipment which has a built-in dynamotor.

After the rectifier socket has been located, the various terminals may be identified by a combined visual inspection and voltage check. By removing the rectifier tube from its socket, and using a high range A-C voltmeter (0-1000), the plate terminal or terminals can be located by measuring from B minus or chassis to the various terminals. The terminal at which a high reading is obtained with respect to the chassis is a plate terminal. If a full wave rectifier tube is used as such, there will be two such terminals. It should be noted that the voltage reading from plate to plate will be the total voltage across the high voltage secondary winding, while the reading from either plate to B minus will be half the plate to plate reading; because, in measuring from plate to B minus, the meter is actually connected across one half of the high voltage secondary. When the high voltage terminals have been found, a lower range on the voltmeter can be used to determine the filament terminals. If the tube is a directly heated cathode type, the filament terminals can be readily identified since there will be only these two additional connections. With the indirectly heated type cathode, there will be the two filament terminal connections and the cathode connection to the filter circuit.

Important reference test points in any receiver are the B plus and B minus terminals of the plate supply. To quickly identify these points, certain simple relationships can be used.

An examination of the schematic diagram will reveal the circuit arrangement of the parts of the power supply. If the schematic shows that the filter choke is connected to one side of the rectifier filament, one can expect that in the power supply one lead from the choke will connect to a filament terminal of the rectifier socket. The other side of the choke, as shown on the schematic, connects to the B plus terminal of the power supply output. Therefore, locating this lead in the chassis and tracing it from the choke to a terminal will locate the B plus point in the chassis.

Checking with the schematic indicates that the filter condensers are connected one from each side of the choke to B minus. By locating the filter condenser and identifying the loads connecting to the choke, the remaining condenser leads can be traced to B minus. Electrolytic condenser leads or terminals are usually color coded, although a standard code does not apply to all circuits. In general, it can be said that the black lead from the electrolytic condenser will connect to B minus.

The visual check outlined above can be supplemented by a continuity check with an ohmmeter. In many cases the actual circuit wiring is such that some of the leads are buried in cabling or hidden from sight. For such conditions, the use of a low range ohmmeter, aids in tracing the leads.

TESTING "B" SUPPLY FILTER CIRCUITS

a. One method of testing filter circuits for defective parts is by resistance analysis of the input and output circuits. By comparing the readings taken with those which are normal, and using a practical application of Ohm's Law for series-parallel circuits, the defective part may be determined. An advantage of this type of testing is that the power supply is inoperative during test; therefore, no damage can result to any part due to excessive current flow, should a short-circuit exist. By referring to Figure 1 it may be seen that the

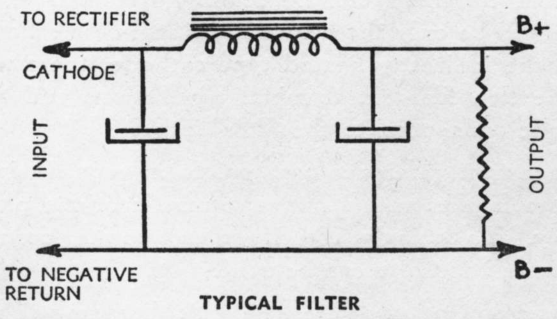


FIGURE 1

input of the filter is actually the output of the rectifier, and the output of the filter is the final output of the whole power supply.

If the ohmmeter test prods are connected across the input terminals of the filter circuit, a reading will be made of the equivalent resistance of a complex network, composed of the leakage resistance of the choke in series with the parallel resistance of the second condenser leakage and bleeder resistor. See Figure 2. The leakage resistance of normal elec-

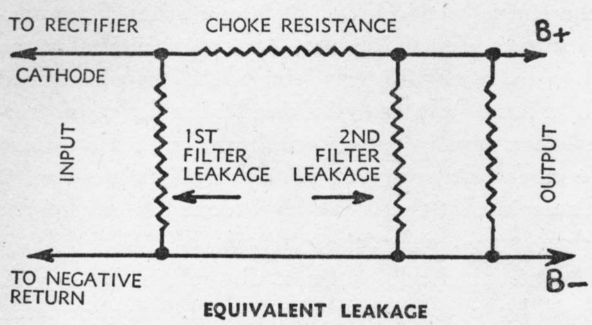


FIGURE 2

trolytic condensers is relatively very high, so for practical purposes, will not greatly affect resistance conditions. The ohmmeter would really read the resistance of the filter choke in series with the resistance of the bleeder resistor.

If the ohmmeter prods are connected across the output terminals of the filter circuit a reading will be made of the equivalent resistance of the bleeder resistor, shunted by the leakage resistance of the second condenser, and also shunted by the resistance of the choke in series with the first condenser. In this case the ohmmeter would read, for practical purposes, the resistance of the bleeder resistor only. Thus the resistance of the input circuit is higher than that of the output circuit by the value of the choke.

If the choke were short-circuited the readings at both input and output would be identical. If the choke were open-circuited the input reading would be very high (leakage resistance of first condenser), and the output reading would remain practically the same. If either condenser were open-circuited both readings would remain about the same. If the first condenser were short-circuited the input resistance would be low, and the output reading would be the value of the bleeder resistor in parallel with the choke. If the second condenser were short-circuited the input reading would be the value of the choke, and the output resistance would be very low. Likewise, other possible troubles may be found by similar analysis.

b. The choke performs a very important function in the operation of a filter circuit. To understand its action it will be necessary to review some fundamental ideas.

When direct current starts to flow through an inductance it is opposed by an opposition that is different than resistance. The opposition is due to a counter-E.M.F. that is set up in the inductance because of the change in the magnetic field, produced by the coil current changing from zero. The magnetic field was non-existent, or zero, until current started to flow.

Since a change in the magnetic field of a coil will produce an E.M.F., the variation in the magnetic field due to the current change, will produce an E.M.F. or voltage that opposes the change in current. Because of this, the current does not immediately reach a value as determined by resistance and the applied voltage according to Ohms Law; but requires a certain length of time to do so. The time required depends upon the inductance of the coil. The larger the inductance, the longer the time required for the current to reach its final value. If after the current reaches its final value the applied voltage is suddenly decreased or removed the current in the coil will begin to decrease. This again will produce an inductive voltage, but it will have a polarity that will tend to sustain the current for some time after the applied voltage has decreased to zero. The characteristics of choke coils account for the opposition they offer to changes in current. When alternating current is applied to an inductance the current encounters this opposition as well as the opposition due to resistance. The opposition that an inductance offers to the change in current or to a-c because of self-induced voltage, is called inductive reactance. Inductive reactance becomes greater as either the inductance, or frequency of the applied voltage is increased. Hence, the limiting or opposing action to the flow of current becomes greater when either the inductance or the frequency of the current-changes is increased.

The ability of an inductance to store electric energy as a magnetic field and then later to return this energy to the circuit, together with the opposition it offers to changes in current, is put to good use in filter circuits. The current from a rectifier is a series of pulses. During a part of the rectified pulse the current increases from zero toward some maximum value. In this time the first filter condenser charges to a voltage approximately equal to the maximum value of the rectified pulse. The choke coil prevents these pulses from reaching the output of the filter, because of the high opposition it offers to them. When the pulse decreases toward zero, the condenser voltage causes a current to flow that adds to the current produced by the E.M.F. of self-inductance. Thus, the condensers and the choke tend to keep the current constant, thereby eliminating hum and making the rectified current flowing through the load a steady current rather than a series of pulses.

The inductance for a filter may be obtained from either a specially constructed iron core coil or by making use of the inductance of the loudspeaker field coil. It is economical to use the speaker field coil as the filter choke, because the current demanded by the equipment will produce a magnetic field sufficient to operate the speaker. The inductance of the field coil will be sufficient for filter action; hence, one less part will be required and additional current to magnetize the speaker field will be unnecessary. When the filter inductance is connected in the negative lead of the power supply, the d-c voltage drop across the coil due to its resistance is sometimes used to supply bias voltages.

Common troubles in filter chokes are: open or partially open coils, internal shorts across the terminals of the coils, leaks or partial leaks to the frame of the inductance, and shorted turns.

An open choke will be the cause of no voltage output from the power supply, and a partially open choke coil causes low voltage output. High hum or ripple in the output voltage will result if the coil develops a short across its terminals. Sometimes the filter condensers develop an internal short from one positive lead to the other. This will effectively short out the choke and cause a hum. Condensers that are used to resonate the choke should also be suspected when this type of trouble is encountered. If a large percentage of the coil turns short out, similar trouble may be expected. Leaks or shorts to the choke frame, or iron core, will cause low or no voltage output, and are similar in effect to shorted or leaky filter condensers.

c. It is known that the rectifier supplies a pulsating d-c voltage to the first filter condenser. The first condenser charges to a voltage approaching the highest value of this pulsating d-c voltage. When the value of the pulse begins to drop, current will flow out of the condenser and will tend to keep the flow of current constant. The second condenser acts in somewhat the same manner. However, both the input and output condensers serve another purpose as well. The first filter condenser serves as a low impedance path for the high voltage a-c applied across the rectifier. Hence, there will be very little drop in this a-c voltage. Therefore, the resultant rectified voltage will be higher than if no condenser were present at this position. The second condenser can be thought of as acting as a short circuit for any a-c voltage. Hence no a-c voltage willl be present at the output of the filter.

It is evident that if the capacity of the first condenser is low, the output voltage of the filter will be lower than normal, and will have considerable ripple voltage in it. This will cause the radio apparatus to work inefficiently, and hum.

Lack of sufficient capacity in the second filter condenser will cause the filter circuit to act in a similar manner as far as the hum or ripple voltage, but the d-c output voltage will be only slightly affected. Sometimes insufficient capacity will cause motor-boating or oscillation, because of the common impedance path that the filter presents to the signal currents. If the second filter is large enough, and in good condition, there will be no common impedance in the filter circuit, because the condenser will act as a short circuit across the impedance. Therefore there will be no common coupling impedance to cause either regeneration or degeneration. If regeneration occurs, the equipment might break into oscillation whereas degeneration would cause lower amplification. This may cause distortion if, because of it, some frequencies are amplified more than others.

Summing up these facts, low amplification, instability, and high hum level can be caused by the second filter having insufficient capacity, or having decreased in capacity. These are common troubles when electrolytics dry out or lose electrolyte through evaporation or decomposition; the results being a decrease in capacity, and the troubles just discussed. If the filter condensers decrease in capacity (a common trouble in electrolytics), or open circuits (common to all condensers), the trouble mentioned above will occur. When a condenser decreases in capacity, it is equivalent to a good condenser that is partially open-circuited. Shorted filter condensers are the cause of very low or no voltage output from the filter.

Partially shorted filter condensers cause the voltage to be lower than normal, and the hum level to be high. The resistance of the dielectric used in filter condensers other than electrolytic types should be several megohms. Values of 20 to 100 megohms are not uncommon for these types. For electrolytic filter condensers to be considered good, the dielectric resistance should be higher than 500,000 ohms; however, they often work satisfactorily with leakage resistances of 100,000 ohms. Generally, if the leakage resistance of electrolytic filter condensers is less than 100,000 ohms, they should be replaced. Exceptions to this are cathode by-pass condensers or other low voltage by-pass condensers of the electrolytic type, as leakage values of less than 100,000 ohms are often not troublesome. These figures are arbitrary, being dependent upon whether or not the equipment works satisfactorily. The voltage applied and the capacity of the condenser, are factors that influence the leakage resistance. Increasing the applied voltage and the capacity of the condenser, increases the leakage resistance. Another method of stating the condition of an electrolytic condenser is in terms of milliamps per microfarad. Usually 0.5 milliamp per microfarad is the maximum acceptable leakage current. An 8 mfd condenser with a leakage current of 4

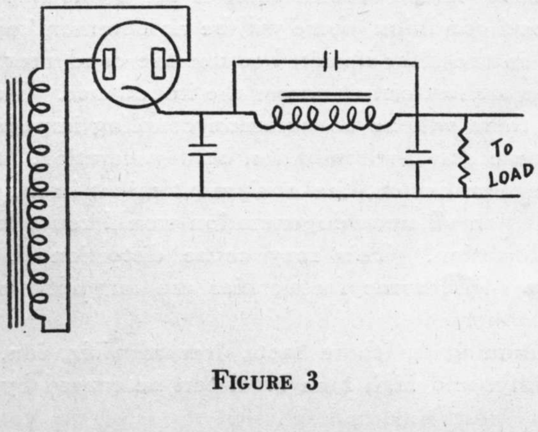


Figure 3

milliamps would just pass as being acceptable. Leakage current higher than this would mean that the condenser should be replaced.

Some filter circuits use a condenser across the filter choke to resonate it to the frequency of the hum voltage (See Fig. 3). Since a parallel resonant circuit offers very high impedance to its resonant frequency, very little hum voltage will be apparent at the output of the filter.

When the current taken from the power supply is low, the choke can be dispensed with, if efficiency

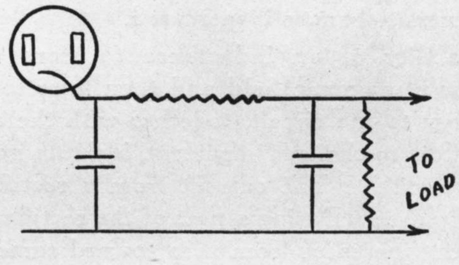


Figure 4

is not of paramount importance. Instead of the choke coil, a resistor can be used (See Fig 4) to offer opposition to the hum frequencies. Unfortunately, the resistor offers practically the same resistance for both the hum frequencies and the d-c flowing through it. Since this will cause a d-c power loss, this type filter is not as efficient as the choke type of filter. However, it is much cheaper to construct, and is very compact. The fact that the resistor offers nearly the same opposition to a wide range of frequencies, it is used to good advantage in many circuits. Filter circuits making use of this

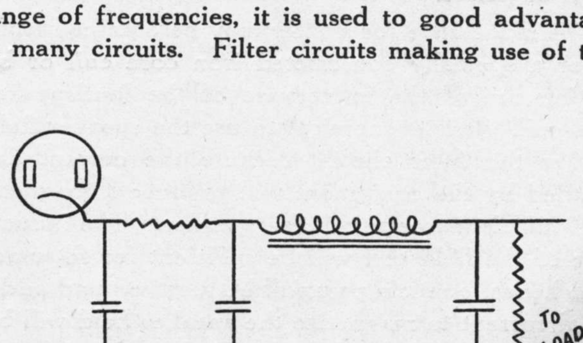


Figure 5

idea use a resistor of a few hundred ohms before the filter choke (See Fig. 5). Condensers are connected across the ends of the resistor to B minus in the same way they were when the choke was used. This circuit is effective in eliminating a wide band of disturbance frequencies.

LOCATING INPUT AND OUTPUT TERMINALS

It is necessary in servicing equipment to determine the signal input and output terminals, because the proper output load and the proper signal source must be connected to the correct points to check the operation of the equipment.

The general knowledge that the grid is the input side of a vacuum tube amplifier and that the plate is the output end is invaluable as a key to determining the input and output terminals of the equipment under inspection. By locating a tube which has its grid circuit connected to a pair of terminals for external connections, the input stage and the input terminals are identified in similar manner. The location and identification of the output stage and terminals may be accomplished by looking for the tube socket which has the plate circuit connected to a set of terminals for external connection.

The wide variation in the physical appearance of coils, transformers, condensers, and resistors, requires that a number of factors be relied upon to identify circuits, parts, and connections. In some equipment, the parts are individually housed and the wiring is easily traced. With such an arrangement, a visual inspection can be made to determine the input and output stages and terminals. It is understood that a general knowledge of how to locate the power supply and power distribution circuits and the usual grid circuit connections has been acquired. Other factors which will aid a visual check are the relative sizes of the tubes, knowledge of tube type designations and applications, the general appearance of various type input and output connections, information as to the purpose of the equipment, and an organized method of approach to the problem. An explanation of what is meant by the relative sizes of tubes will take into consideration the purpose of the piece of equipment. An audio amplifier with a power output stage will most likely be designed with power output tubes that are of larger physical dimension than the voltage amplifier tubes. In such a case, the output tubes will be larger than any others in the set with perhaps the exception of the power rectifier (if one is present). The conclusions arrived at by a visual inspection can be verified by voltage checks at the socket terminals.

Occasionally the equipment under inspection will have certain parts grouped together in one sealed housing and the wiring may be cabled in such a manner that visual tracing of the circuits can not be easily accomplished. Under these conditions, it is necessary to resort to instrument measurements to trace the circuits. Voltage checks of the socket terminals will give an indication of the various connections to the tube elements if the connections are not already known. The power distribution wiring can also be traced in this manner. After these facts have been determined, continuity checks with an ohmmeter will facilitate further tracing of the signal circuits. The statements concerning the input and output sections of an amplifier tube being in the grid circuit and plate circuit respectively are still the key for circuit tracing.

Assume that a piece of equipment is to be serviced, and that an inspection of the externally evident connections reveals that all connections are made to a terminal block strip that has eight terminals without identifying markings. Since this is the only point for making external connections it is likely that two of the terminals will be input terminals for signals and two will be signal output terminals. The balance of the terminals will probably be for connection to power sources. Looking at the underneath part of the chassis, it is seen that two of the terminals are connected to a twisted pair of wires. This suggests that they may be a-c lines. Further checking shows that the twisted pair is connected from socket to socket in such a manner that it is evident that they are filament leads. If separate filament leads are used, then, it is most probable that the plate supply voltage is provided by a separate power source and that two of the other terminals on the terminal panel are B plus and B minus terminals. The B minus terminal can be identified by noting whether or not there is a direct connection to the chassis. The connection to the chassis may not be made directly at the terminal but rather at some other point connected to this terminal by a lead. Caution should be used since the B minus bus may not be connected to the chassis at any point while one side of the input or the output, or both, may be connected to the chassis. In any event, the B minus bus will be a common connection for a larger number of parts than any of the other terminals. The B plus terminal can be found by looking for bleeder resistors, output transformers, chokes, by-pass condensers, etc., that would normally be found connected to the B plus bus. If the component parts such as the output transformer, etc., are readily recognized (there would be no power transformer in this equipment since the B supply voltage is *obtained from an external* source), the output *terminals* could be identified as being connected to the one winding of the output transformer. The other two terminals on the panel would be the input terminals. This last assumption should be checked by tracing the wiring connected to these terminals to make certain that they are connected to the grid, or input circuit, of a tube. To apply voltages to this piece of equipment, check the type tubes used, and if any one tube is familiar, the filament voltage rating of that tube can be used as a basis for connecting the filament supply voltage.

