RECEIVER HUM

45RH

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

DO YOU REMEMBER NAMES?

The secret of Jim Farley's success as a politician?—He can call 50,000 people correctly by their first names. The average man is more interested in his own name than in all the other names on earth put together; remember that name and you pay him a very effective compliment, but forget it or misspell it and you are instantly at a disadvantage.

One of the simplest ways of gaining good will and making people feel important is by remembering names, yet how many of us do it? We are introduced to a stranger, chat for a few minutes, and ten to one we can't even remember his name when we say goodbye.

The technique of Napoleon III of France, who boasted he could remember the name of every person he met, can be used to advantage by anyone, even today. If he did not hear a name distinctly, he politely asked that it be repeated; if it was an unusual name, he would request that it be spelled out. During a conversation, he repeated the name at every opportunity and tried to associate it with peculiarities of the man's features. If the man were some one of importance, Napoleon would, when alone, write the name on a piece of paper, concentrate on it for a few minutes, then tear up the paper.

How well do you remember names?

J. E. Smith.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1942 Edition

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Receiver Hum

ORIGIN OF HUM

Hum is a common trouble that the service man will constantly be required to eliminate. It is evasive and hard to trace down. Rarely indeed can a service man take his set analyzer and by making the usual routine measurements locate hum, especially in an A.C. operated receiver. A thoughtful and systematic procedure must be followed. In many cases, it is necessary to make many investigations and measurements before hum is finally located and overcome. In this book we will cover important sources of hum thoroughly, so that anyone versed in

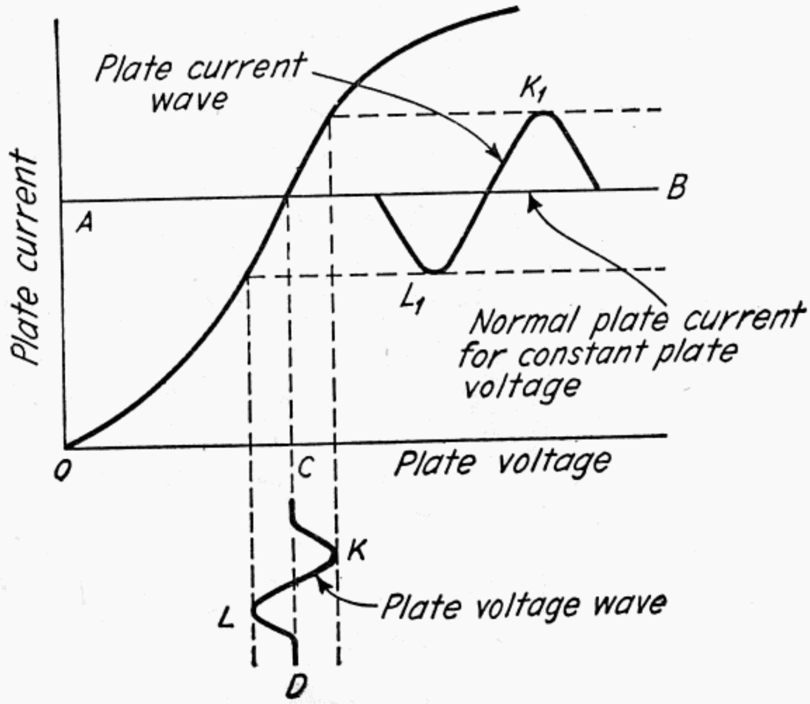

FIG. 1

radio servicing can locate the source of hum and make the necessary corrections.

Hum may be caused by any low frequency variation in the voltage supplies of any vacuum tube stage of an A.C. receiver, when the variation is due to improper connection to the A.C. supply or to inadequate filtering in the power pack. If this variation or "hum ripple" exists in an audio or the detector stage (second detector in superheterodyne receivers), the hum will appear in the speaker output whether or not the set is tuned to a station. However, a hum ripple introduced into an R.F., I.F., first detector or oscillator stage will not get through to the speaker unless it is modulated on an incoming carrier or the beat frequency, or unless it sets up self-oscillation and forms its own carrier.

Figs. 1 and 2 are shown to refresh your memory on the action of tubes as amplifiers. Fig. 1 shows the variation in plate current due to plate voltage variation, while Fig. 2 shows the effect of a C voltage variation. Similar curves could be drawn for changes in screen grid, filament and suppressor grid voltages, the only difference being in the degree of change.

In the detector or A.F. system, any supply variation at a hum frequency will be amplified and relayed by the associated equipment and will therefore be heard even if the R.F. system is not tuned to a station.