IDENTIFYING TUBE SOCKET CONNECTIONS AND CIRCUIT COMPONENTS

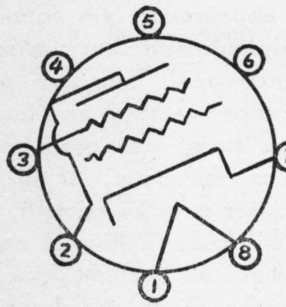
a. Since there are some 700 different types of tubes manufactured for domestic radio receivers alone, it is quite evident that it is not practical to memorize all of them. Therefore with this thought in mind, we will show that by an analysis of the schematic and measurement of the voltages impressed on the individual elements it is possible to identify them. In some cases it is also necessary to trace that part of the circuit immediately connected with a particular terminal to definitely identify the terminals.

The various elements of a tube have different voltages and polarity with reference to either the common B minus terminal or some other element of the tube. The elements at a positive voltage with respect to B minus are listed as follows in the order in which the highest voltage is applied: plate, screen grid, cathode. However, for output tubes the screen grid is generally at a slightly higher voltage than the plate. The screen grids of voltage amplifiers are generally at a lower positive potential than the plate. The reason for the slightly higher voltage on the screen of some output tubes is due to the fact that plate current flows through the resistance of the primary winding of the output transformer, causing a slight voltage drop across the primary winding. The screen current is taken directly from B plus hence there will be no voltage drop. This is why the screen is at a slightly higher voltage than the plate, and the amount by which it is higher is equal to the voltage drop that occurs in the transformer. These facts enable the student to find the plate, screen and cathode socket terminals simply by voltage measurements.

The control grid terminal can usually be definitely identified by referring to the schematic and noting the type of coupling device used between the control grid and preceding circuit. Then checking the actual circuit components connected to the terminal, serves to positively identify the control grid.

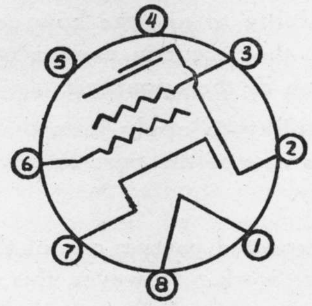
The filament or heater terminals usually can be identified by tracing them directly to the source of supply voltage. In a-c sets these leads are usually twisted to prevent hum because of fields set up by the current. To carry the heavy current required by the filaments or heaters, these leads generally are of a heavier gauge wire than the others connected to the tube socket.

An easy method of identifying socket terminals of tubes is to refer to a tube manual. These usually show the bottom view of the socket, but they can be turned over easily as shown in Figures 6 and 7.



BOTTOM VIEW

FIGURE 6



TOP VIEW

FIGURE 7

Sketch the bottom view with the conventional numbering as shown in Figure 6. Draw a second circle to represent the top view but with the numbers in reverse. Complete the job by connecting the various elements to their proper numbers. Use key as reference on socket.

It is most important to be able to identify the socket terminals of tubes without the use of a manual. This can ordinarily be accomplished by using a d-c voltmeter.

Read the voltages from the various socket terminals to B minus. This should differentiate between several of the tube elements if their normal voltage to B minus is known. Normally the plate terminal will show the highest reading, with the screen second, and cathode to B minus, the lowest.

As an additional check, it is sometimes necessary to trace that part of the circuit immediately connected to a given terminal. As an example, the lead from the control grid in an r-f amplifier connects to a tuning condenser. Tracing the lead from the tuning condenser will identify the control grid.

Other checks may be visual. The two filament leads are usually twisted together to cut down on magnetic interference. This makes them easy to identify. The plate lead is connected to the primary winding of the r-f transformer so if this can be located it will be possible to identify the plate terminal.

b. Assuming that the necessary theoretical knowledge has been acquired, you require in addition, certain fundamental capabilities to service radio apparatus.

These capabilities are:

1. Ability to recognize the actual physical appearance of circuit parts from schematic representation.

2. Ability to determine the terminals, or leads, connecting any parts to others in a circuit.

3. Ability to analyze how certain types of defects, that occur in various parts, affect the operation of the apparatus.

4. Ability to apply tests that will indicate whether or not the part or circuit is working properly.

Testing suspected parts is one of the steps necessary in service work. However, this requires deciding which parts are resistors, condensers, and coils. It is also necessary to know which particular resistor, condensor, or coil is being tested so that its value may be compared with data given either on the schematic or other source of information.

Quite frequently it is possible to determine approximately which parts are defective from the way the equipment is acting. Voltage measurements and an analysis of the circuit diagram also aid diagnosing the most likely cause of the trouble. By these means, the possible cause of trouble is narrowed down and only a few parts need be tested. But before these parts can be tested, they must be located. The service man besides being familiar with the actual appearance of these parts must have some method to identify and locate them. This is true because their appearance is entirely different from the schematic representation. A method that is very effective is to locate on the schematic diagram the circuit in which the suspected part is connected. Next inspect the actual circuit and trace the leads until you arrive at a part connected as indicated by the diagram. If certain easily defined reference or starting points are established this may be readily accomplished. The schematic shows that all parts are connected either directly or indirectly to the various tubes. Therefore the tube sockets make the best reference points.

The schematic tells which tube element is connected to the part to be identified. By referring to the actual tube socket and locating this particular socket terminal, it is only necessary to trace the wires to the part. As an example, suppose a resistor is suspected to be the cause of trouble and that you wish to locate and test it. The schematic diagram might indicate it to be located in the plate circuit of the 1st a-f tube. This resistor can be located physically by referring to the tube socket and tracing the circuit connected to the plate terminal.

If more than one part is connected to a common terminal the desired part can be identified, either from physical appearance, or by using service instruments such as the ohmmeter, etc., as outlined earlier. Suppose a mica condenser and a resistor, having the same physical appearance, are connected to common circuit terminals and that the resistor is open circuited (opened up). The two parts could be located by the above method and identified by disconnecting them from each other, and testing individually with an ohmmeter. If the capacitance of the mica condenser is large enough, the battery in the ohmmeter will cause a flow of enough charging current to indicate as a slight kick of the meter needle. As a further check, the ohmmeter leads may be reversed and applied again to the condenser. The condenser will discharge and charge in the opposite direction, and hence, will give a much higher kick on the meter. This indicates which of the two parts is the condenser. If the condenser is assumed to be good, it would not be necessary to disconnect the two parts to test for an open resistor. When the ohmmeter is applied to a parallel combination of an open resistance and a condenser, the only reading is that due to the charging of the condenser. This would cause the meter needle to jump up, then fall back to zero.

Suppose that the resistor above is in good condition, but that the condenser is shorted or leaky. Check the two parts with the ohmmeter. That part having a resistance very close to the value given by the schematic is evidently the resistor.

As a third condition, assume both the parts to be good, and that it is merely desired to identify these parts. The condenser will check as indicated by the charging surge. The resistor will have a resistance of approximately the same value as indicated on the schematic.

TROUBLES THAT OCCUR IN AUDIO OUTPUT STAGES

Troubles frequently occur in the plate circuit of the audio output tube, due to the high voltages and large currents which are present. The audio output tube is designed to deliver power to the speaker. Although many different types of tubes and many different details of circuit arrangements may be used, the basic troubles are all similar.

There is always a plate load which couples the plate of the tube to the B supply line. The part which serves as the plate load must pass the heavy plate current, which may cause break-down of the part. Also, a part for by-passing R. F. or high audio frequencies is generally used from plate to B minus (or cathode). The high voltage across these points may cause break-down of this part. These are the most likely troubles in this circuit, although manufacturing defects, climatic conditions, etc., may also cause other types of defects.

Since the cathode is the electron emitter of the vacuum tube, all the currents of the individual elements of the tube will flow from the cathode. Therefore, a resistor connected in the cathode circuit from cathode to B minus will have flowing through it the sum of the currents of all the elements which draw current. The voltage drop developed across the resistor may be used as grid bias by connecting the grid to the negative end of this resistor. A means of developing a signal voltage in the grid circuit must be added, so a resistor (in resistance coupled amplifier) or a coil (in a transformer or an impedance coupled amplifier) is connected between the grid and the negative end of the cathode resistor. The application of a signal in the grid circuit causes changes in the space current of the tube and hence will cause a change in the voltage drop across the cathode resistor. In most cases, this is undesirable since these voltage changes reduce the effectiveness of the signal voltage in the grid circuit and degeneration is said to take place. To reduce the degeneration, a condenser of proper capacitance is connected across the cathode resistor. The condenser tends to prevent changes of potential across the cathode resistor, and it is said that the condenser by-passes the a-c signal around the cathode resistor, thereby causing the bias voltage to remain constant. The capacitance of the condenser must be selected so that the reactance of the condenser is low as compared to the ohmic value of the bias resistor at the lowest frequency at which degeneration should be negligible. Electrolytic condensers are used to by-pass low-resistance cathode resistors in audio or other low frequency amplifier stages because of the high capacitance required to satisfy the conditions. The leakage current of these capacitors should be low but is not critical.

It is obvious that since the cathode circuit is common to all the other electrode circuits of the tube, that defects in the cathode circuit will have an effect on the currents and voltages of the other electrodes.

Open Cathode-By-pass Condenser in the Audio Output Stage.

An open cathode by-pass condenser in this stage causes the overall amplification to be reduced. The loss in low-frequency amplification is more pronounced than the high-frequency loss. An oscilloscope or an output meter connected across the cathode resistor indicates that appreciable signal voltage is developed across this resistor when the condenser is open. Resistance measurements and d-c voltage measurements do not depart from normal values when the condenser is open, and therefore these measurements cannot be used as a check for this condition. Since the presence of appreciable signal voltage across the cathode resistor is one of the results of an open cathode condenser, this defect can be determined by connecting either an output meter or an oscilloscope across this resistor.

Open Cathode Biasing Resistor.

An open cathode resistor causes the output stage to be practically inoperative so far as normal signal amplification is concerned. However, if a strong signal is fed into the grid circuit of this stage, some signal output will be obtained. The signal will not be constant and definitely will be distorted. It will sound choked.

D-C voltage measurements will indicate that the plate voltage, the screen voltage, and the cathode voltage, are all higher than normal with respect to B minus. If the cathode condenser has extremely high leakage resistance and there are no other leakage paths to B minus, the cathode voltage will be almost as great as the voltage reading from plate to B minus (if the meter used for measurement has a high ohms-per-volt rating).

Resistance measurements will indicate that the resistances from plate to B minus and from screen to B minus have not changed. The resistance from cathode to B minus however will be equal to the leakage resistance of the cathode condenser. Since this leakage resistance is many times greater than the normal value of the cathode resistor, this check is a positive means of identifying the failure of the cathode resistor.

Completely Open Cathode Circuit.

A completely open cathode circuit means that both the condenser and resistor are open circuited. The conditions which exist with these defects are: no signal amplification, high plate, screen and cathode voltage as measured with respect to B minus. A measurement of the plate and screen voltages with respect to the cathode indicates that there is zero voltage. This contrasts with the measurement made when only the cathode resistor was open and the condenser had normal leakage current flowing. In this latter case there was an appreciable voltage reading from plate or screen to cathode. A completely opened cathode circuit can be identified most readily by checking from plate to B minus and then from plate to cathode. If a large voltage reading is obtained from plate to B minus and none from plate to cathode it is a definite indication that the cathode circuit is open.

Shorted Cathode Condenser or Resistor.

The d-c voltage, resistance, and performance checks will give identical results for either a shorted by-pass condenser or shorted cathode resistor. The overall amplification will be reduced and considerable distortion will be noticed. The d-c voltage measurements from plate and screen to B minus will be lower than normal while the cathode voltage will be zero. Resistance measurements from plate and screen to B minus will be normal while the measurement from cathode to B minus will indicate zero resistance.

A completely shorted cathode circuit can be determined by either a resistance check from cathode to B minus or by a voltage check from plate to B minus, plate to cathode, and cathode to B minus.

Open Cathode By-pass Condensers (General).

The conditions of an open by-pass condenser may not always be due to a defect in the condenser itself, but may be due to poorly made connections either at the cathode terminal of the tube socket or at the point where the condenser connects to B minus.

If the connection is not a clean break, an intermittently open connection will result. This of course would cause the amplifier to intermittently decrease in output and low-frequency response (sound thin). This same intermittent condition could be caused by a break in the lead within the condenser case.

A suspected part or connection could be converted from an intermittent to a complete open (in most cases) by exerting a small amount of pressure on the leads. The pressure should not be great enough to break or cause undue strain on a good lead.

When a completely open condition has been achieved it is wise to check across the joints of the connections to the cathode terminal and the B minus terminal with an ohmmeter to eliminate the possibility of a poor joint as the cause of the trouble.

If the joints pass the test, then the condenser is definitely at fault. Replacing the condenser should clear up the trouble.

Open Cathode Bias Resistors (General).

Cathode Bias Resistors open up sometimes because excessive current flows through them and the power dissipating capability of the resistor is not sufficient to stand the overload for any considerable length of time.

The cause of excess current through the resistor may be a defect in the output tube itself (such as a short between the various tube electrodes) or other circuit defects. A shorted plate to cathode by-pass condenser (or a leaky condenser) will, of course, apply practically the full plate supply voltage across the cathode resistor with a consequent high current through the resistor. Sometimes a bleeder resistor from B plus to the cathode is used to stabilize the bias voltage of the tube. If this resistor drops to a low value, the increase in current through the cathode resistor may be greater than the resistor can withstand. A shorted or leaky blocking condenser between the grid of the output stage and the plate of the preceding stage will cause excessively high plate current to flow through the cathode resistor.

It is wise to look for causes of failure of a cathode resistor rather than assume that replacing the resistor will restore the circuit to normal operation.

An open cathode resistor is not always an indication that some other circuit is defective. In manufacturing resistors, as with any parts, it is not possible to have every resistor identical with every other resistor of the same specifications without a prohibitively costly inspection set-up. It is natural then that occasionally a resistor will have defects that show up only under service. It is also true that resistor wattage ratings are determined under specified conditions of ventilation and temperature of the surrounding air and parts. A resistor that can safely dissipate only five watts of energy without burning up when it is mounted on a board in still air, may be capable of handling twenty-five watts of energy when a cool air is blowing on it. The same resistor might very well burn out if enclosed in an air tight box with only one-half a watt of energy supplied to it. The conditions of temperature and ventilation to which a piece of equipment is subjected will influence the performance of the various resistors in the circuits. A cathode resistor may burn out because a piece of equipment was placed too near a radiator or other heat producing device.

Completely Open Cathode Circuit (General).

A completely open cathode circuit, where the circuit consists of a condenser and a resistor, may be due to the resistor opening up for any of the reasons mentioned in the previous section. The open resistor throws an excessive voltage across the condenser and hence the condenser may open up.

Not all cathode circuits that have biasing resistors use a by-pass condenser. The condenser may be left out because the circuit is a push-pull stage where a condenser is not necessary to reduce degeneration since the circuit does not produce a degenerative effect across the cathode resistor. On the other hand some circuits using a single-ended output stage do not have the condenser because the degenerative effect is used to reduce distortion in the output. In these cases, an open bias resistor will give the same indications as a completely open cathode circuit.

Many circuits have the cathode of the output tube connected directly to B minus because the tube derives its bias from a fixed bias source from grid rectification of the signal, or because the tube is designed to operate with zero bias. In these circuits, an open cathode circuit is caused by broken or loose connections between the cathode pin of the tube and the B minus return. It has been found occasionally that in any circuit an open may be caused by a faulty connection between the tube pin and the socket terminal.

Complete Shorts in the Cathode Circuit (General).

A complete or dead short from B minus to the cathode in circuits using a bias resistor and condenser is seldom due to a failure of the resistor. The Candohm or metal cased resistors are practically the only types that can develop such a defect. In these types, the defect is caused by the cathode end of the resistor shorting to the case internally when the case of the resistor is used as the B minus end of the resistor.

It is not uncommon to have the cathode circuit shorted out because wires or lugs, that connect directly to the cathode, are grounded to the chassis or B minus bus by vibration or other mechanical means. The necessary repairs involve redressing the wiring or straightening the lugs to remove the short.

Cathode condensers often develop internal shorts which requires that they be replaced with a new unit. If the cathode condenser is found to be shorted, the bias resistor should be examined to make certain that it has not developed an open circuit condition that caused the condenser to become defective.

TROUBLES THAT OCCUR IN AUDIO AMPLIFIER STAGES

A first audio tube operates as a voltage amplifier, rather than as a power output amplifier. A relatively high plate impedance is used, which limits the plate current to a relatively low value. Since the plate current is lower, the parts carrying the current may be of lower wattage rating. 250,000 ohms is representative of the impedance commonly used in circuits of this type.

An opened plate load resistor would remove B plus potential from the plate of this audio tube, and stop current flow through the entire plate circuit. Since the resistor is removed from the plate, the resistance between plate and ground is extremely high, between cathode and ground it is normal, and between plate and B plus it is extremely high.

Carbon resistors are generally used in high resistance, low current circuits of this type; wire-wound resistors would be impractical for this application. With increased age and continued exposure to heat, carbon resistors may open-circuit. As a rule, these resistors open-circuit due to the heat developed in them by short-circuits in associated parts, which cause excessive current flow through them. However, weakened leads due to damage during assembly, may finally break, causing an open-circuited condition; also, poorly soldered leads may become disconnected, causing the same effect as an open-circuited resistor.

A shorted plate load resistor eliminates the voltage drop across the resistor, thus raising the potential of the plate, and increasing the current through the circuit. The increased current produces a large IR drop across the cathode resistor. Since the resistor is shorted, the resistance between plate and ground is about equal to the bleeder resistance of the power supply; between cathode and ground it is normal, and between plate and B plus it is zero.

Carbon resistors themselves do not usually short-circuit, although certain types sometimes drop in resistance value. However, their leads may short-circuit; if a resistor is mounted by its own leads, sagging or twisting of the resistor may cause them to touch.

A short-circuit between the audio tube plate and ground places the plate of the tube at ground potential, causing tube current to stop flowing. Thus there is a large IR drop across the plate load resistor, due to the greatly increased current through this part. Since the plate is shorted to ground, the resistance between plate and ground is zero, between cathode and ground it is normal, and between plate and B plus it drops greatly.

This trouble is usually caused by a shorted R. F. by-pass condenser, or tone-compensating condenser. A small mica condenser is often used across the output circuits of a first audio tube, to by-pass to ground any remaining or stray R. F. currents which may not have been completely removed from the audio signal by preceding R. F. filters. Also, somewhat larger paper condensers are often used to by-pass to ground certain high audio frequencies, in order to either obtain a more nearly flat overall frequency response, or to purposely make the response favor the lower-pitched notes.

It should be noted that a shorted by-pass condenser between the plate and cathode would produce somewhat different effects from those occuring when the plate is shorted to ground. In this case heavy current would pass through the cathode resistor, producing a large voltage drop across this part. This plate to cathode connection is often used for by-pass condensers, instead of the plate to ground connection, so the distinction in the effects produced should be thoroughly understood.

Also, a short-circuit between plate and ground is effectively produced by the shorting of one lead (the one connected to plate) to chassis or some grounded object. In high-gain stages the parts and wires of both grid and plate circuits are sometimes enclosed in braided shielding, which may give rise to this type of trouble.

As a result of each trouble mentioned in this description, there is no output from the audio tube; therefore, there is no signal from the speaker or signal pattern on the scope.

Although a resistance coupled audio amplifier is commonly used because of its simplicity, low cost, and uniform transfer of a wide range of audio frequencies, other types of coupling are frequently used to secure other advantages. For instance, transformer coupling has the advantage of providing an increase of amplification in the coupling itself, independent of tube gain. Also, the tube may be operated at a higher plate voltage, since there is less D. C. voltage drop acros a transformer primary than across a plate load resistor. That is, the inductance of the winding provides a high A. C. impedance for the tube, with a relatively low D. C. resistance.

The effects produced by troubles in the plate circuit of the tube, whether resistance or transformer coupled, are similar. The transformer primary may open-circuit, due to excessive current, or the effects of corrosion (especially in moist climates). It may short-circuit, due to insulation breakdown between the ends of the winding as they are brought out to the primary leads. Also, a short to ground may occur, due to insulation breakdown between the winding and the iron core (usually mechanically fastened to the chassis). These same troubles are also found in other forms of impedance coupling.

A resistor is often used in the cathode circuit of a first audio tube in order to establish two points with a potential difference, to be applied between the cathode and control grid, for biasing purposes. This is a simple method of obtaining a potential difference, as the anode current must pass through the cathode resistor, and thus produce an IR drop across it.

With one end of the resistor connected to cathode, and the other to B minus, the cathode is made positive with respect to B minus. By connecting the return of the grid circuit to the negative end of the resistor, a potential difference is thus established between grid and cathode, the grid being negative with respect to cathode.

Any value of resistance in the circuit between the tube grid and B minus does not disturb the potential difference between grid and cathode; this is because no grid current flows (in a class A amplifier) in the grid circuit, to produce a voltage drop.

A by-pass condenser presenting a low impedance path for the alternating audio signal is generally shunted across the cathode resistor, to prevent degenerative effects, unless degeneration is desired. The condenser prevents grid bias changes in accordance with audio signal changes. Since the condenser offers an easy path for A. C., the signal currents are not weakened in amplitude by the D. C. resistance of the cathode resistor.

As the effective resistance in the cathode circuit increases, the voltage drop rises. The exact amount of rise is difficult to predict, however, as several variable and interdependent factors enter into the reading. For instance, with increased grid bias (due to rise in cathode circuit resistance), the tube resistance rises, lowering the amount of plate current (necessary for meter action). High mu tubes tend to cause more error of readings in this respect than low mu tubes.

Also, otherwise negligible stray resistances are very important in interpreting readings in open, or extremely high, resistance circuits. Again, when the voltmeter is shunted across the very high leakage resistance of the condenser, the constants of the circuit are changed the moment the meter is connected. In some circuits this reading from cathode to ground with a practically open cathode resistor, may rise to a surprising value.

The reading to be expected from plate to cathode also depends upon these variable factors; but in general, it should be the difference between the plate to ground and the cathode to ground readings. The resistance readings under this condition are unaffected, except for an extremely high resistance between cathode and ground.

Under both the open-circuited resistor and the open-circuited condenser conditions, the signal amplitude as indicated by speaker and scope, decreases. In the first case this is due to failure of d-c current, in the second case it is due to a signal voltage drop from cathode to ground, when all of the drop should occur from plate to ground.

Under the short-circuited condenser condition, the indications by the speaker and scope depend upon the amplitude of the audio input signal. With a low level of input signal the short-circuit is likely to cause an increased output, while with a high level of input signal it is likely to cause weakened and distorted output.

Cathode resistors in the first audio circuits are usually carbon, since they do not have to carry heavy current. These resistors are subject to open-circuit troubles, if they become too hot. Shorts in related circuits, and tube shorts, may cause excessive current flow, thus overloading the resistor. Short-circuits are less probable, although a virtual short may occur, due to physical contact between the leads.

Electrolytic cathode by-pass condensers may open-circuit, but more often lose capacity due to drying of the electrolyte. Short-circuited condensers may occur as a result of the rise of voltage accompanying an opened cathode resistor, although the leakage may be enough to control the rise of voltage thus protecting the condenser. Electrolytic cathode by-pass condensers are generally used in audio circuits, since high capacity is desirable in order to provide low reactance to the lowest signal frequency the amplifier is designed to handle.

The student should realize that the cathode resistor method of obtaining grid bias (self-bias) is not universally used. Another popular method (fixed-bias) is to connect the cathode directly to ground, and the grid return to a more negative point in the voltage divider system. Very often the voltage drop across a part of the filter choke (placed in the negative leg of the power supply) is used for biasing purposes.

Also, a grid bias cell is sometimes used, particularly in first audio circuits, for obtaining bias. This is a low-voltage, no-current source of voltage, usually about one or one-and-one-half volts. It is a very small device, held in a containing socket under light spring tension. These units are very fragile, and must not be tested for voltage with an ordinary voltmeter. Trouble often develops between the cell and the spring contact terminals, due to the accumulation of dust. This usually introduces noise into the circuit.

The troubles which may be found in other biasing systems are varied, depending upon the parts involved. In fixed bias systems the troubles ordinarily found in voltage dividers, where appreciable current may be flowing, must be considered. Vitreous-enameled, wire-bound resistors ordinarily stand considerable heat without breaking down, but if the enamel flakes off, leaving the resistor wire exposed, adjacent turns of the wire may short-circuit. Also, the resistor has more tendency to open-circuit when the wire is exposed to the air, due to increased oxidation.

Wire-wound resistors are often subject to open-circuits at their terminals. This is because the type of wire used cannot be soldered very easily; therefore, contact is generally made by some means of clamping or riveting. Loose connections may thus develop at these points.

Loose connections also are common wherever electrical connection depends upon mechanical pressure, without actual bonding or soldering. For instance, sometimes the cathode or voltage divider, or both, is connected to the chassis by rivets or screws which may in time loosen, due to vibrations and temperature changes. This is particularly true where a rivet or screw is also used for mounting a part.

In the case of fixed bias utilizing part of the voltage drop across the filter choke (which may be the speaker field), the ordinary open-circuit, short circuit, and "ground" conditions to which all iron core coils are susceptible, should be considered. Also, a resistance network may be used across the choke, to divide the voltage across it. These resistors are generally of rather high resistance and therefore pass little current. The troubles which develop in them are usually the result of manufacturing defects. However, if the choke should burn out, the increased current through them would probably cause them to open.

Fixed bias systems have the advantage of eliminating the necessity for a cathode by-pass condenser, and the troubles they may cause. However, sometimes additional by-passing precautions must be used in the grid return circuit, to combat hum.

One other grid biasing method, called contact bias, or automatic bias, is sometimes used with high mu tubes requiring only about one volt bias. By connecting cathode directly to ground, and grid to ground through a very high grid leak (about 5 or 10 megohms), enough electrons accumulate on the grid to develop a bias voltage. The very high value of grid resistance prevents these electrons from leaking off to ground fast enough to prevent the potential differences from being maintained between grid and ground. Troubles in this circuit are most likely to arise from variations in resistance in the grid leak. It is somewhat difficult to manufacture a very high resistance, low voltage resistor which is absolutely stable.

It has already been established that the grid of a vacuum tube is the most critical circuit element. It follows, therefore, that any components connected to this element must be in good condition.

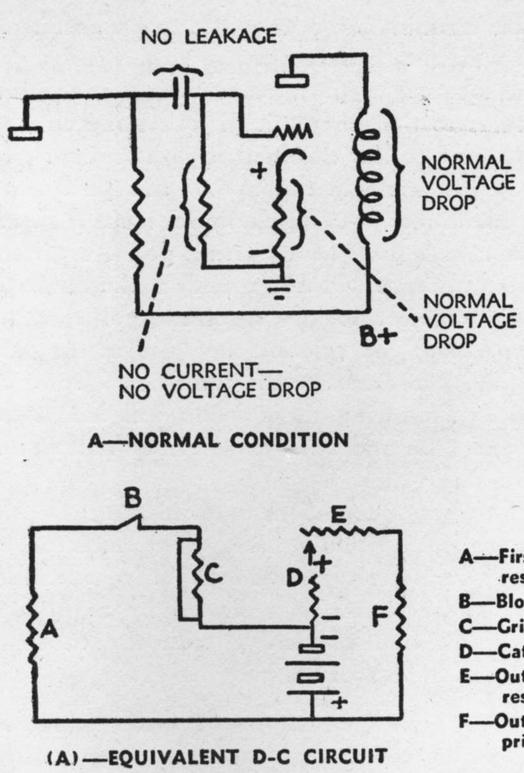
If the coupling or blocking condenser develops a partial open, an excessive amount of signal voltage will be lost across it, the loss increasing as the frequency decreases. Therefore, the "gain" of the amplifier will decrease.

If the condenser becomes leaky, this leakage resistance will be in series with the grid leak resistor. This series combination will, therefore, act as a voltage divider from the first audio plate to B minus.

Direct current will then flow through the grid leak, producing a voltage drop across it, with the grid end being positive. This voltage is of such polarity as to oppose the voltage developed across the cathode resistor, thus reducing the effective bias between grid and cathode. If the condenser leakage is great enough (resistance low enough), the voltage developed across the grid resistor may be even greater than that across the cathode resistor, thus placing the grid at a positive potential with respect to cathode.

Reducing the effective grid bias lowers the plate resistance of the output tube. Since the resistance of the tube varies with changing bias, the resistance of the tube in the equivalent circuit is shown as a variable resistor. When the bias is normal, the arm is in a high resistance position. When it is low, the arm is in a low resistance position.

When the grid bias of the output tube drops, due to a leaky grid blocking condenser, the plate current of the tube will be higher than normal. This is because of its lowered plate resistance. Therefore, a quick check for this condiion is a voltage measurement across the output transformer primary. Dividing this voltage by the resistance of the transformer winding, the current may be determined. If the calculated current is higher than normal, the coupling condenser may be leaky. If, by temporarily shorting the grid leak, a drop in voltage across



A—First audio plate resistor.
B—Blocking condenser.
C—Grid leak.
D—Cathode resistor
E—Output tube resistance.
F—Output transformer primary.

FIGURE 8

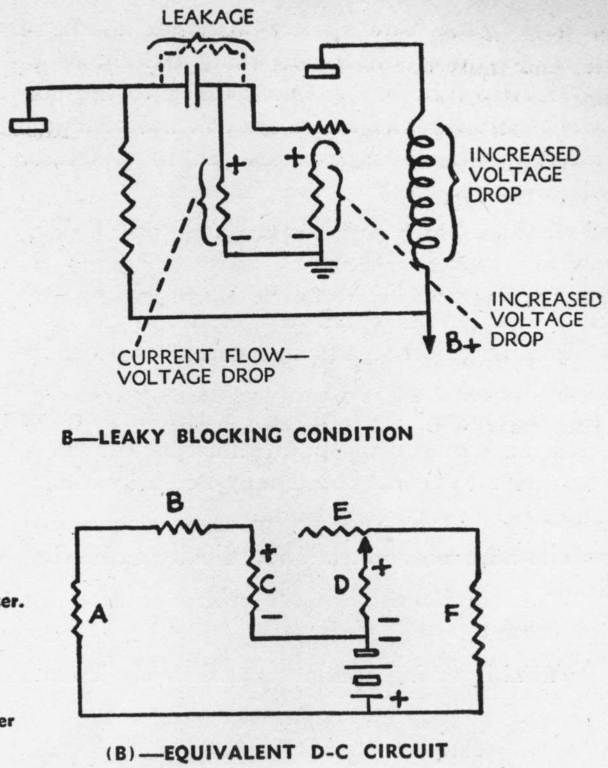


FIGURE 9

the winding occurs, a leaky condenser is definitely indicated.

The most direct check for a leaky blocking condenser is a measurement of the d-c voltage across the grid leak resistor. Any voltage drop across this resistor is definite indication of a leaky condenser.

Other indications of a leaky blocking condenser are a higher than normal cathode voltage on the output tube, and a lower than normal plate voltage on the first audio tube. Under these conditions distortion will be so high that it will be impractical to use the equipment.

As an alternate method of determining which stage of an amplifier is defective, a signal can be applied at the input and output of each tube. First apply the signal at the plate of the output tube. This will check the output transformer and speaker but will provide no amplification. Then feed the signal into the grid of the output tube. Since the vacuum tube is now in the circuit the signal should be amplified considerably if there are no defects present. Applying this same procedure through successive stages toward the input, an increase in signal output should be obtained. The point at which the signal disappears is the branch of the circuit which is defective. Then by making a few simple voltage and resistance checks, the defective part can be determined.

As a quick over all check to determine if the amplifier is operating, the signal can be fed directly to the input terminals. If no signal is heard then proceed to isolate the defective stage as above.

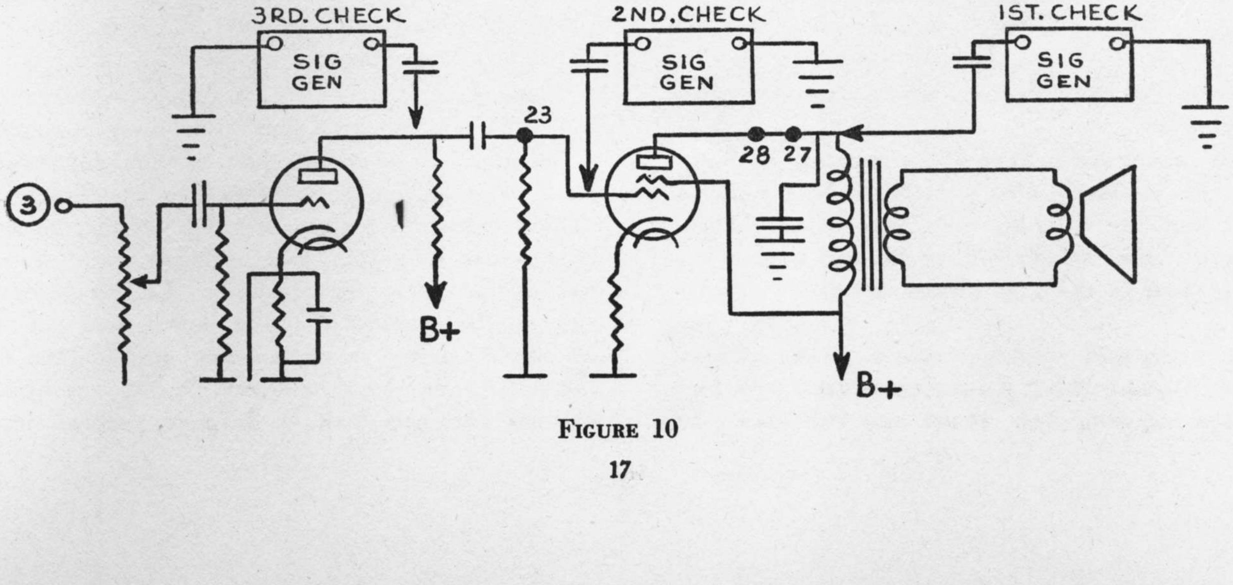


FIGURE 10

The same procedure applies to either a-f or r-f amplifiers, the only difference being the choice of an appropriate type of generator tuned to the correct frequency. In the audio system, use an audio generator. In the r-f system use an r-f generator tuned to the frequency of the amplifier.

It is necessary to be able to identify each part of an **amplifier** before any intelligent servicing may be accomplished. The schematic diagram, if available, shows how a part is connected in the circuit, but gives no information regarding its size, shape or location.

When identifying parts from a schematic, one or more reference or starting points must be known.

In a receiver, several points may be easily identified and used as a starting point.

a. The antenna connection is usually marked.

b. B plus and B minus have been identified in a previous chapter.

c. Variable tuning condensers are easily located but closer examination is required to determine the stage to which each belongs.

When locating a part, start with some known point (refer to the schematic to locate the connecting lead), and follow this lead to its terminal. The schematic will indicate the use of this part and it may be identified. As an example, if an R.F. tuning condenser is used as a starting point, ordinarily one of its terminals will be grounded, the other terminal will connect to the secondary of the R.F. transformer and the grid of the tube in the same stage. This information is obtained from the schematic. Following these leads will locate and identify the tube and R.F. transformer that belong to a particular stage.