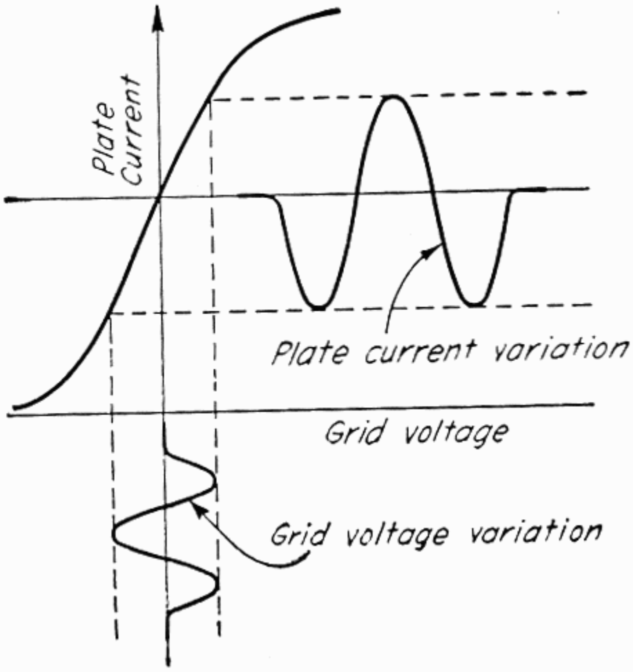

FIG. 2

If the variation takes place in an R.F. or I.F. stage, and the amplifier tube operates *absolutely* on the straight portion of its operating characteristics (acts in a linear fashion), the corresponding variation in the plate current will be wiped out by the tuned section. Unfortunately, the characteristics of any practical amplifier stage are far from straight. Because of this, the incoming carrier or beat frequency will be modulated by the undesired variation. When the R.F. or I.F. system is well designed,* it will take a large variation in the operating voltages

* R.F. and I.F. systems are always designed to have a low factor of cross-modulation and modulation distortion. When such distortion is reduced to a negligible amount, hum modulation in the high frequency sections of the receiver will be negligible. The use of variable mu tubes ('35, '51, '58) reduces such distortion and hum modulation as well.

to cause the introduction of hum (hum modulation). Hum modulation may automatically take place in tubes like the '24 or '57 having normally a low C bias cut-off, when they are fed with a strong carrier signal.

Because the high frequency system of a receiver is built to have tremendous gain, every precaution is taken in the elimination of supply variations, for a high input signal may cause hum modulation in the input stages and a low input signal may be hum modulated in the last R.F. stages. As a service man, you will be required to be on the lookout for defects which will introduce hum modulation.

Any defect which will cause the high frequency stages to oscillate will also allow the variations in supply voltages to in-

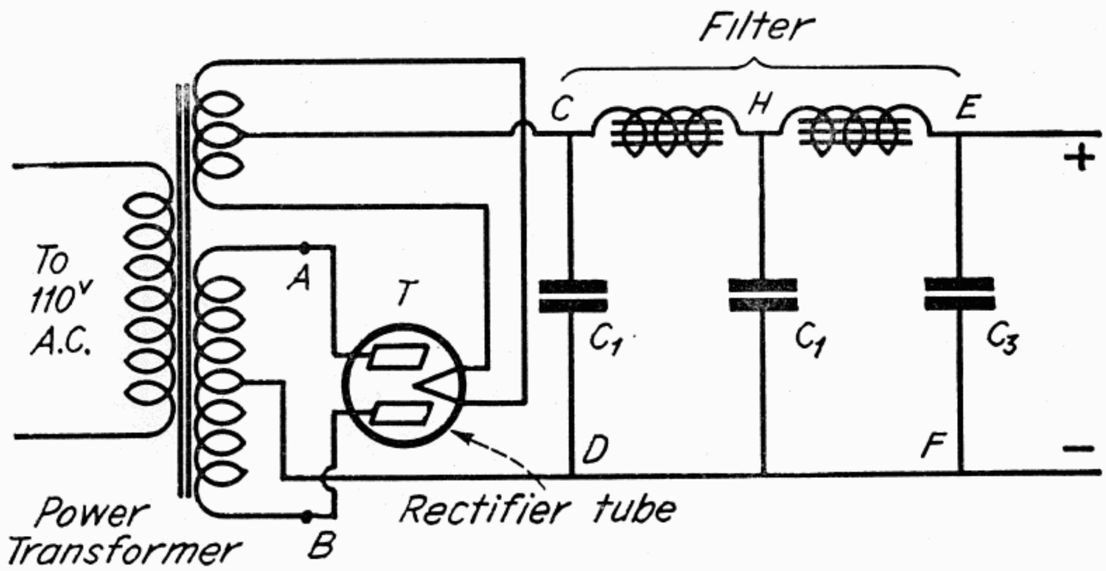

Fig. 3

troduce hum modulation. This condition is natural in the oscillator of the superheterodyne and the supply voltages must be adequately filtered to remove hum modulation. A good radio receiver designer takes all possible precautions in the prevention of hum in all stages of the receiver, and it is your duty to keep defects from marring the original design qualities.