It is not always expedient or even the best practice to trace leads visually. It is often much quicker to use an ohmmeter to check continuity in leads or circuits. These circuit tests should be made with the power off and preferably with the tubes removed from their sockets.

TROUBLES THAT OCCUR IN R.F. STAGES

R.F. stages are designed to amplify high frequency signals; therefore, the coils and condensers used have less inductance and capacity than similar parts of audio stages. Although R.F. and audio parts differ in size and construction, their defects are found in essentially the same way, that is, by voltage and resistance tests which indicate various degrees of shorts and opens.

The R.F. stage may also be considered as an I.F. stage, since an I.F. amplifier is really an R.F. amplifier, designed to operate at fixed low radio frequency. The fact that its tuning is fixed does not change its general function as an R.F. amplifier.

I.F. transformer windings (both primary and secondary) generally have a resistance of from 5 to 50 ohms. Since there is no step-up in the turns ratio of many I.F. transformers, the resistance of both windings may be about the same.

Most variably tuned R.F. amplifiers use a tuned secondary and untuned primary, although this is not always the case. When there is no condenser across the primary, there is little likelihood that the winding will short-circuit. However, if the ends of the winding are crossed against each other as they are brought out to terminals, an insulation breakdown between them may cause a short.

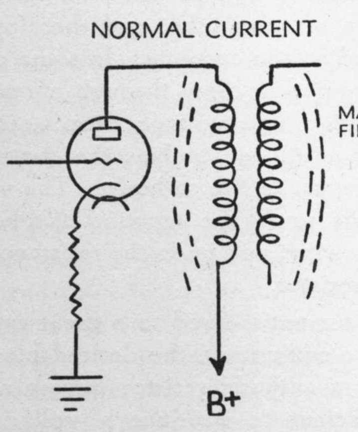
There is much more likelihood that a short will occur if either a variable or semi-variable (trimmer) condenser is shunted across the winding. Variable condenser plates may become bent or warped, causing a short when the rotor and stator sections are intermeshed. The mica insulation between trimmer condenser plates may become broken or cut, due to the use of too much pressure on the screw adjustment. In either case, the coil winding will be effectively short-circuited. In a typical I.F. transformer, trimmer condensers are often used to tune both primary and secondary windings. Once adjusted, they remain fixed.

Open-circuits may occur in R.F. or I.F. transformer primaries, due to excessive plate current through them. Tube shorts or shorts in related circuits might cause excessive current. Also, corrosion of the wire may cause weakness in the wire which will result in burn-outs, even under normal current conditions.

Closely related to this action is electrolysis of the wire, which occurs particularly in moist climates, due to the high potential difference between the wire and the chassis. The moisture in the coil form itself provides a conducting path between the wire and the chassis.

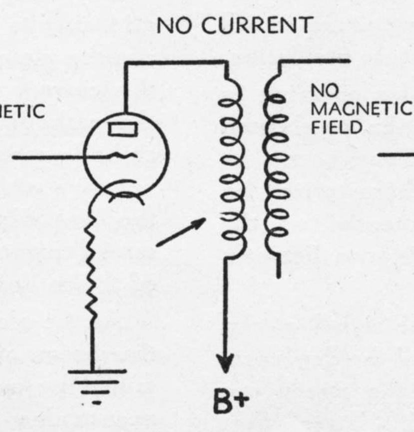
Also, temperature changes cause expansion and contraction of the wire and coil form. This varying stress on the wire may cause it to snap. It sometimes happens that the ends of the winding are bruised in manufacture, as they are secured to terminals. Any stress on the wire will cause opens at these weakened points.

The student should understand why both opens and shorts in the transformer primary produce the same results so far as the signal is concerned. In both cases the magnetic field of the primary is eliminated. In the open-circuit condition no plate current flows. In the short-circuit condition the current is by-passed around the coil, by way of the short. Since no plate current flows through the coil in either case, no magnetic field is built up; therefore, no transfer of signal energy is made to the secondary.



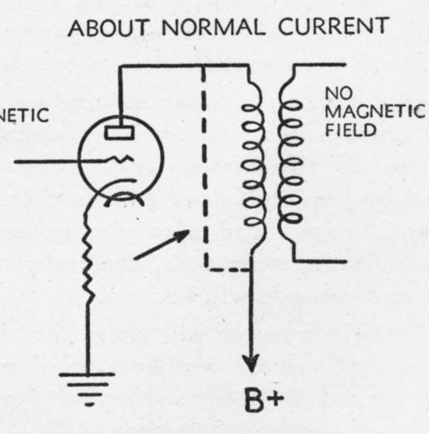
A—NORMAL CONDITIONS

FIGURE 11



B—OPEN PRIMARY

FIGURE 12



C—SHORTED PRIMARY

FIGURE 13

The screen grid and pentode type tubes are used in r-f stages because it is possible to realize higher degrees of amplification without undesirable feedback between plate and grid circuits than is possible with the triode. The use of these tubes requires that the screen grid be maintained at zero r-f potential with respect to the cathode (when the tubes are used in conventional amplifier circuits) and at the same time be maintained at a positive d-c potential with respect to the cathode. The latter condition is accomplished by connecting the screen grid to the B supply voltage, either directly or through a voltage-dropping resistor, at some point positive with respect to the cathode.

The relation between the plate voltage and the screen voltage is one of the factors governing the operating characteristics of the tube circuit. If the circuit is designed with a screen voltage-dropping resistor of a definite value, any change in this value will affect the operation of the circuit. Anything which causes the d-c screen potential to be reduced from the normal value will cause the amplification of the stage to be reduced. If the screen voltage drops to zero, either because of an open-circuit in the d-c supply to the screen or because of a short-circuit from screen to cathode or B minus, the signal output from the stage will reduce to zero.

Maintaining the screen at zero r-f potential with respect to the cathode is accomplished by connecting a condenser from screen to cathode or B minus. The condenser must necessarily be of such a value that its reactance at the frequency of operation is negligible.

In equipment where care has been taken to prevent coupling between screen circuits of various stages, an open screen by-pass condenser will cause the amplification of the stage, in which the defect occurs, to be considerably reduced. If there is coupling between stages, however, regeneration will take place, and under certain circumstances it will be sufficient to cause the stages to go into oscillation.

One of the most common troubles occuring in screen circuits in r-f stages is an open or shorted condition of the screen by-pass condenser. A shorted by-pass condenser will be characterized by no signal output and zero d-c potential on the screen. At the same time, the resistance between screen and cathode will be zero.

An open condenser will cause the signal output to be considerably reduced because of the degeneration produced by the variation of the screen potential at the signal frequency. This latter effect will be produced if there is no regeneration between the screen circuits of the various stages. If there is regeneration produced between the various stages then an open by-pass condenser will cause the stages to break into oscillation at the resonant frequency of the tuned circuits. Under conditions of oscillation, heterodyning will occur between the incoming signal and the interstage oscillations. The heterodyning will produce an audio note, or squeal, in the output which will vary in frequency as the receiver is tuned through the station. It is possible in some equipment that the oscillation and hence the heterodyning will occur only over a portion of the tuning range.

It is not possible to determine an open condenser condition by d-c voltage measurements or by resistance checks. It is possible to check for this defect by using an output meter or an oscilloscope connected from screen to B minus. An open condenser will be indicated by the presence of signal voltage between these two points. Of course, if a condenser of similar rating is handy it is possible to check for an open condenser by momentarily connecting the good condenser across the suspected one. If doing this causes a noticeable improvement in the output or restores the equipment to normal performance, the original condenser is definitely defective.

An open screen resistor will cause the signal output of the equipment to be zero. This condition will show up under tests, and can be definitely determined by screen voltage and resistance checks. The resistance from screen to B minus will be very high, and the d-c voltage will be zero. This, of course, contrasts with the zero-voltage, zero-resistance condition for a shorted by-pass condenser (which will also cause the signal output to be zero).

A shorted series screen resistor should cause the gain of the stage to increase, and the output to be distorted. A voltage and resistance check will identify this defect.

The cathode lead completes the plate and screen grid circuits of a vacuum tube, and therefore, carries the plate and screen currents. In some designs, this current is caused to flow through a resistor in the cathode lead. The voltage drop across this cathode resistor is utilized to bias the control grid negative with respect to the cathode. The value of the bias depends upon the amount of plate and screen current flowing, and upon the resistance value of the cathode resistor.

As the plate current is fixed to a great extent by the design of the equipment, the desired bias is obtained by using a cathode resistor having a resistance value sufficient to produce a voltage drop equal to the desired bias voltage.

Any change in the cathode resistor will cause a corresponding change in the bias voltage. If the cathode resistor is shorted out, zero bias will result; if the resistor is open, all plate and screen current will cease.

In many cathode circuits, the resistor is shunted by a condenser connected directly from the cathode socket terminal to B minus. This is a by-pass condenser which functions to provide a low-resistance path for a-c. If this condenser becomes open, bias will vary with a-c signal changes of tube current, and degeneration will occur within the stage.

However, if the cathode resistor and condenser is common to two successive stages (as is sometimes the case), an open condenser will cause regeneration between stages to be excessive and the stages will go into oscillation.

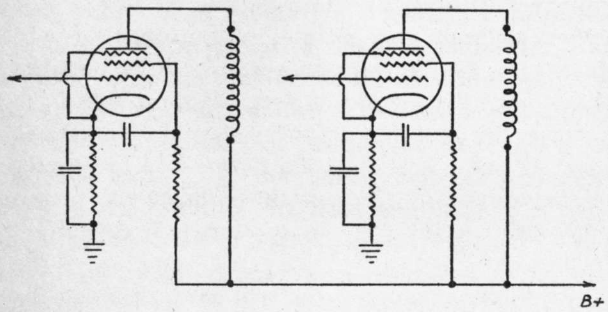


FIGURE 14

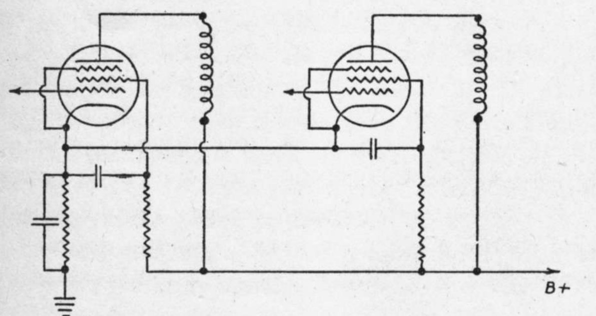


FIGURE 15

The two circuits, the individual and the common cathode circuit, are shown in figures 14 and 15, respectively. These are simplified diagrams and, hence, show only the elements essential for illustration.

An open by-pass condenser cannot be readily tracked down by d-c voltage or resistance measurements and the effect upon the signal output will depend upon not only in which circuit it occurs,—i. e., plate, screen, or cathode circuit, but also upon the design of that circuit.

The most commonly used screen circuit (because of its fewer parts and its regenerative action) which uses a single voltage-dropping resistor and a single condensor for two or more r-f or i-f stages is shown in Figure 16. If the condenser C opens up in this particular circuit the regeneration taking place between the two stages because the impedance R is common to both will be sufficient to cause the circuit to break into oscillation. These r-f oscillations

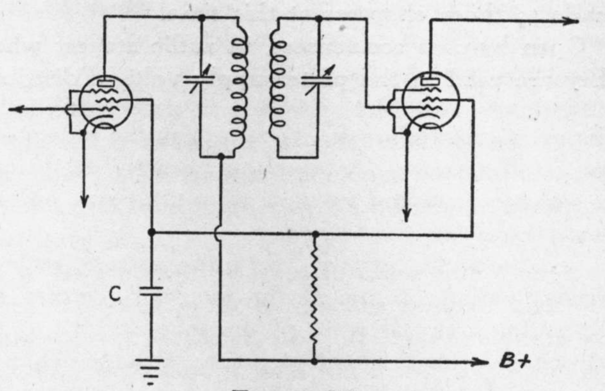


FIGURE 16

will, if the stages couple into detector and A.V.C. circuits cause the A.V.C. voltage to reach a high value regardless of whether or not the receiver is tuned to receive a signal. The high A.V.C. voltage will cause the sensitivity of the receiver to be considerably reduced. If a station or signal is tuned in, heterodyning will occur between the r-f oscillation of the defective stages and the signal. This produces an audible howl in the output which changes frequency as the incoming signal frequency is shifted. Normal reception of the signal is impossible under these conditions.

Another circuit which is often used is shown in Figure 17. Separate decoupling resistors R_1 and R_2 and separate by-pass condensers C_1 and C_2 are used. This circuit is considerably more stable than

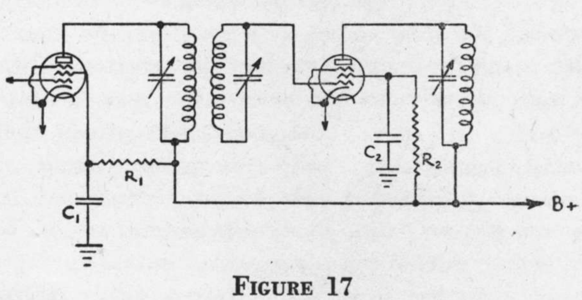


FIGURE 17

the one shown in Figure 16 and if one or even both the condensers open simultaneously the circuit most likely will not go into oscillation. However, degeneration takes place within each stage because of the variation in screen potentials, and the gain or sensitivity of the stage, or stages, is considerably reduced.

The same effects will be noticed in plate circuits which use decoupling resistors and by-pass condensers in the same manner as the screen circuits of Figs. 16 and 17.

The effects of open cathode by-pass condensers was discussed previously and reference should be made to those chapters at this time.

Open by-pass condensers, in audio stages; when they are used in the plate supply voltage distribution circuits cause either oscillation or reduction in gain dependent upon the nature of the circuit and whether or not common coupling develops between stages. Oscillation in audio stages may take place at radio or audio frequencies. Audio frequency oscillations may occur at any frequency in the audio band. Very low frequency oscillations in the order of a few cycles per second is called motor-boating because of its sound.

Most of the troubles are due to open circuits and short circuits, either complete or partial. It is the serviceman's job to locate the cause of trouble in a radio unit and repair the unit in as short a time as possible. This could be done by testing each part individually for open or short circuits but there are much quicker and better methods of locating defective units. If the stage that is not operating properly in a multi-stage receiver can be found quickly, then the defective part may be located by simple resistance and voltage checks. The process of locating the defective stage is known as **signal tracing.**

One widely used method of locating a defective stage in a receiver is that of **signal substitution.** For example, each stage of an audio amplifier may be checked for normal operation by using the signal from an audio generator instead of depending on a receiver signal. If the audio generator is connected to the input of the final amplifier of a two-stage amplifier and a normal signal is heard in the speaker that stage would be considered to be operating correctly. If the audio generator were then connected to the input stage of the amplifier and no signal were heard in the speaker, then the input stage must be defective. Once this is determined, the tube socket terminals should be checked to see that voltages are applied to the tube. If the plate voltage is lacking, then the parts in the plate circuit should be checked for open or short circuits. If the plate and other voltages are correct, then the input device should be checked for defects.

A second method of signal tracing is to connect the audio generator to the input of the amplifier and to use a separate indicator for tracing the signal. This indicator could be another audio amplifier with speaker, an oscilloscope, or even a sensitive output meter. The indicator should be first connected to the input device of the unit being checked to be sure that a signal is reaching the grid of the first audio tube. If a signal is present, the indicator should then be connected to the plate of the tube or to the output device to see if a signal is present. If no signal is indicated, then the component parts of the plate circuit should be checked for defects. If a signal is present, the indicator should be connected to the grid of the next tube and the signal checked. If a signal is present, the indicator should then be connected to the plate of the tube and a check made for signal. If no signal is indicated the voltages and parts in this circuit should be checked. If the plate circuit of the tube is operating in a normal manner, then the secondary of the output transformer will probably have an open or shorted output winding and can be checked with an ohmmeter. The point where the signal disappears will indicate the approximate location of the trouble.

It is evident that the path of a signal through an amplifier may be checked by one of several indicating units, such as a similar amplifier, an output meter, an oscilloscope, or the commercial signal tracing units. If the amplifier does not work properly the defective stage may be quickly isolated by this procedure.

One of the simplest ways to determine if an amplifier is operating is to quickly remove and re-insert the 1st amplifier tube. If the circuits are in operating condition a loud click will be heard in the speaker. It is caused by the breaking and re-making of the electrical contacts of the first tube. This interruption or noise is amplified by the following tubes, and causes a click in the speaker. If removing the first tube did not produce a click in the speaker, the second tube should be removed and re-inserted. If a click is heard, it means that the first tube is bad, or it has no plate voltage, or the coupling device (condenser or transformer) between the two tubes is defective. This **quick check** may be made before applying the tests as outlined in this experiment. Indicator units used in signal tracing should be of a type suitable for the circuit under test. The audio amplifier would use such indicators as output meter, speaker, oscilloscope, etc. Amplifiers operating at radio frequency would require a test instrument that would give an indication at radio frequencies. Vacuum tube voltmeters, r. f. oscilloscopes, detectors with an audio amplifier, etc., would be satisfactory for this purpose.

Signal tracing in an r. f. amplifier is very similar to that used in an audio amplifier. The circuits operate in much the same manner except that all signals are at radio frequency.

In signal tracing the unit used as an indicator must be capable of operating at the frequencies used in the amplifier. Or it must be capable of accepting the radio frequency signal and converting it to an audio signal. Such an instrument would be a detector, or rectifier, followed by an audio amplifier. With this combination a speaker or output meter could be used to indicate the presence or lack of a signal in the r. f. amplifier. The detector could be connected to the various stages of the r. f. units so their output can be checked. If a signal were present in the output of the first amplifier tube but missing at the output of the second stage a defect would be indicated in the second stage. Once the trouble was localized a volt-ohmmeter could be used to check the parts associated with that particular tube and the exact trouble determined.

Signal tracing in an r. f. amplifier can be done by both the "signal substitution" method and the indicator method. In the first method the detector should be connected to the output terminals of the r. f. amplifier and the signal generator successively connected from the output coil to the input circuit. The point where the signal disappeared would indicate the location of the defective stage. In the indicator method the signal generator should be connected to the input of the r.f. amplifier and the detector successively connected from the r. f. amplifier input terminals to the output terminals. Here again the point where the signal disappeared would indicate the location of the defective stage.

Other indicators may be used in checking r. f. amplifiers. The oscilloscope, if its amplifiers will pass radio frequency, is very good. The scope should be adjusted to show the modulated r. f. signal. A vacuum tube voltmeter is an instrument that will read radio frequency and may be used as an r. f. output meter.

Hum, oscillation, and noise are common troubles which are sometimes very difficult to locate, because they often may not be determined by the use of voltage, current, or resistance checks. They must sometimes be found by careful recognition of slight differences between sounds from the speaker.

Hum may originate in the power supply, due to defects in the ripple filter. Open filter condensers, or condensers having reduced capacity due to the drying of the electrolyte, are the most common cause of this kind of hum. Shorted or partially shorted filter chokes are another cause.

If the tube filaments are shunted with center-tapped resistors, with the center-tap grounded, an open half of the resistor will cause hum. Very often these resistors are constructed with variable center-taps. In this case hum will result if the resistor is out of adjustment.

Closely associated with this trouble is leakage between the heater and cathode of indirectly heated tubes, which will vary the emission of the cathode at the heater supply frequency.

Induction hum, due to magnetic coupling between a power transformer and filter choke (or audio transformer), will also produce hum; however, this is unlikely to occur in well designed commercial radios. It is possible, though, where original components are replaced, and their position changed or shields not replaced, for hum of this kind to occur.

If the laminations of a power transformer become loose, a characteristic buzz, which is very similar to a hum, will be produced. This buzz may be definitely determined by placing the ear very close to the transformer, and then to the speaker. If the buzz is louder at the transformer loose laminations are the trouble. This buzz is not conveyed through the speaker, but is heard directly from the part itself.

The types of hum already mentioned are steady in character, and independent of dial setting. Another type of hum which occurs only when in tune with a signal, is called modulation hum. It is caused by the modulation of a carrier signal by the A. C. power supply frequency. When A. C. heater leads are brought into the range of grid leads, or bypassing is inadequate, or line-buffing condensers are open, this trouble may be produced. Cathode to heater tube leakage may also cause this trouble. Very often, by-passing one or both sides of the power line to ground (at its entrance to the chassis) will eliminate modulation hum. Also, reversing the line plug will sometimes affect this hum, particularly if the grounding of the set is poor.

Oscillation is generally caused by some kind of inter-stage coupling, and may occur in more than one tube circuit. Coupling between the plate circuits of different stages, and the screen grid circuits of different stages, constitutes the most frequent cause of oscillation. This coupling generally results from open by-pass condensers in the plate or screen grid circuits, or shorted R. F. chokes.

Again, high resistance connections between shields and ground may cause this trouble. Shields should always be carefully replaced in original positions, when replacing coils, tubes, etc. Also, if leads from sensitive R. F. and I. F. circuit parts are placed in different positions from the original, oscillation may result. Manufacturers often place the plate and grid leads in just such a relation as will produce certain critical degrees of regeneration. Altering these constants may cause oscillation, or too much regeneration.

Noise is sometimes one of the most difficult troubles to locate. It may occur in any part of a radio—in fact, in almost any connection. Radio noise may be classified as natural atmospheric static, interference from other electrical devices, and noise originating in the set itself. Noises external to the set may usually be determined by shorting the antenna and ground terminals of the set, and noting whether the noise persists. If so, the noise is likely to be coming from the set itself, if not, it is likely to be coming from outside the set. However, this test will depend considerably on how well the set is shielded.

Set noises may be caused by loose connections, broken leads, leaky or arcing condensers, noisy resistors, noisy tubes, dirty or loose switch and socket contacts, rosin joints, corroded or dirty variable condenser wiping contacts, scraping variable condenser plates, noisy audio transformers, loose speaker cones, dragging voice coils, and many other troubles.

A good test to make for noise is a slight jarring of the chassis, and moving of leads, and parts. Thumping of tubes will often disclose a noisy tube. Condensers and resistors must sometimes be disconnected or replaced, as a definite check of their condition. Practical, common sense is necessary to dictate the best procedure to employ under particular conditions. Very often noises are intermittent, making their location very difficult.

The most helpful procedure to follow in trying to determine the cause of hum, oscillation, or noise, is to localize the trouble. The simplest method is to either remove one tube at a time (beginning with output tube), or to short out the input circuit of each tube (beginning with output tube). By this method, a particular circuit will be reached where the trouble is not indicated by the speaker; while moving to the next circuit, the trouble is indicated by the speaker. The trouble is between these two points.

In case the trouble originates in the power supply, or some circuit common to several stages, this method will have to be used with reservation. For instance, trouble may appear to be coming from the output stage, when it is actually coming from the supply to this stage.

Conclusions: It is evident from this that signal tracing on an r. f. amplifier is similar to that of an audio amplifier. The method is the same but an indicator that will respond to radio frequency signals is necessary.

Notes: If a separate indicator is not available the detector and audio amplifier of a receiver may be used to check the r. f. stages provided the detector and audio amplifier are operating satisfactorily. There are several commercially manufactured indicator units. They usually contain r. f. and audio amplifiers, an oscillator, and a detector; and are so arranged that any stage of a receiver may be checked. They may use a vacuum tube voltmeter, oscilloscope, or even a "magic eye" tube to indicate the strength of the signals in the receiver.

ALIGNMENT OF R.F. AMPLIFIERS

This chapter will tell the student the basic steps in the alignment of an R. F. amplifier. These steps will serve as an introduction to alignment in general, which becomes more involved in superheterodyne circuits.

The proper use of the signal generator and output meter are studied, with special emphasis on dealing with the difficulties which A. V. C. presents.

The ability to align receivers accurately is an absolute essential to good servicing, as misalignment often occurs, due to the aging of equipment, the change in the placement of wires, the replacement of parts, climatic conditions, etc.

When two or more tuned stages are used in an R. F. amplifier, it is necessary that all stages be tuned to the same frequency. Otherwise, loss of sensitivity and selectivity will result. In early model radios this "tracking" of stages was accomplished by tuning each indivdual stage separately. This method of tuning from station to station required considerable time and trouble.

Later model radios use single-control tuning, whereby the controls of all stages are "ganged" together mechanically. Since it is difficult to manufacture coils and condensers with perfect precision, it is necessary to provide adjustments to compensate for the differences in the resonant circuits of the different stages. Otherwise, the various stages will not track properly. Small semi-variable (trimmer) condensers are usually used in parallel with main tuning condensers for this purpose. Once these trimmers are adjusted, all stages may be tuned together easily, by means of a single control.

The adjustment of these trimmers should be made at a high-frequency setting of the variable tuning condensers, as the tracking in this range is more critical. Further adjustment at low-frequency settings is sometimes made by bending the outside rotor plates (where split plates are used) to various angles, as the variable condenser setting is changed. However, it is not good service practice to do this. Sometimes a low-frequency "padder" is used (semi-variable condenser in series with coil and variable condenser), for low-frequency adjustments.

Whenever low-frequency adjustments are made, a readjustment of the high-frequency trimmers may be necessary.

It is very important, in aligning R. F. stages, to use a generator signal of a very low value. Different levels of output are more accurately judged from weak signals than from strong ones. Even more important than this, however, is the difficulty of alignment when strong signals are used, due to the compensating effects of automatic volume control circuits, when used.

A. V. C. tends to increase the sensitivity of one or more R. F. stages when the signal reaching the detector is weak. Also, it decreases their sensitivity when this signal is strong. The net effect, therefore, is to produce a rather constant output, regardless of the signal strength. By using a weak signal, the A. V. C. circuit has less controlling effect on the output, and the R. F. circuits may be aligned while in a condition of maximum sensitivity.

It is important that the amplitude of the signal be reduced by adjustment of the generator attenuator not by means of the receiver A. F. volume control. If the audio control of the receiver is used, a strong signal will still be applied to the input of the receiver, and A. V. C. action would be very pronounced.

The output meter, used between the plate of the output tube and ground, indicates the alternating signal voltage. An output meter is an A. C. meter with a blocking condenser in series, to prevent a reading of D. C. voltage.

Output indication may also be obtained by connecting an A. C. meter directly across the secondary of the output transformer. The voltage across these points will be lower, however, due to the step-down characteristics of this transformer. No blocking condenser is necessary for this connection, as no D. C. voltage is applied.

The use of an output meter is necessary for exact alignment, as the ear is not sensitive to small changes in output. However, if the slight errors made in several adjustments are added, a total error is produced, which **would** be noticeable to the ear.

In the alignment of R. F. circuits, special tools which contain a minimum of metal are preferable. Ordinary screwdrivers or spin-type socket wrenches sometimes temporarily disturb the constants of the circuit, while adjustment is being made; hence, they should not be used.

For precision alignment, both generator and receiver should be turned on and allowed to heat, before adjustments are made. This usually takes about fifteen minutes. Otherwise, slight misalignment may result when the parts become normally heated.

Special circuits may call for further adjustments in a T. R. F. receiver. For instance, wave traps in antenna, or other circuits require "peaking" at certain frequencies. Also neutralizing circuits for the cancellation of plate-to-grid feedback in multi-stage amplifiers, require adjustments for minimum output.

It is not only necessary that R. F. stages be adjusted to the **same** frequency. They must also be set to a **particular** frequency, depending upon the degree of rotation of the rotor plates. That is, the stages must not only be aligned so that they track with each other; they must also be adjusted for certain tuning points and limits.

Commercial receivers have "calibrated" dial scales to which the stages are made to conform. These scales match the particular variable condensers used. To properly align the R. F. stages, the dial itself is first set so that the ends of the scale correspond to the fully open and fully closed positions of the variable condensers. This provides a graduated indication for all condenser settings.

Next, the stages are aligned (synchronized together) near the high-frequency limit of the dial. This is done by setting the modulated signal generator and receiver dial to the same high frequency, and adjusting the high-frequency trimmers for maximum output. These trimmers are usually mounted on the end of the variable condenser frame.

Then the stages are aligned near the low-frequency limit of the dial. This is done by setting the generator and receiver dial to the same low-frequency, and adjusting the low-frequency padder or other low-frequency adjustments for maximum output. It may be necessary to reset the split rotor plate sections of the variable condenser, in order to obtain perfect agreement between the generator and receiver dial at various intermediate positions.

Adjustment at one end of the dial also affects the setting at the other end to a certain degree so that it is necessary to repeat the adjustments at first one end of the dial and then the other, until complete calibration is obtained.

SUPERHETERODYNE LOCAL OSCILLATORS

The function of the local oscillator is to supply an unmodulated R. F. signal of a fixed amplitude and of a frequency different from the incoming broadcast signal by exactly the amount of the I. F. frequency. In general production the oscillator is tuned higher, by the amount of the I. F. frequency, than the desired signal. Thus, if a 1,000 K. C. signal is to be received with a receiver having an I. F. frequency of 455 K. C. the oscillator would be tuned to 1,455 K. C.

If, for any reason, the frequency of the oscillator should change so that it no longer maintains a difference of the amount of the I F., no signal would pass through the I. F. amplifier and thus nothing would be heard in the speaker. Obviously, if the oscillator stopped functioning it would produce the same result. If this were the case all the voltages throughout the balance of the receiver could be correct and still the receiver would not function.

If for any reason the output of the local oscillator should change in amplitude, it would affect the operation of the receiver in the form of a loss in efficiency but would probably not prevent it from operating entirely. In this case the defect would probably be either a defective tube or a partial open or short circuit.

A local oscillator is used in superheterodyne circuits to produce a signal which, when mixed with the station signal, will produce a signal having the frequency of the I. F. amplifier. By the use of this oscillator the strength of the station signal is boosted, and its frequency is converted to a lower fixed frequency (I. F.), which may be amplified with greater gain and stability.

The oscillator is mixed with the signal by many methods, but in all cases the production of the new intermediate frequency is due to "Beat note" action, causing new signals to be created. These new signals have frequencies equal to the sum of, and difference between, the two original frequencies.

There are a number of different types of oscillator circuits, all of them depending on the feedback of energy from the plate to the grid circuit.

To determine whether or not an oscillator circuit is oscillating, the simplest and most definite check is a measurement of voltage across the grid leak. As a general rule, a negative grid voltage between about five and fifty volts indicates satisfactory operation. This suggested voltage range covers most types of circuits and tubes. No voltage between these points gives definite indication that the circuit is not oscillating, for one reason or another.

As a supplementary check for an inoperative oscillator, a measurement of voltage across the plate resistor is also significant although less definite. There should be a certain voltage drop across the resistor, due to normal plate current. If the osclilator becomes inoperative, causing the bias voltage developed to drop to zero, the plate current of the tube raises, producing a larger voltage drop.

Closely related to this check is the measurement of voltage from the plate of the oscillator tube to ground. There should be a certain normal voltage reading between these points, due to the normal IR drop across the plate resistor. If the oscillator becomes inoperative, increasing this drop, the voltage from plate to ground will decrease.

Since these plate circuit readings depend directly upon the grid bias voltage, the measurement of the grid bias voltage is the most important check.

If a scope should be placed from grid to ground, or from plate to ground, while the oscillator is operating properly, a certain A. C. voltage amplitude would be indicated. If the oscillator should be made inoperative, the amplitude would drop to zero.

TRANSMITTER OSCILLATORS

Radio frequency oscillators as used in transmitters are usually designed to furnish exciting or driving voltage for succeeding amplifier stages. The oscillator's main function is to establish and maintain the operating frequency. Only enough power is taken from it to excite the following amplifier. The less power taken from an oscillator the more stable its operation will be. An oscillator used in this manner will have low plate current and high grid bias.

Oscillators can, and often are, used to supply usable power to an antenna or other load device. The power consumed, or dissipated, in the oscillator circuit will go up as the power drawn from it is increased. An oscillator delivering power to a load will have relatively high plate current and low grid bias. The increase in plate current from the no load condition to the loaded condition roughly represents the power drawn from the oscillator.

An oscillator that fails to operate but has plate voltage applied, will have an abnormally high plate current and very little, if any, grid bias.

When an oscillator is not crystal-controlled, its frequency of operation depends on the adjustment of its tuned circuits. To set the frequency to some given value, some means of measuring the frequency must be used.

One means is by the use of the absorption wave meter, which uses a calibrated condenser to tune a coil. The wave meter is coupled to the oscillator, and the meter dial turned; when resonance is obtained between the wave meter and the oscillator, a light which is in series with the meter coil and condenser will light up. For a given amount of coupling between the wave meter and the oscillator, the lamp will light most brightly when the circuits are tuned to the same frequency (in resonance).

A more accurate means is by the use of the heterodyne frequency meter. This measuring instrument uses a calibrated oscillator which feeds into a detector and audio reproducer. When a second R.F. voltage (whose frequency is near that of the calibrated oscillator) is also fed into the oscillator, an audible beat note is produced. As the frequency is varied so that the two frequencies approach equal values, the note will vary from a high to a low pitch. When the two frequencies are exactly equal, the note will disappear (or be of zero frequency). Hence, this method is called heterodyning to zero beat.

The frequency meter may be set to a desired operating frequency, and the transmitter tuned to zero beat with it, or an unknown frequency may be measured by adjusting the meter to zero beat with it, and noting the resulting meter dial reading.

CLASS "C" R.F. AMPLIFIERS

a. **GENERAL**—The class "C" r-f amplifier is used because it amplifies r-f power with high efficiency. This means that a large percentage of the d-c power supplied to the plate of this type of amplifier is converted into radio-frequency energy. In some designs the efficiency may be as high as 75%. As an aid in understanding this statement, suppose the plate current of a certain class C amplifier is 100 milliamperes at 1000 volts. If such is the case, then the d-c power in watts will be .1 x 1000, or 100 watts. Therefore, if the stage is 75% efficient, the r-f power developed by the stage will be 75 watts. The remaining 25 watts will be expended at the plate of the tube and in various parts of the circuit in the form of heat. Compare this with Class "A" amplifiers which have about 25% efficiency. If the stage in the previous example were a Class "A" stage, 25 watts would be the useful r-f power developed, while 75 watts would be wasted as heat. This comparison makes it evident that the saving in power is worth while.

For this reason r-f amplifiers of transmitters are not operated as Class "A" amplifiers. Audio amplifiers cannot be Class "C" operated because of the distortion that would result. If it were desired to amplify a **single** audio frequency, then a Class "C" amplifier could be used, provided that the plate were coupled to its load by a resonant circuit tuned to the operating frequency.

In transmitters, R.F. amplifiers operate at a given frequency, and have the useful loads coupled to the tubes through resonant circuits. Because of this they may be Class "C" operated without distorting the R.F. signal.

The reason resonant circuits are required is because of their ability to store energy and to continue oscillating for a time after the exciting voltage is removed. Suppose a condenser and coil are connected in parallel, and that they resonate at 1000 K.C. Also suppose that the capacity of the condenser is such that a considerable amount of electrical energy can be stored in it. Now, if a battery is momentarily connected across this combination, the condenser will charge. After the battery is removed, an oscillatory current will flow between the coil and condenser, until the energy is consumed. The energy is used up as heat by the current flowing through the circuit resistance. See Figure 18.

Closing "S" charges the condenser. When "S" is again opened, the condenser discharges through the coil. This sets up an E.M.F. in the coil that causes it to charge the condenser in the opposite direction. Then the cycle repeats. Hence the current is oscillating back and forth, and the circuit is said to be oscillating.

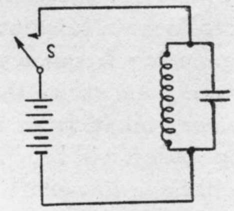


FIGURE 18

This property of resonant circuits was used in the early days of radio to make a simple r-f generator. The circuit is as shown in Fig. 19. A buzzer and battery are connected across the resonant circuit. Because of the action of the buzzer in closing the battery circuit, the condenser is periodically charged. When the buzzer contacts open, the electricity stored in the condenser surges back and forth as an oscillatory current, at a frequency equal to that of the resonant circuit.