In A.C. operated receivers, voltage and current are supplied to the tubes in two ways. To supply the filaments, A.C. current is taken directly from the line and applied through a step-down transformer. To supply the D.C. potentials the line voltage is stepped up and then it is rectified and filtered by the power pack of the receiver.

The alternating current applied to the filament is one source of hum, for as the alternating current varies, it follows that the temperature of the filament must also vary. This is particularly true of tubes with thin filaments, having little or no thermal lag. This, of course, affects the electron stream from the filament to the plate and it will vary in unison with the variations in temperature.

This is particularly true of tubes in which the filaments are electron emitters such as the '26, '71A, '45, '47 and '50. It is less noticeable in the case of tubes whose cathodes are indirectly heated, such as the '24, '27, '35 and '56. If correct voltages are applied to a '26 tube, the hum may not be of sufficient magnitude to be troublesome. However, if incorrect voltages are applied or if the tube filament deteriorates through long use, hum will result.

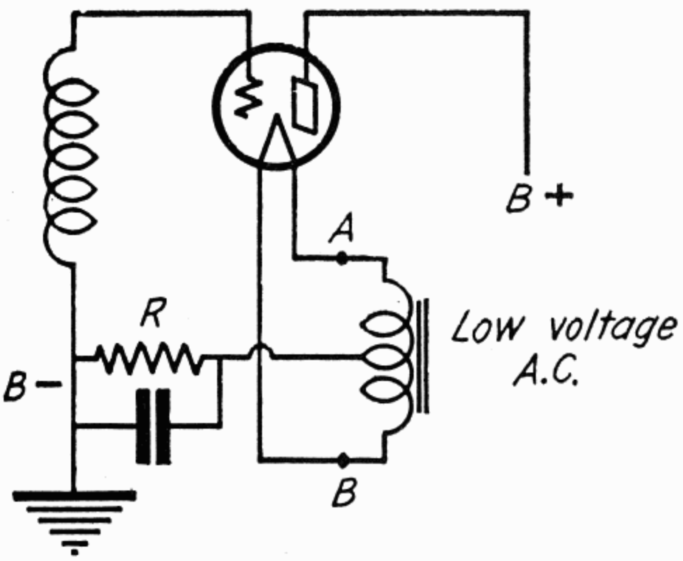

Fig. 4

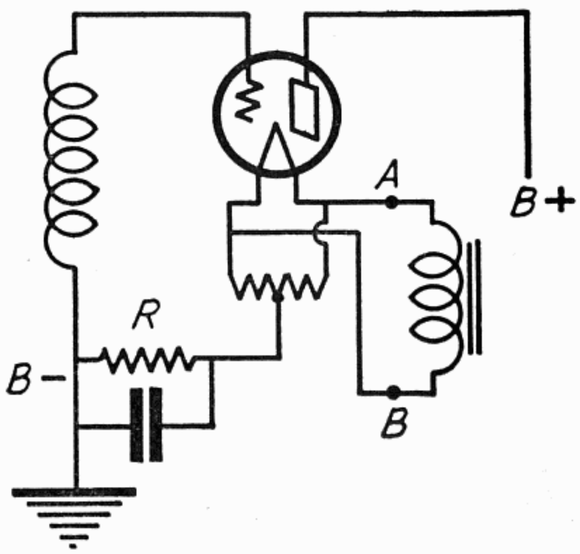

Fig. 5

These circuits are typical of the output A.F. stages in modern receivers. They have been used in the R.F. and intermediate A.F. stages of old receivers.

The plate and grid voltages of the A.C. tubes are supplied by an alternating current rectifier and filter as shown in Fig. 3. The voltage from such a source is never the pure unvarying voltage that can be obtained from batteries, but has, in addition to the regular rectified voltage, small variations super-imposed on it. These variations correspond to a 120 cycle frequency in the case of an '80 type rectifier and a 60 cycle frequency in the case of an '81 rectifier. The variations, although small, may result in hum if they are present in the grid bias, screen grid, or plate voltage supply.

In battery operated receivers hum is generally absent unless the battery supply is replaced by A and B eliminators. Then the receiver is A.C. operated and we have the same problems as in receivers employing power packs—it is impossible to filter out all the "ripples" in the rectified A.C. and there are small variations in filament, plate and bias voltages.

Hum voltages may also be introduced into tube circuits by magnetic induction. The strong alternating magnetic field of a power transformer may reach out and influence other parts of a receiver, for example, the audio frequency transformers. If the audio transformer is so placed that the magnetic field from the power transformer links with it, there will be a small voltage induced in the audio transformer which will be amplified, resulting in a hum. This is often true even though both transformers are well shielded. In many cases, the lead wires to the audio transformers pick up enough magnetic energy from the power pack to cause a hum output.