The buzzer causes the condenser to be charged each time the contacts are closed. The ability of the condenser to store energy keeps the circuits oscillating while the contacts are open. Therefore, the condenser is charged by pulses of current each time the contacts close.

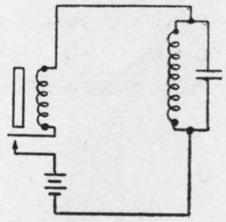


FIGURE 19

A vacuum tube operated in a Class "C" condition will supply power to its tuned plate circuit in much the same manner as does the buzzer of Fig. 19. The Class "C" tube is biased beyond cut-off; consequently, plate current will flow only when the exciting voltage applied to the grid is going through the part of its positive half cycles which is greater than the negative bias. See Fig. 20. The plate current that flows during this time furnishes energy to the tuned plate circuit, the action of the tube being similar to that of the buzzer mentioned previously. However, the tube supplies the current pulses in synchronism (time) with the oscillations of the tuned circuit, since all related circuits are tuned to resonance at the same frequency. For a portion of every half cycle the tube delivers energy to the resonant circuit. This is desirable because the circuit can store sufficient energy on the positive part of the cycle to keep the energy level through the negative half cycle the same as it was through the

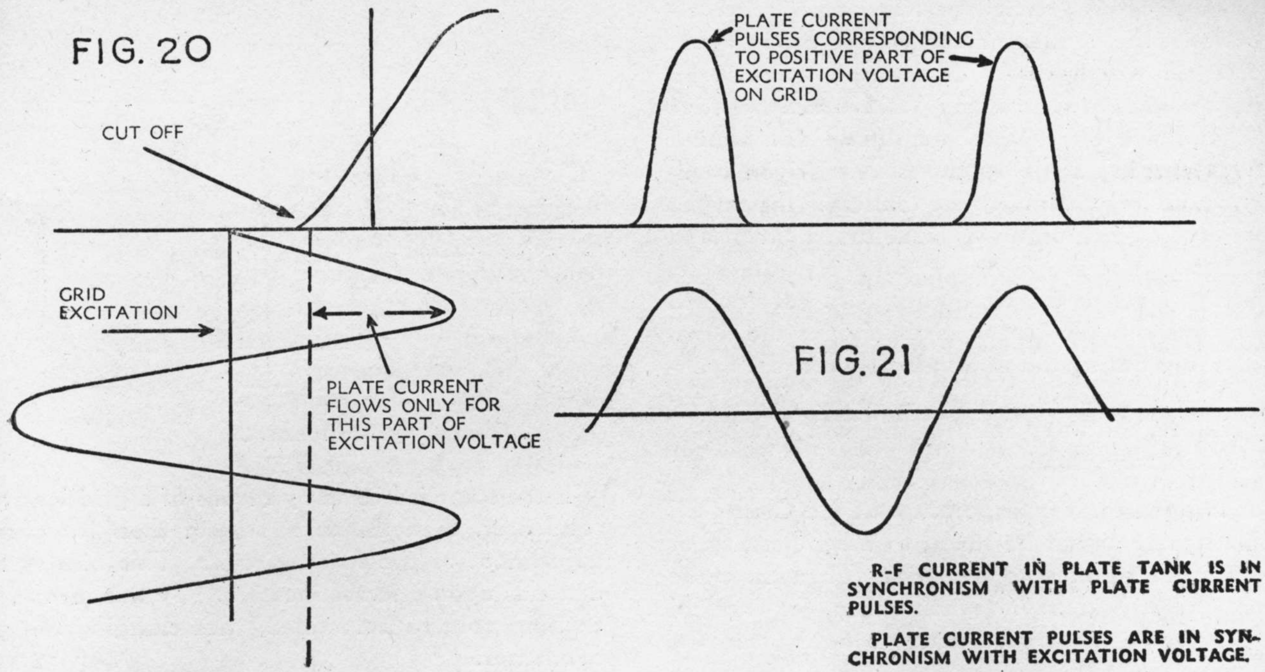


FIG. 20

FIG. 21

R-F CURRENT IN PLATE TANK IS IN SYNCHRONISM WITH PLATE CURRENT PULSES.

PLATE CURRENT PULSES ARE IN SYNCHRONISM WITH EXCITATION VOLTAGE.

PLATE AND GRID TANKS ARE TUNED TO SAME RESONANT FREQUENCY.

TUBE ACTS IN A MANNER SIMILAR TO THE BUZZER IN SWITCHING ON CURRENT. PULSES EVERY HALF CYCLE PREVENT OSCILLATION FROM DECREASING IN AMPLITUDE AS CIRCUIT CAN STORE ENOUGH ENERGY TO CARRY OVER A CYCLE.

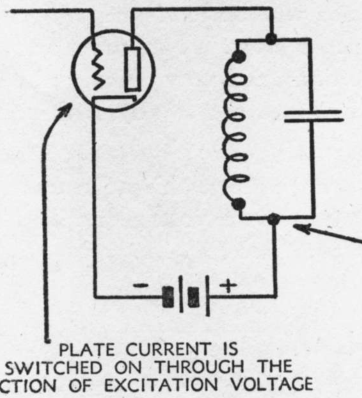
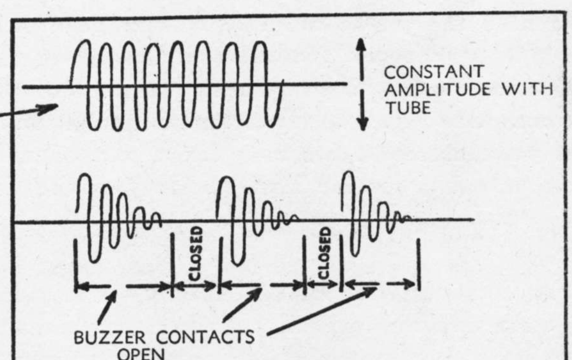


FIG.22



APPROXIMATE WAVE FORM OF BUZZER EXCITED RESONANT CIRCUIT

FIG.23

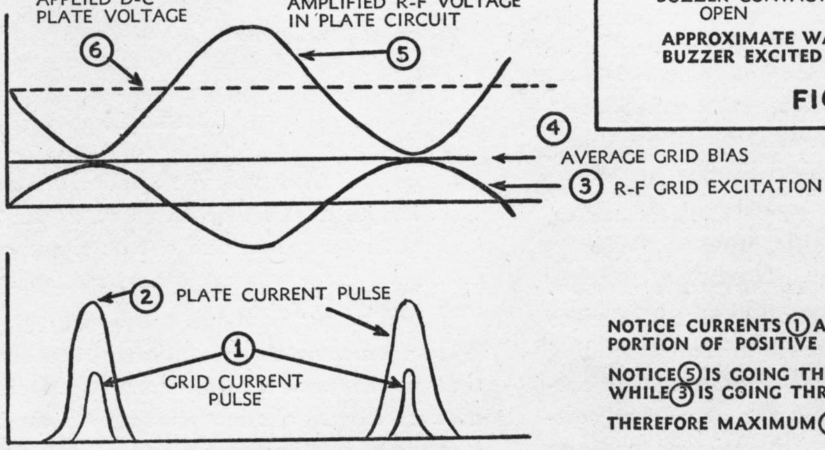


FIG.24

NOTICE CURRENTS (1) AND (2) FLOW ONLY FOR A PORTION OF POSITIVE PART OF (3)

NOTICE (5) IS GOING THROUGH NEGATIVE PEAK WHILE (3) IS GOING THROUGH POSITIVE PEAK.

THEREFORE MAXIMUM (2) OCCURS AT MINIMUM (5)

positive half cycle. Hence the R.F. current circulating between the condenser and coil of the resonant plate circuit will have an undistorted wave form. Corresponding portions of the positive and negative half cycles will have equal amplitude and similar form. Referring again to the buzzer-driven oscillatory circuit, we can easily see that since the buzzer cannot act in synchronism with the tuned circuit and quickly enough to supply energy on every half cycle, the energy level of the circulating R.F. current will not be constant. In fact, the oscillations die down considerably during the intervals between the opening and closing of the buzzer contacts. This seriously distorts the wave form of the R.F. developed in the oscillatory circuit. See Fig. 23.

For this reason it is imporant that the Class "C" amplifier plate circuit be tuned to the frequency of the excitation applied to the grid. Then the plate current pulses will be in synchronism (or integral multiples in the case of frequency doublers, triplers, etc.) with the R.F. current in the resonant plate circuit, and will produce undistorted amplification.

When the plate tank circuit (resonant circuit) is tuned to the frequency of the grid excitation, it offers resistive opposition (no reactance) to the plate current, which is characteristic of any circuit tuned to resonance. Now, because the opposition to the plate current is purely resistive in nature, the plate current will be maximum when the net instantaneous plate voltage will be minimum. Consequently, the pulses of plate current occur when the plate voltage is low. Hence, the power dissipation in the tube is low during the flow of plate current. See Fig. 24. This, together with the fact that plate current flows only for a part of a half cycle, accounts for the high efficiency of the Class "C" stage.

b. **GRID DRIVE EXCITATION**—The preceding discussion was primarily given to impress upon the student the necessity for correctly tuning the plate circuit of the amplifier. Having covered the necessity for careful plate circuit adjustment, we will now discuss the adjustment of the grid circuit.

Since the Class "C" stage is biased beyond cutoff, the excitation voltage must be great enough to overcome this negative voltage. For maximum efficiency the grid must be driven in a positive direction sufficiently to cause plate current saturation. If the grid circuit has a resonant circuit coupled to the source that is driving it (oscillator or preceding stage) then it is evident that this circuit must be correctly tuned in order to develop the necessary voltage at the grid. See Fig. 25.

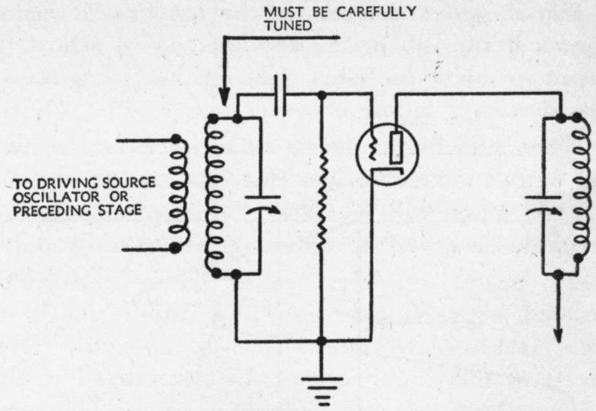


FIGURE 25

If the stage is biased by means of a grid leak and condenser, then this is another reason for careful adjustment of the tuned circuit. This bias system depends upon grid rectification. By this means, the exciting voltage is rectified, thus charging the grid condenser.

On the negative half cycles the grid condenser discharges through the grid leak, and produces a voltage that biases the grid beyond cut-off. If the circuit is not properly tuned, then insufficient voltage will be available at the grid for rectification; hence, the grid bias will be low, and will permit a high plate current to flow. The tube and circuit equipment can be damaged very quickly under such conditions, so it is important to adjust the grid circuit properly.

In high-power transmitters, this adjustment must be made without any plate voltage applied to the stage being adjusted. See Fig. 26.

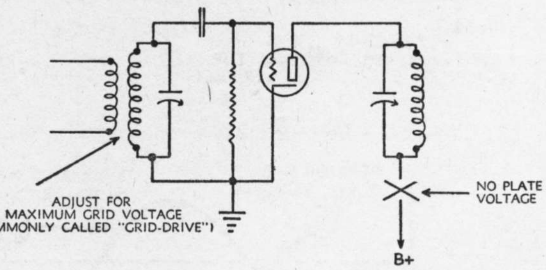


FIGURE 26

The excitation voltage applied to the grid of the R.F. amplifier must be adjusted to the proper value, so that the amplifier will not be either over or under-excited. Incorrect excitation results in inefficiency, and abuse of the tube.

The amount of excitation is usually specified as that which produces a certain grid current, and is measured with d-c instruments. This is made possible due to the rectifying action of the grid.

The designer determines the amount of excitation; it is the job of the service man to adjust the circuit to this value when placing the transmitter in operation.

When sufficient coupling exists between the input and output of an amplifier stage there is a possibility that the stage will oscillate. This is generally undesirable because the oscillations are uncontrollable.

All triode amplifier stages have considerable coupling between their input and output, due to the tube grid-to-plate inter-electrode capacity. The effects of this coupling must be neutralized so that the possibility of self-oscillations of the stage will be eliminated. This is usually accomplished by feeding a voltage to the grid that is exactly equal in amplitude and opposite in polarity to that which it receives through the grid-to-plate capacity existing inside the tube. Such a procedure is called "neutralization."

The discussion covered makes it clear that unless it is absolutely known that the circuit is already properly adjusted, and in good operating condition, certain precautions must be taken before the d-c voltage is applied to the plate of an R.F. amplifier.

It is general practice to allow the filaments or heaters of all the tubes of a transmitter to reach proper operating temperature before any other steps are taken. If the transmitter is known to be in adjustment, and in good condition otherwise, the plate voltage may be applied after the filaments have warmed up for a period of from 15 seconds to several minutes, depending upon the size and type of the tubes.

c. **PRELIMINARY TUNING**—The procedure for placing into operation, transmitters that are operative, but merely out of adjustment, is as follows:

1. The filament power is turned on, and the tubes are allowed to heat for the specified length of time.
2. The a-c voltage is applied to the rectifier plates (if rectifiers are used). Caution should be exercised to see that this does not cause d-c plate voltage to be applied to any tubes except the oscillator.
3. If the oscillator is not crystal controlled, it should be tuned to the operating frequency.
4. The grid circuit of the amplifier immediately following the oscillator should be adjusted to resonance, and for the proper grid current. (The plate voltage must be off.)
5. The stage should then be neutralized.
6. The plate voltage is then applied to the stage, and the plate tank **rapidly** adjusted to resonance. It is important that this be done rapidly to prevent damage due to high plate current.
7. All adjustments must be repeated to eliminate any errors due to interlocking actions that occur.
8. If there are other stages of amplification, the same procedure must be successively followed. The plate voltage is applied to each stage **after** it has been adjusted.
9. The plate of the final stage is readjusted for proper operation with the antenna.
10. All current, voltage, and frequency indications should be checked to see if they have changed from their proper values.

High plate current will probably flow if this procedure is not followed, which will cause the tube to overheat. Thus the electron emission powers of the cathode will be permanently impaired if the tube is left in this condition for any appreciable length of time.

If this condition should exist in a transmitter capable of considerable power output, the tube would draw so much current that the plate would become red hot, and the tube might be damaged permanently. There is also a possibility of damage to chokes, resistors, or other parts in the plate and cathode circuits, and also to power supply parts as well.

Usually, these parts are protected by fuses or circuit-breakers which automatically open-circuit when considerably more than normal plate current flows. However, it is possible to have higher than normal current, and yet not high enough to cause the fuse or circuit-breaker to open. Consequently, if too much reliance is placed upon these protective devices, and adjustments are made with the power on for a long period of time, the high current might be sufficient to cause damage.

When the dials of the tuning controls are frequency-calibrated, it will speed up the adjustment if they are set to the operating frequency before the voltage is applied. This will place the circuits near their final adjustments, and will therefore reduce the current flow while the final adjustments are being made. If for some reason the voltage must be applied, it should be turned on only for a few moments at a time. The plate current should be noted during this time, and if it is not dangerously high, the necessary adjustments should be completed as rapidly as possible. However, this should not be done except when necessary for certain tests or experimental purposes. Always follow the procedure outlined, unless it is definitely known that the transmitter is already adjusted, or that the design is such that no damage can result.

Remember that the various circuits are sometimes protected by fuses or circuit-breakers, as quite often a transmitter may momentarily be overloaded, which will cause the fuses or circuit-breaker to open-circuit. Ignorance of this safety provision might cause a considerable waste of time in looking for trouble, when all that is needed is a new fuse, or a resetting of the circuit-breaker. The transmitter might need neither readjustment nor repair.

In a grid leak-biased Class "C" stage, the plate current will be excessively high when there is no grid excitation. This is true whether the lack of excitation is due to improper adjustment, or to the failure of some circuit part. Again, it will be seen that the plate current also depends upon the adjustment of the plate resonant circuit (plate tank). Also, as the grid current becomes higher, the plate current becomes lower, and vice versa; this is because as the grid current rises, the bias voltage developed across the grid leak also rises, limiting the plate current. The student should definitely associate a high grid current with a high excitation voltage, and with a high grid bias voltage.

d. **FREQUENCY DOUBLING** — In the discussion on how a Class "C" amplifier stage supplies energy to the plate tank circuit, it was pointed out that the pulses supplying the energy occur every other half cycle. Also, the ability of the circuit to store energy makes possible the continuation of oscillation until the next pulse of energy is delivered to it. It was further pointed out that if the pulses occur at regular intervals so that the frequency of the tuned circuit is some integral multiple of the pulses, the circuit will continue to oscillate at about the same amplitude, provided that the time between the pulses is not too great, and the energy storage ability of the circuit is large enough. Unless the tank circuit is tuned exactly to integral multiples (whole number, not a fraction) of the energy pulses, distortion or failure of the tank circuit oscillations will result.

This being true, it is possible to drive an oscillatory circuit (plate tank circuit) by a Class "C" tube whose grid is excited by a frequency one-half that to which the plate tank is tuned. This may be expressed in a different manner, by saying that the plate tank is tuned to double the frequency of the grid tank, and thus acts as a frequency doubler.

Adjustment for grid drive is the same as previously discussed—the only difference in tuning being that of the plate circuit.

The method of obtaining frequency doubling, tripling, etc., is very important, as this principle finds extensive application. Because of the fact that it would require extremely thin crystals to oscillate at very high frequencies (so thin that they would fracture too easily) it is customary to use crystals of such a frequency that their physical size is practical. Then by carefully choosing the crystal frequency so that it may be multiplied by an integral number to obtain the desired frequency, the difficulties are eliminated. The Class "C" amplifier is well suited for frequency doubling.

SUMMARY

1. High plate current is caused by low or insufficient grid bias. Since the grid bias for this type of amplifier depends on grid rectification, there will be no bias if the grid does not receive R. F. excitation. Therefore, the plate current will be high, and the grid current will be low (or zero).
2. Failure of the grid to receive grid excitation may be due to a detuned (out-of-resonance) condition of the grid tank circuit, failure of the oscillator, or insufficient coupling between the oscillator and amplifier. High plate current may also be caused by a detuned condition of the plate tank circuit.
3. When positive informaiton is lacking as to whether a transmitter is ready for immediate operation, it is best that a certain definite precautionary procedure be followed, such as the step-by-step transmitter adjustment procedure.

NEUTRALIZING THE TRANSMITTER AMPLIFIER

Neutralization is necessary to eliminate the undesirable effects resulting from the feedback of the amplified voltage to the grid of the tube through the interelectrode capacity of the tube.

There are several circuits which may be used for obtaining neutralization, outlined as follows:

1. One which makes the interelectrode capacity serve as part of the tuning capacity (Fig. 27).

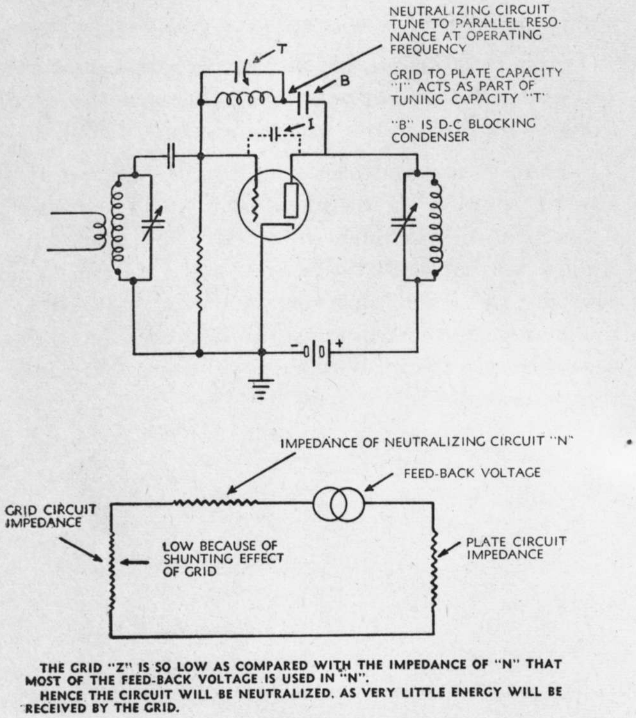


FIGURE 27

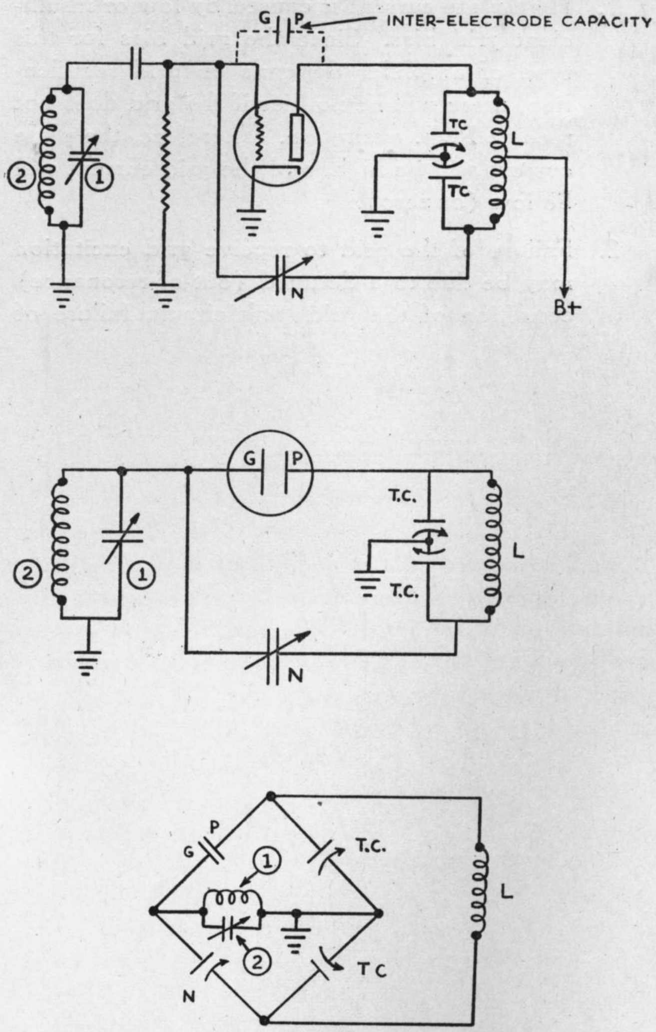


FIGURE 28

2. One which makes the grid-to-plate capacity one of the arms of a balanced bridge (Figs. 28 and 29).
3. One which feeds back to the grid (by means of inductive coupling) a voltage that is equal in value and opposite in polarity to that fed back through the tube capacity (Fig. 30).

The plate voltage should not be applied to the amplifier during neutralization. The oscillator should be adjusted for the operating frequency, and the R. F. amplifier adjusted for correct grid drive. A milliammeter should be inserted in the grid circuit as when adjusting for correct grid drive.

This procedure will present three methods of neu-

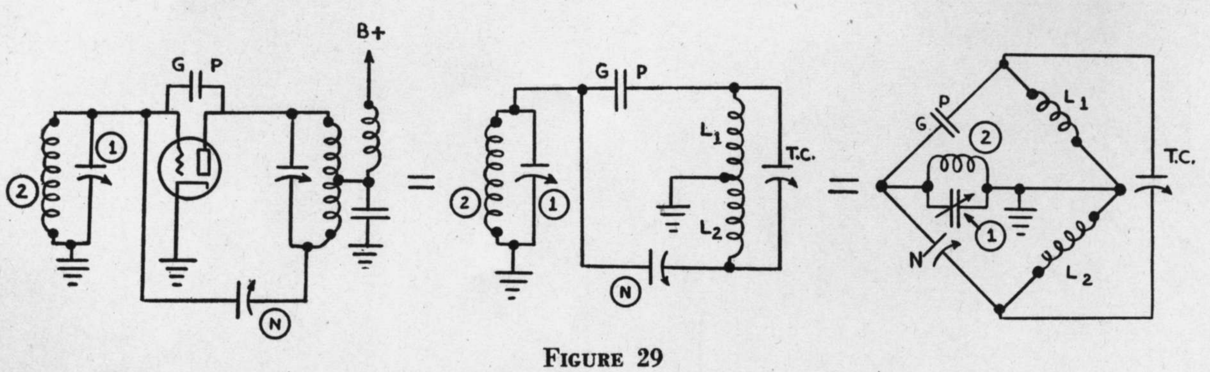


FIGURE 29

tralizing a typical amplifier. The first method is based upon the interaction between the plate and grid circuits when the amplifier stage is not neutralized. If the plate tuning is varied through resonance, the grid current will dip sharply. If the cacapity of the neutralizing condenser is varied a little at a time, while the plate tank condenser is rocked

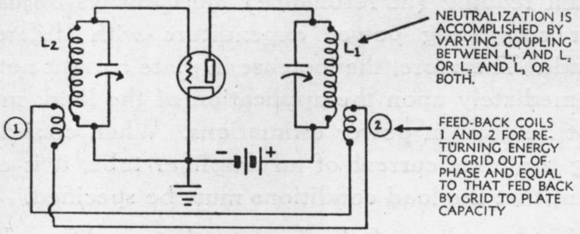


FIGURE 30

through resonance, the deflection of the meter will become less as neutralization is approached. If complete neutralization is obtained, the grid meter needle will not vary when the plate tank condenser is rocked through resonance.

The second method is based upon the increase in R. F. voltage across the plate tank circuit when the plate tank of an unneutralized amplifier stage is thrown out of resonance. This R. F. voltage is indicated by the scope. The vertical scope plates are inductively coupled to the plate tank. The horizontal scope amplifier is turned off, and the brilliance should be at low level, to prevent burning of the screen. When the plate tank is tuned to resonance, a small vertical line will appear on the scope if the amplifier is not neutralized. The neutralizing condenser should be varied until only a dot appears.

Further variation of the neutralizing condenser will make the line appear again, because the amplifier will be thrown out of neutralization.

The third method uses a light bulb (instead of the scope) coupled to the plate tank, to indicate when neutralization has been obtained. The procedure is similar to that with the scope, the difference being that the bulb will glow as long as the amplifier is not neutralized. Adjusting the neutralizing condenser will cause the glow to disappear when neutralization is reached.

RETUNING THE TRANSMITTER AMPLIFIER WHEN LOADED

The purpose of the R. F. amplifier is to raise the power level of the R. F. energy, so that it may be put to some useful purpose. This energy may be used in many fields, including surgery, diathermy, induction furnace engineering, etc.

Probably the most important use is in the wireless transmission of messages through space. The device which uses the R. F. energy, no matter what its purpose, is called the "load". In radio transmission the load is the radiation resistance of the antenna.

In the discussion so far, the adjustments preliminary to placing the transmitter into operation were made without a load (other than circuit losses). It will be found that when the amplifier is loaded, certain adjustments will have to be reset, as will be explained.

The d-c plate supply voltage furnishes energy which is converted into R. F. power for the various uses already mentioned. By measuring the plate voltage and plate current, the amount of R. F. power which is being developed may be estimated.

Assuming that the efficiency of conversion of D. C. to R. F. is constant as the load varies within a given range the d-c plate current will increase as the load is applied to the amplifier. This fact may be demonstrated by placing any metallic object such as a coin or jumper clip in the field of the plate tank circuit. If the metallic object is placed inside the plate coil and left for a few minutes, it will become heated.

It will be noted that when the object is placed in the field of the plate circuit, this circuit will require readjustment. But as the plate current meter is again brought to minimum reading, this reading will be higher than that before the load was applied. This higher reading is due to the expanding of energy in heating the object, this energy being supplied by the D. C. power supply.

Likewise, when the amplifier is loaded by an antenna, the D. C. power used from the power supply will increase for similar reasons. The antenna expends energy in radiating R. F. waves out into space. As the radiated power is increased, the D. C. power expenditure is increased, as indicated by a rise in amplifier plate current.

The student should be careful in interpreting the plate current readings to remember that the minimum reading (at resonance) must always be used for comparing power expenditure with different loads. Therefore, the increase in plate current noted immediately upon the application of the load, must not be used in power estimations. When considering the plate current of an amplifier tube, it is evident that the load conditions must be specified.

The coupling of the load to the amplifier plate circuit may be accomplished by means of link coils, resonant transformers, or autoformers. As an experiment a small loop coil can be used to couple a light bulb (as a load) to the plate circuit. The R. F. current induced in the loop coil will flow through the lamp, causing it to heat sufficiently to glow.

The current flowing in the loop coil will cause a magnetic field to be set up which bucks or opposes the field of the plate coil, thus reducing the net magnetic field. Since the inductance of the plate coil is dependent upon the strength of this magnetic field, its inductance will decrease, causing the circuit to become detuned. Since detuning the plate circuit in itself causes higher plate current, it is necessary to retune the circuit in order to determine the increase in current due to the load conditions.

The difference in D. C. power used when the amplifier plate circuit is unloaded and when it is loaded is the amount of power being supplied to the load. Since the efficiency of transfer of this power is less than 100%, the R. F. power actually taken by the load will be some fraction of the D. C. plate power consumed.

No matter how the load is coupled to the amplifier, it will cause the plate circuit (and sometimes the grid circuit) to become detuned, and these circuits will have to be retuned.

GENERAL
SERVICE PROCEDURE
ON
RECEIVERS
AND
TRANSMITTERS

PART II

PHILCO TRAINING SCHOOL

GENERAL SERVICE PROCEDURE
FOR
RECEIVERS AND TRANSMITTERS

I. General procedure for fast and accurate repairs.

- A. Make a visual inspection.
- B. Check power circuit to see that equipment can be connected without causing damage.
- C. Localize trouble; this step is most important when trouble is not of a simple nature.
- D. Locate defective component or components in section found at fault.
- E. Replace defective part.
- F. Check overall performance of equipment.
- G. Repeat steps (A) to (F) if performance is below normal.

II. Use of visual inspection.

- A. Look for broken tubes, broken plugs, tubes out of sockets, loose connections and other obvious damage or defect.
- B. Check to see that tubes and connector plugs are in proper sockets.
- C. Inspect equipment for dirt or moisture on parts susceptible to trouble from this source.
  1. Condensers in radio frequency circuits; especially those across high impedence circuits or having a high A-C or D-C voltage applied in series with them.
  2. Wire wound resistors in voltage divider network may break due to excessive moisture.

III. Preliminary ohmmeter check.

- A. Check power input circuits with ohmmeter to see that equipment can be connected without causing damage.
- B. Correct values to be expected may be obtained from Maintenance Manuals.

IV. Inspection with equipment operating.

- A. With power turned on visually inspect glass tubes to see that filaments are energized and feel metal tubes lightly to see that they are warm. In case of transmitters, dummy antenna should be properly connected.
- B. Check dynamotor or inverter to see that it is running.
- C. Operate equipment in normal manner to determine which function is defective.
- D. Replace, one at a time, each tube inset, with tube known to be good.
- E. If all functions of equipment are found to be inoperative, follow procedure "A" (explained on following pages).
- F. If one or more functions of equipment is operative, follow procedure "B" (on following pages).

RECEIVERS

V. Receivers, procedure "A."

- A. Measure B+ voltage at input terminal of receiver proper.
- B. Introduce signal from external source to input of first audio stage. Refer to point A, Figure 1. If signal passes, proceed to check I-F section, as in Paragraph "D" below.
- C. If no signal is heard, progressively apply signal to individual stages working toward headphones, points "B" and "C," Figure 1.

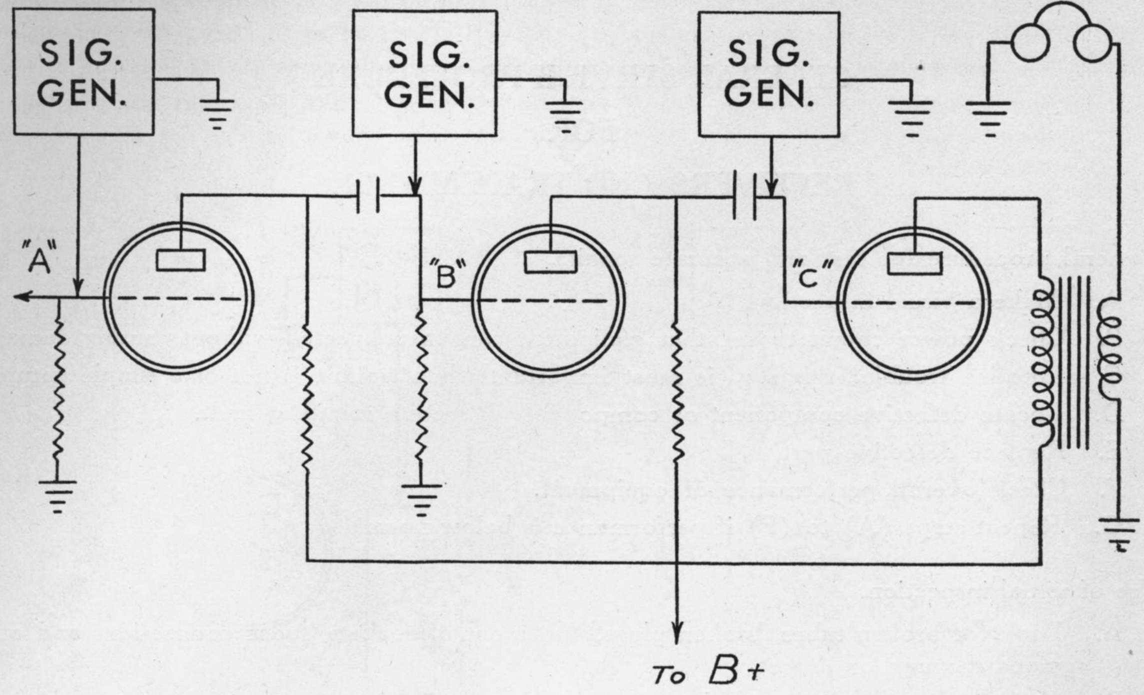


Figure 1

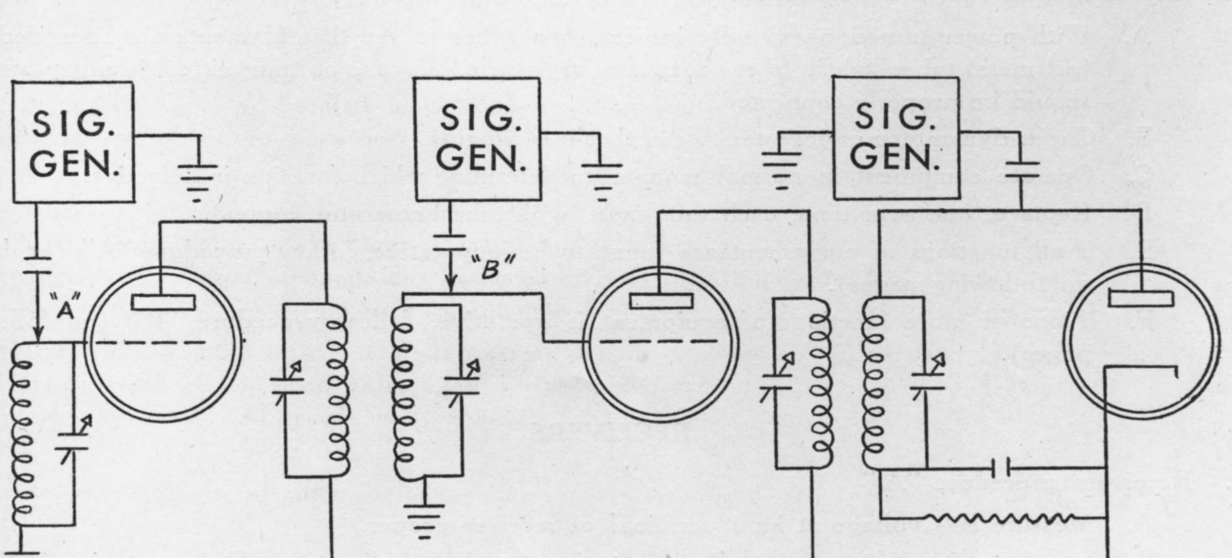


Figure 2

D. Apply signal of correct frequency and amplitude to the grid of the mixer stage, point "A," Figure 2. If signal passes, proceed to check R-F section as in Paragraph "F" below.