Electrostatic induction is another cause of hum. About the rectifier tubes there exists a strong electrostatic field due to the high voltage alternating current applied to this tube. This field may influence parts of the receiver, such as the detector tube or its circuit. The circuits or parts so influenced pick up electrostatic voltages which are amplified.

In most manufactured receivers, hum has been guarded against by careful shielding and placement of parts, but you can readily see how any abnormality in the receiver may result in slight hum voltages which through amplification, quickly reach large magnitudes.

HUM IN A.C. FILAMENT TUBES

The filaments of A.C. tubes are supplied with raw alternating current. In order that hum in receivers be kept down to a minimum, the filament circuits must be connected to the signal-carrying circuits in such a way that the A.C. ripple is balanced out of the amplifying circuit. (It must be remembered that the filament or cathode is the common return for all circuits.) Figs. 4 and 5 show the connections to an A.C. filament type tube and the method employed in obtaining the grid bias. This method is common for all direct heater type tubes such as the '26 in R.F. stages or the direct heater power tubes such as the '45, '47 or '50. The filament voltage is supplied through a low voltage step-down transformer. The plate current flows through a resistor connected between B negative and the center tap of the low voltage secondary as in Fig. 4 or the center of a resistor placed across this supply secondary as in Fig. 5.

In some circuits, the center tap connection may be made through an adjustable resistor connected directly across the winding, and the bias resistor is, of course, connected to the center tap. In any case, the center point must be a true electrical balanced center, for if any alternating voltage from the filament is applied to the grid of the tube, it will be amplified and appear as a loud hum. Notice that the grid is connected to the A.C. filament by means of the grid bias resistor. When point *A* is positive, point *B* is negative. This is fundamental in any A.C. circuit. If the biasing resistor *R* is connected to either point *A* or *B*, the grid will receive in addition to the bias voltage, a strong A.C.. voltage which will cause hum. Somewhere between the positive point *A* and the negative point *B*, there is a *balanced neutral point*, where the A.C. voltage between *A* and *B* changes from positive to negative. If the grid resistor is connected to this point, no A.C. voltage will be applied to the grid—consequently no hum voltage will be amplified. This point is the electrical center of the circuit. The two halves of the transformer filament winding must be perfectly balanced if the center tapped winding method is used. If a hum adjuster is used, this neutral point may be found by adjusting the resistance to the point which gives minimum hum. In the same way, all other transformer windings for any tubes require this balance for minimum hum. Anything that tends to upset this balance, no matter what it is or in what circuit, will cause hum.

HUM DUE TO RECTIFIER TUBES

We will now consider hum which can be traced to the rectifier tube in the power pack. Hum from this circuit is in many cases caused by a defective tube or connection.

In the '80 type rectifier, there are two plates. Each plate rectifies one-half of the alternating current wave and the complete action results in full-wave rectification. If one plate or circuit is open, only one-half of a wave is rectified, and we get a 60 cycle ripple instead of one of 120 c.p.s. The filter system designed for a full-wave rectifier is not as efficient as one designed for half-wave rectification. Therefore, if one of the plate circuits becomes open, a loud hum results, because the filter system is not designed to filter out 60 cycles. An open of this type might occur in the tube prong where the lead wire from the plate is not properly soldered to the prong. A drop of solder will, of course, correct this. Look for a defect in the tube, or a bad socket grip on the tube prongs.

If the filter system following a full-wave rectifier is of the brute force type, unbalanced rectification up to a certain degree will not produce noticeable hum. But if insufficient filtering is used or just enough to reduce hum to an acceptable amount, any unbalance is likely to lead to increased hum. The use of a tuned filter is bound to result in serious hum when the two halves of the rectified waves are unequal. This is because the resonant filter is tuned to twice the frequency of the power line. Unbalance results in harmonics which are only partially filtered. The greater the unbalance, the greater the possibility of hum.

Unbalanced rectification may result from mechanically unsymmetrical elements in a full-wave rectifier tube, an internal or external open between the plate and filament of one rectifier section, or an internal or external leak between one plate and the filament.* Examine the tube socket. It should be free of dirt, dust and sticky oil. If high voltage has broken down the wire insulation or charred or carbonized the socket in spots, a new socket should be used and the wire insulation replaced. The tube should be checked for unequal rectification and open elements. It must be assumed that some unbalance can be tolerated.

Where two half-wave rectifiers are used in a full-wave manner, the possibility of having unequal rectification is greater. Low emission on one tube, gas in one tube are possible sources of trouble.

When a full-wave rectifier becomes gassy, usually indicated by a pink or blue haze or glow around the tube elements, the rectified current is so much distorted that the filter will be unable to properly filter out the ripples. A heavy current will flow in the choke coils, cutting down their effective inductance and in that way introduces hum. Any gas in the tube will give rise to so-called "gas oscillation" which may be radiated to the signal system of the receiver. In this way hum may be introduced. A gassy tube may cause the input filter condenser to break down, destroying the filter system or the power transformer. On the other hand, a leaky input filter condenser may make the rectifier gassy. Before replacing the gassy tube, be sure that there are no defective parts which will make the new tube gassy. A quick test for a shorted filter condenser is obtained by connecting an ohmmeter between the chassis and a filament socket terminal of the rectifier.

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* A short between the elements will destroy the tube.

Mercury vapor tubes depend on ionization for their operation. They glow continuously. Special precautions are taken to remove noise due to the ionization action, usually recognized as a fuzzy or ragged hum. The tube should be enclosed in a tube shield, the latter having many holes to allow sufficient circulation of air. These tubes must not overheat. It is usual to insert a 1 to 6 millihenry R.F. choke in the plate leads, close to the plate electrodes. As a further aid in reducing hum, a 0.1 mfd. high voltage buffer condenser may be connected from plate to cathode or filament. The power transformer should have an electrostatic shield or a line filter to prevent outgoing hum radiation. All primary and secondary leads should be twisted. Never remove the line fuse always built into apparatus using a mercury

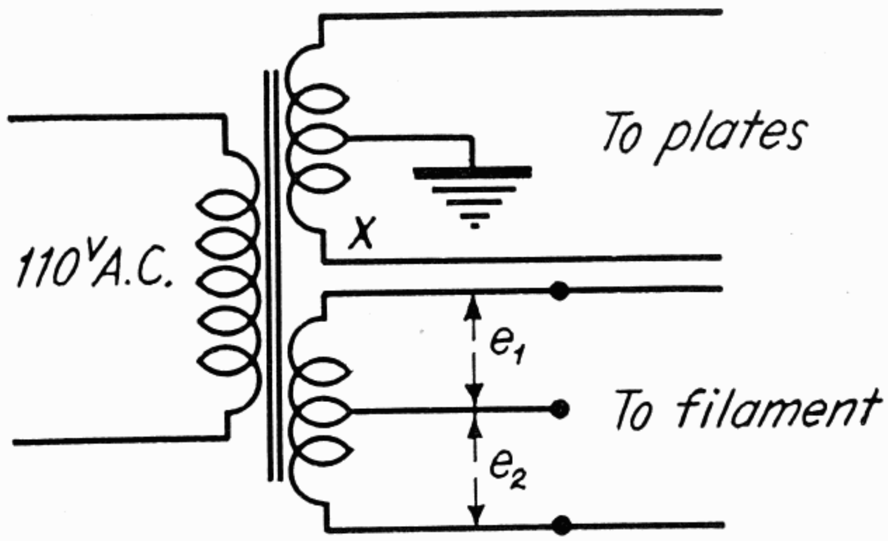


Fig. 6

vapor rectifier. If the fuse is of correct value and blows repeatedly, the rectifier is being overloaded. Bear all these facts in mind when servicing such systems.

HUM TRACED TO POWER TRANSFORMERS

The power transformer is supposed to deliver two equal A.C. voltages to the two plates of a full-wave rectifier. A great many of the causes for unbalanced voltages may be traced directly to the power transformer. A number of the common ones will be considered here.

An open high voltage secondary winding as shown in Fig. 6 at *X* will result in unbalanced voltages. No voltage reaches the lower plate of the rectifier and it acts like a half-wave rectifier. A partial short may exist across one half-section of the secondary or part of the circuit. In this case that plate circuit receives less voltage and the voltages applied to the two plates of the rectifier are unequal. This invariably results in hum. An A.C. voltmeter would show the absence of voltage on one plate or unequal voltages on both plates if it were connected between the center tap of the transformer and the plate of the rectifier. If the windings are shorted, it would be evidenced by the overheating of the transformer. If the open is at the terminal leads, it may be corrected by soldering. However, if it is internal or the short is internal, the transformer should be replaced.

The same conditions of an open or partial short may exist in any of the low voltage windings which have center taps for balancing purposes. Center taps are to be found at the rectifier filament winding and at the secondaries supplying filament