E. If no signal is heard, progressively apply signal to individual stages working toward first audio, points "B" through "D," Figure 2. After defective stage has been isolated make various voltage and resistance checks to determine which of the components is causing the trouble.

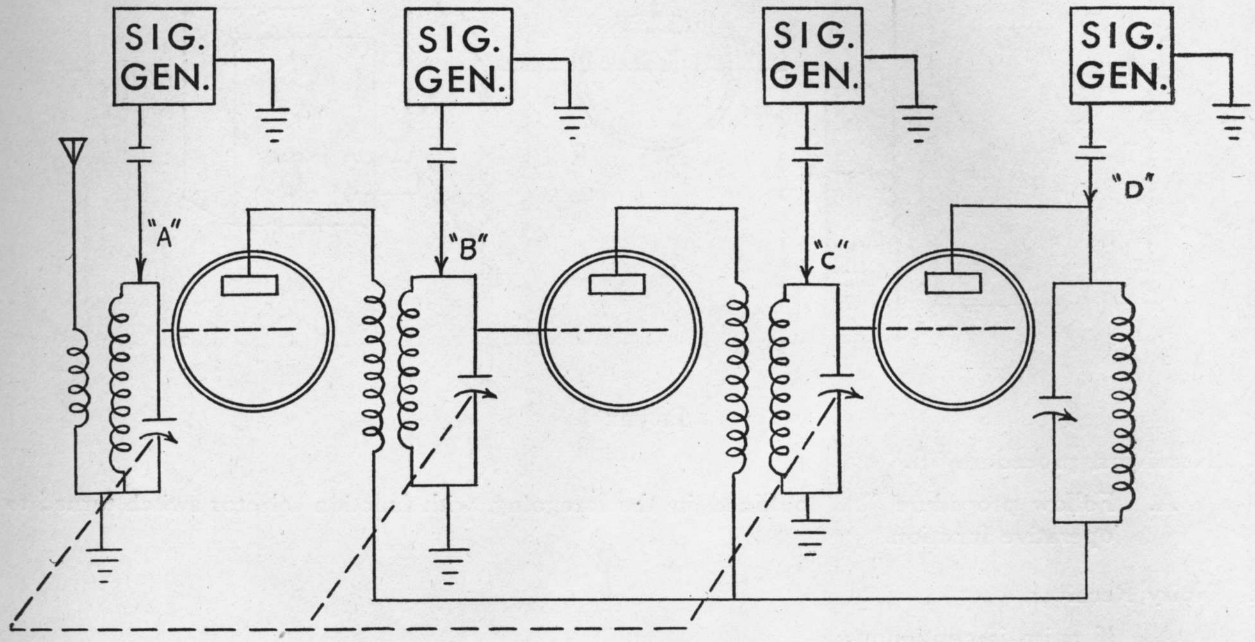


FIGURE 3

F. Apply a signal to the antenna input of a frequency corresponding to the dial setting, point "A," Figure 3. If signal passes, receiver is okay.

G. If no signal is heard, progressively apply signal to individual stages working toward mixer grid, points "B" through "D," Figure 3. After defective stage has been isolated make various voltage and resistance checks to determine which of the components is causing the trouble. If R-F signal fails to pass any stage, check oscillator (step H).

H. Measure grid bias of local oscillator with meter having sensitivity of at least 1,000 ohms per volt. Refer to Figure 4. Use isolating resistor when dictated by nature of circuit. Isolating resistor is to be of a value equal to the grid leak resistance and is to be connected in series with the probe connected to the oscillator grid.

I. As an alternate check on the operation of the oscillator and coupling system, substitute a signal generator for the local oscillator and inject a signal at the point of coupling to the mixer stage. Refer to Figure 4. The frequency of this signal will be the dial setting of the receiver, plus or minus the I-F frequency depending on circuit design.

J. After defective stage has been localized, measure the plate, cathode, and grid voltages with reference to ground. Compare reading with voltage table furnished in Maintenance Manual. In the case of a multi-electrode tube measure other electrode voltages to ground and check against table.

K. Check for defects those components that are associated with the electrode having other than normal voltages.

L. Replace defective components. Use parts called for in latest official information whenever possible. Use parts having exactly equivalent electrical characteristics in all cases. In radio frequency stages, original placement of wiring should be duplicated to maintain sensitivity and stability of receiver.

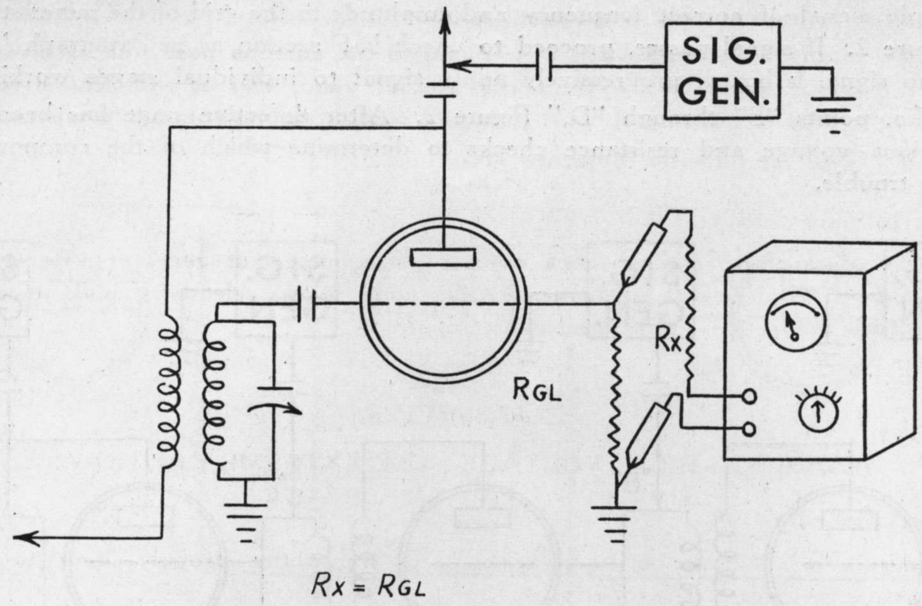


FIGURE 4

VI. Receivers, procedure "B."

A. Follow procedure "A" outlined in the foregoing, with function selector switch turned to inoperative function.

VII. Noisy Receiver.

A. If noise is continuous:

1. Disconnect antenna, and ground antenna post; if noise stops, source of noise is external to receiver proper; if noise continues, trouble is in the receiver, proceed with next step.
2. Make visual and mechanical inspections as outlined in procedure "A."
3. With receiver volume control at maximum, ground the control grid of first audio amplifier. If noise still continues, progressively ground the control grids of individual stages working toward headphones. Use .25 mfd. condenser to shunt the grids if grounding would change bias.
4. Ground the control grid of mixer tube.
5. If noise still continues, progressively ground the control grid of each stage working toward detector.
6. Ground the control grid of first R-F amplifier.
7. If noise still continues, progressively ground the control grid of each amplifier stage working toward mixer.
8. Ground the control grid of local oscillator.
9. The section immediately following point where grounding grid does not eliminate noise is defective.
10. The stage immediately following the point where grounding does not eliminate noise may be considered to be the immediate location of trouble.
11. Proceed to locate defective component as outlined above in procedure "A."

B. If noise is intermittent:

1. Repeat above procedure while tapping components of stage being checked. (Use common sense to avoid tapping too vigorously). Component requiring lightest tap to produce noise is one probably at fault.

C. If noise is present only with signal applied:

1. Apply an unmodulated R-F signal to the antenna post with receiver and signal generator tuned to low frequency end of band, and of sufficient strength to cause receiver to be microphonic (ringing audible in headphones when receiver is tapped).
2. Tap components to locate noisy unit.

√III. Overall performance check.

A. After completing repairs, check overall performance of receiver. Receiver should meet standard requirements as to sensitivity, noise level, selectivity and smooth operation of controls before it is considered to be repaired.

TRANSMITTERS

WARNING—HIGH VOLTAGE—USE EXTREME CAUTION!

IX. Transmitter, procedure "A."

A. Measure B+ voltage at input terminal of transmitter proper, check to see that dummy antenna is connected properly.

B. IMPORTANT! Check plate current of final amplifier to determine if value is within safe limits. Point A, Figure 5a. Use external meter if necessary. After doing this, tune the plate tank for resonance dip, to determine if any is present, Figure 5b. If no dip is obtained, it indicates either lack of excitation, a defective final amplifier stage, or lack of neutralization.

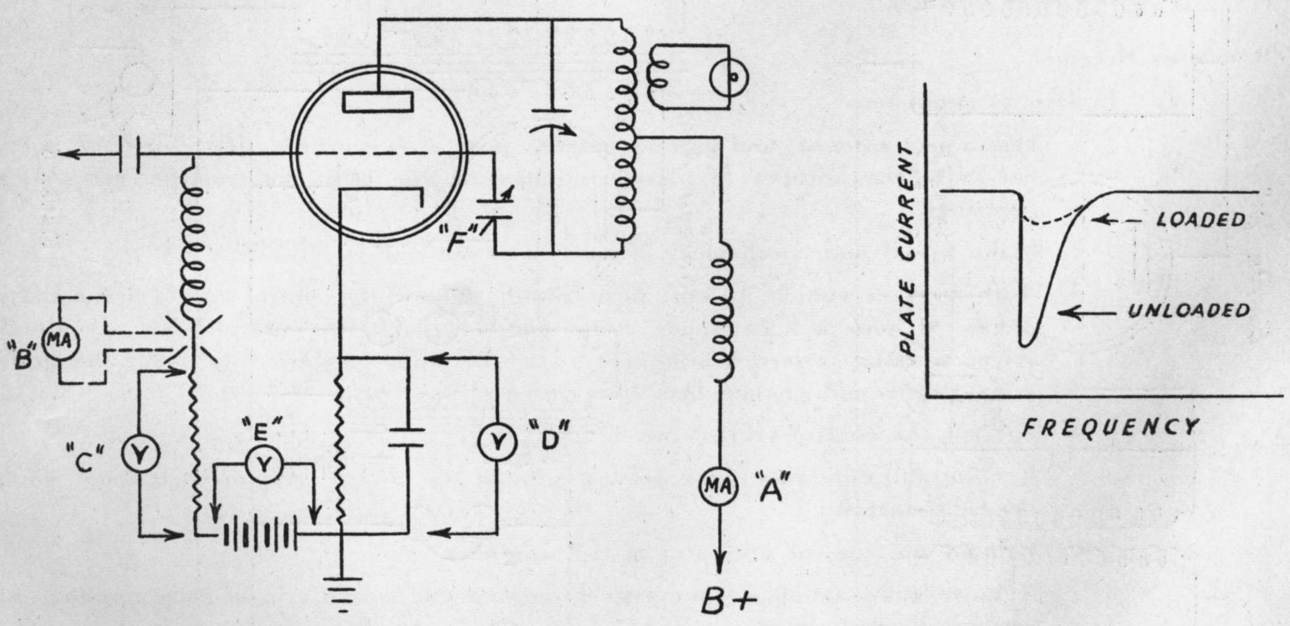


FIGURE 5

C. Check grid current, point B, Figure 5a or grid bias voltage, (point C, Figure 5a) developed across grid leak, to determine if excitation is arriving at that point.

D. If grid current is present but plate current dip is not discernible, neutralize final amplifier.

E. Measure any additional source of bias such as cathode resistors, point D, Figure 5a or fixed bias supply, point E, Figure 5a.

F. If no excitation is present, progressively repeat the above procedure (steps C, D, and E) in individual intermediate amplifier stages, either working toward master oscillator, including master oscillator itself, or starting with the master oscillator and working toward the final amplifier. Points "G" and "H," Figure 6.

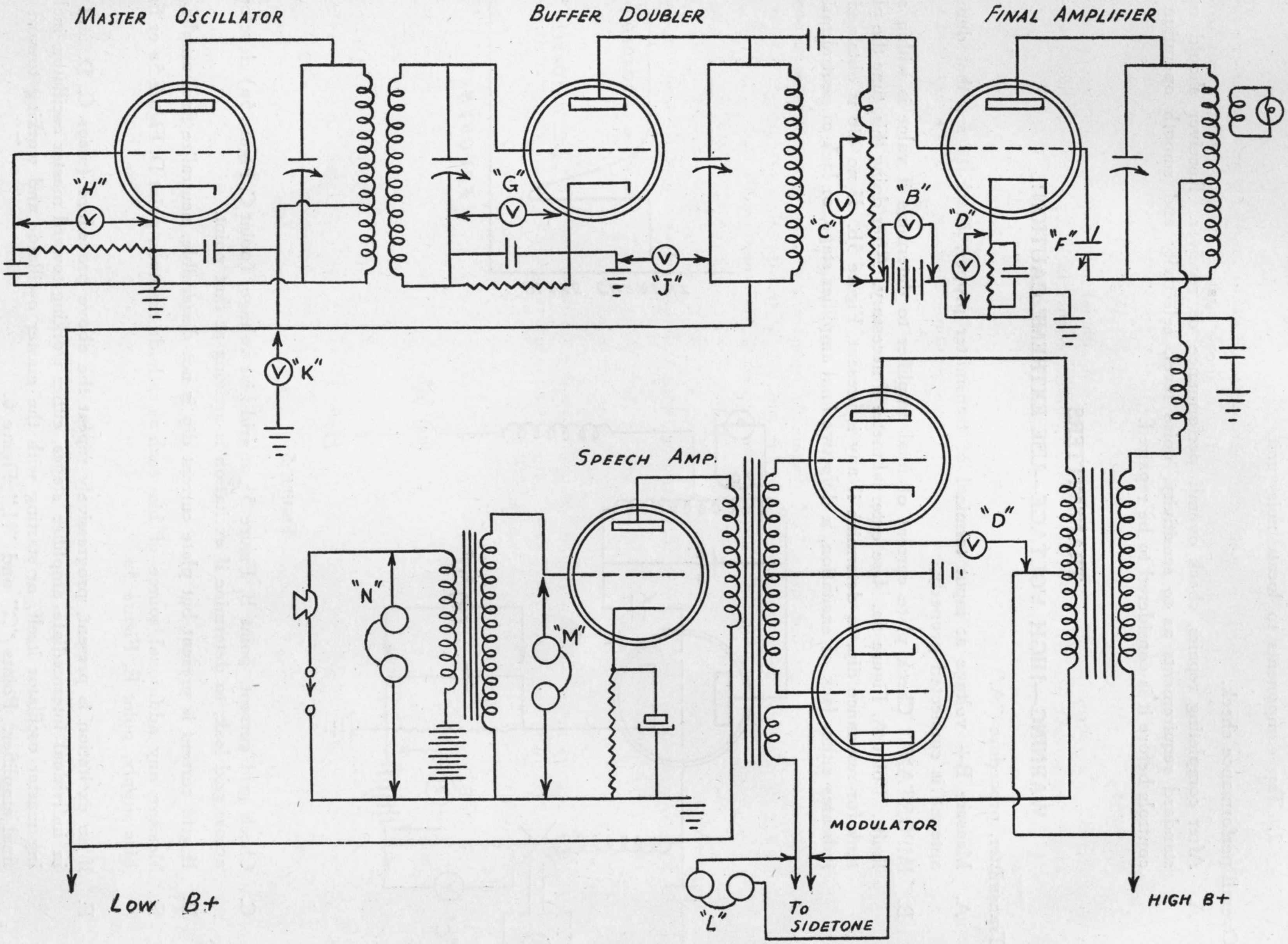

MASTER OSCILLATOR
BUFFER DOUBLER
FINAL AMPLIFIER
"H"
"G"
"J"
"K"
"C"
"B"
"D"
"F"
SPEECH AMP.
"N"
"M"
"D"
MODULATOR
LOW B+
"L"
TO SIDETONE
HIGH B+

FIGURE 6

G. The stage immediately preceding point where the grid excitation disappeared, may be considered to be the immediate location of trouble.

H. After defective stage has been localized, measure the plate voltage; i.e. from B+ side of plate load to ground, points "J" and "K," Figure 6. Compare reading with voltage table furnished in Maintenance Manual.

I. Measure cathode voltage; i.e., cathode to ground, and in the case of a multi-electrode tube, measure other electrode voltages to ground and check against values in table furnished in Maintenance Manual.

J. Check for defects the components associated with the electrode having other than normal voltages.

K. Replace components, use parts called for in latest official information whenever possible. Use parts having exactly equivalent electrical characteristics in all cases. Original placement of wiring should be duplicated to maintain stability and power output.

L. Check audio amplifier and/or modulator.

1. Connect a pair of headphones to the sidetone output terminals. Point "L," Figure 6. Operate equipment in both tone and voice positions checking for the presence of tone or voice signals.
2. If no signal is present in the sidetone output, progressively check each stage or coupling unit working toward microphone. Points "M" and "N," Figure 6.
3. In order to check the operation of the modulator stage, measure the plate voltage; i.e., plate to ground, point "P," Figure 6. Measure grid bias voltage, and with **power off** measure the resistance of the input and output transformers for proper D-C resistance as compared with normal values given in Maintenance Manual.

X. Transmitters, procedure "B."

A. Follow procedure "A" outlined in foregoing, with function selector switch turned to inoperative function position.

XI. Overall performance check.

A. After repairs have been completed, the performance of the transmitter should be checked against existing standards for power output, frequency range, and accuracy of calibration, modulation capability and speech quality.