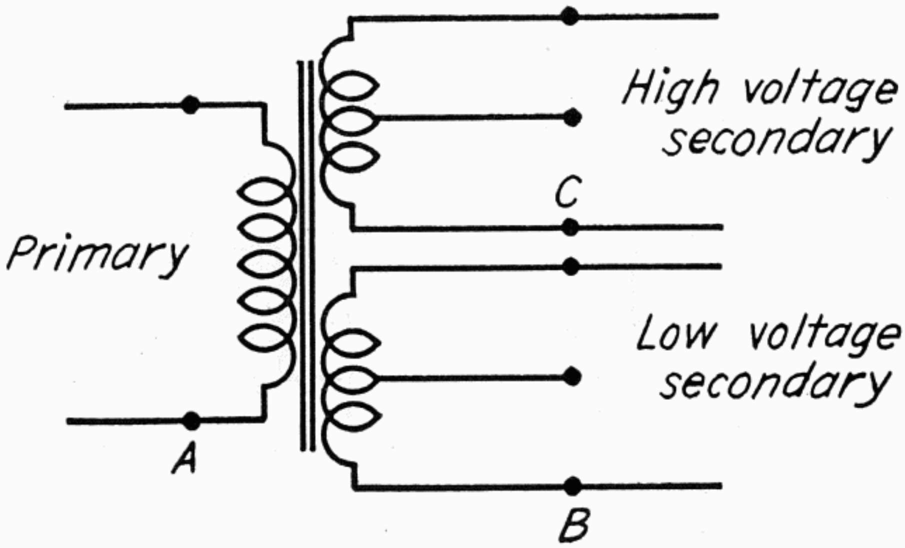


Fig. 7

power as shown in Fig. 6. The voltages on each side of the taps must be equal. The same tests for unbalance apply here as for the high voltage winding except that a low voltage A.C. voltmeter should be used.

Poorly soldered joints are a frequent source of hum. Sometimes resoldering a joint will clear up the hum. The resistance of a poorly soldered joint at one end of a transformer winding may be sufficient to cause unbalanced voltages. All terminals should be carefully examined to see that they are not corroded or poorly soldered.

If there is an electrical leak between windings, hum may result. This is due to poor insulation between windings or a break-down of the compound in which the transformer is embedded. With the transformer disconnected from the receiver, a continuity test, or better still, a megger test between any two windings will show up a leaky condition. Test between *A* and *C*, *C* and *B*, and *A* and *B* as indicated in Fig. 7, for extremely high resistance. The resistance between windings should be very large.

When the center tap of the high voltage secondary connects to the low potential side of the filter which is at ground potential, the absence of a direct ground connection results in hum. An imperfect grounding may also cause hum.

Unless it was the designer's original intention, the presence of a ground at one of the filament circuits will invariably result in hum. This does not refer to the center tap grounding. The reason for this is that either the filament circuit is unbalanced by this ground or a grid bias voltage may be shorted out. Fig. 8 shows a number of different filament circuits used in

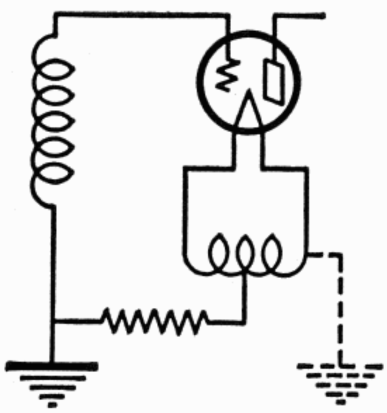


FIG. 8a

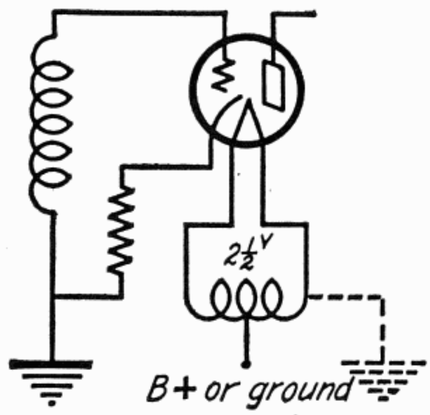


FIG. 8b

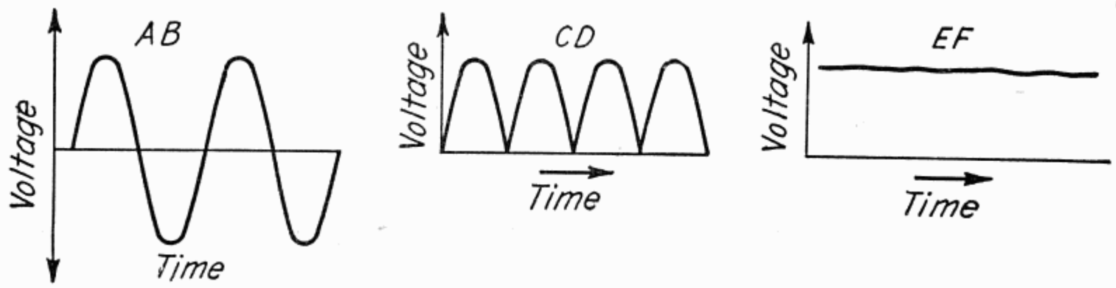
A.C. operated sets and how the presence of a ground upsets conditions. The grounding of any circuit connected to the filament winding will also result in hum, as for example, grounding of the pilot lamp. When the center tap of the filament winding is intentionally grounded, as is sometimes the case with the '27 or '24 type tubes, if either side of the filament winding is grounded, the heaters will be robbed of current. A circuit or continuity test will locate this ground.

If the transformer laminations are not tightly clamped, they will vibrate in unison with the alternations of the magnetic field. If the coil is loose on the core, it will also vibrate. The remedy is to clamp the laminations tightly and wedge the coil on the core by means of an insulating spacer or wedge between the core and coil. As a rule, such mechanical interference will be heard if the rectifier tube is temporarily removed.

HUM TRACED TO THE FILTER SYSTEM

The filter system has for its function the smoothing out of the pulsating direct current which comes from the rectifier. Fig. 9a shows the shape of the alternating current wave which is applied to the rectifier tube. Fig. 9b shows the appearance of the wave after it comes out of the rectifier tube. It is direct current, but not smooth. The function of the filter is to take this wave and smooth it out so it looks like Fig. 9c. The choke coils and condensers in the filter do this work. Any defect, therefore, in these component parts will result in poor filtering and, therefore, hum. The following are some of the major possible causes of trouble from this source.

A:—Depending upon the type of filter system used there will generally be two or three condensers. If any of these are open a loud hum will be heard. In addition, if the first or input condenser, C_1 in Fig. 3 is open, the output voltage will be considerably reduced. If the last filter condenser C_3 is open, motorboating, R.F. oscillation or hum may occur.



(a) (b) (c)

FIG. 9

One good way to test for open condensers is to connect an external condenser of 2 mfd. capacity across points *DC*, *HD* and *ED* as indicated by Fig. 3 while the receiver is operating. If hum disappears, it is a reasonable sign that a condenser in the filter is open or too small.

B:—A condenser which has low insulation resistance will cause imperfect filtering. A good condenser of 1 mfd. has a resistance of about 100 - 500 megohms. Higher capacities have lower total insulation resistance, thus a 2 mfd. condenser has 50 - 250 megohms resistance, etc. Very poor insulation will be shown up by the continuity test. Discharging a good condenser will give a "fat" spark, whereas if the condenser is leaky the spark will be weak. A measurement on a resistance ohmmeter or megger connected across the condenser will also show up bad leakage. The condenser should be entirely disconnected from the circuit when making this measurement. A leaky condenser cannot be repaired, it must be replaced.

C:—If either of the choke coils is shorted, it cannot perform its duty and hum will result. This will also show up as a slight increase in output voltage. The choke should be disconnected from the circuit and checked for resistance or the voltage across the choke measured. (In the latter case, be sure that no parallel device such as a condenser is shorted.) A short is sometimes caused by strands of wire touching the terminals of the choke. Visual observation will show this up.

D:—Choke coils are frequently made with a small air gap as shown in Fig. 10. If this is not properly adjusted, the inductance may be too low and hum will result. The simplest way

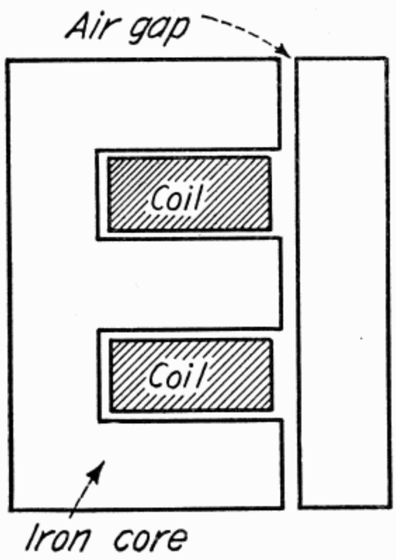


FIG. 10

to find the proper gap is by trial. Start with no gap, that is, clamp the laminations together so as to close up the gap completely and listen to the hum. Then take various thicknesses of paper, up to about .010 in. or .020 in. and place them in the gap, one after the other, making sure to tighten up laminations each time and listen to the hum for each gap adjustment. Choose that gap opening which gives least hum. Of course, an output meter in place of the loudspeaker may be used as a hum indicator.

E:—Hum may be due to insufficient condenser capacity in the filter. Trying additional external condensers at various points along the filter may reduce hum. This applies also to by-pass condensers. However, in some cases, the addition of extra condensers to the by-pass circuits may increase hum due to regeneration.

F:—Where the chokes are shunted by a small condenser, it is reasonable to assume that parallel resonance is used to block out the major hum ripple. Should this condenser open or short, a loud hum will be heard. Assuming that the frequency of the ripple does not materially change from normal, any jarring of the inductance may throw the filter out of resonance. In this case, readjusting the inductance of the choke by varying the air gap, or varying the shunt capacity will eliminate hum.

NEUTRALIZING HUM

Most filters in present-day use are of the "brute force" type. This type of filter delivers a substantially ripple-free current to

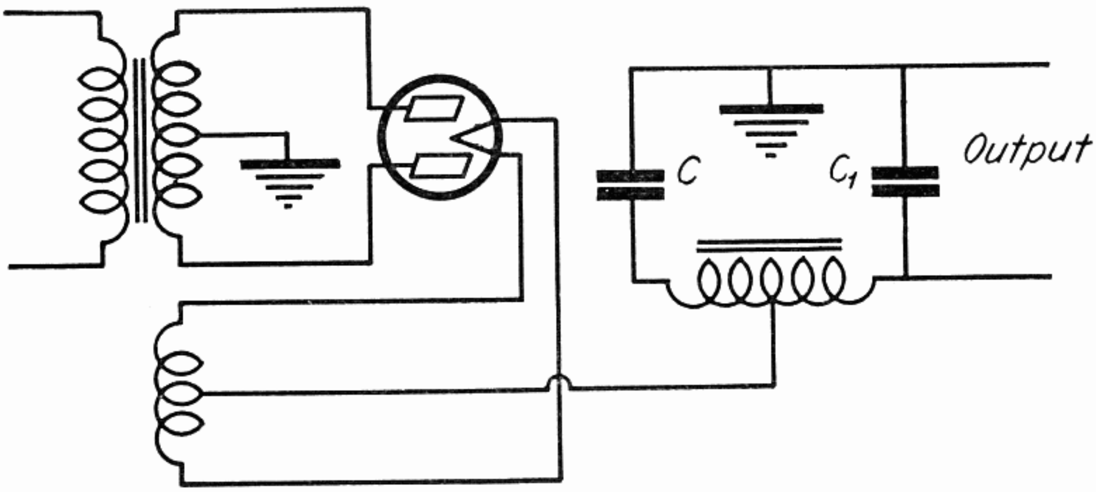


FIG. 11

the voltage divider. There has appeared a number of filter systems which have as their purpose good filtering with the use of minimum equipment. The resonant filter is one type extensively used. However, if they become unbalanced, a loud hum will develop and it will be more noticeable than that due to a slight unbalance in filters utilizing the "brute force" type of filter.

Fig. 11 shows a Meissner filter. It has been utilized in the General Electric, Westinghouse, Graybar, Gulbransen, R.C.A., Kolster, Edison and other receivers. If condenser *C* in Fig. 11 is the least bit leaky, a large hum will develop; whereas, there might be a slow leak in a similarly placed condenser of the "brute force" type as in Fig. 3 with little hum. If hum develops in any "Meissner circuit" watch for this condition. All connections must be very good because the slightest ground, short circuit or leak will cause hum.

The purpose of condenser C and that section of the choke nearest C is to form a series resonant filter shunted across the rectified supply. Anything that will upset resonance will increase hum.

Receivers which use the '26 type of tube in R.F. and first audio stages are very likely to show considerable hum due to the direct filament type electron emitter and hum of this type is very difficult to overcome without adding extra apparatus to the circuit.

Hum very frequently originates in the first audio stage. In many cases it has been balanced out of a receiver completely by introducing a neutralizing hum voltage in this section of the circuit. Fig. 12 shows a first audio circuit so adapted. This system can be effectively applied, no matter what type of first audio tube is used. It is adaptable to resistance coupled stages as well.

"B" voltage is obtained from the regular power source, "C" voltage is obtained by the voltage drop across R_1. A condenser C_1 is connected across R_1, so as to provide a low impedance path for the signal voltages. C_3 is an ordinary by-pass condenser of the kind used in all A.C. receivers to prevent the signal from passing through the supply source.

If R and C_2 of Fig. 12 are of proper values, hum will entirely disappear without disturbing the normal amplification of the receiver. In most cases the amplification will be improved because the signal current will have another path through C_2 and R.

As C_1 and R_1 are included in the grid circuit of the tube, the A.C. ripple voltage will be produced in the grid circuit having a magnitude, phase, and wave form determined by C_2, R, C_1, R_1. When R and C_2 are of correct value any hum in the circuit is completely balanced out. What happens in this circuit is that the A.C. voltage is taken from the plate circuit and fed back to the grid circuit. This bucks the hum signal in the grid circuit and we have satisfactory reception where formerly we had a bad hum.

The exact value of R and C_2 must be determined by experiment. R should be a good variable resistance having a range of from 0 - 50,000 ohms. For C_2 use fixed condensers having a range between .1 and 2 mfd. Connect them in the circuit as shown and vary R throughout its range. If the hum does not disappear, use a condenser of different capacity and again adjust *R*. If the hum is of the modulation type, a signal should be tuned in while the adjustment is made.

STAGE BY STAGE ELIMINATION OF HUM

The hum which is present will generally originate in one of the three major groups: (1) the power supply unit and filter, (2) the radio set, (3) the speaker. Often more than one of these is responsible. A step by step elimination process will frequently help to localize the source of trouble, similar to a method described in connection with stage by stage localization of noise. In this case, it is best to follow this procedure:

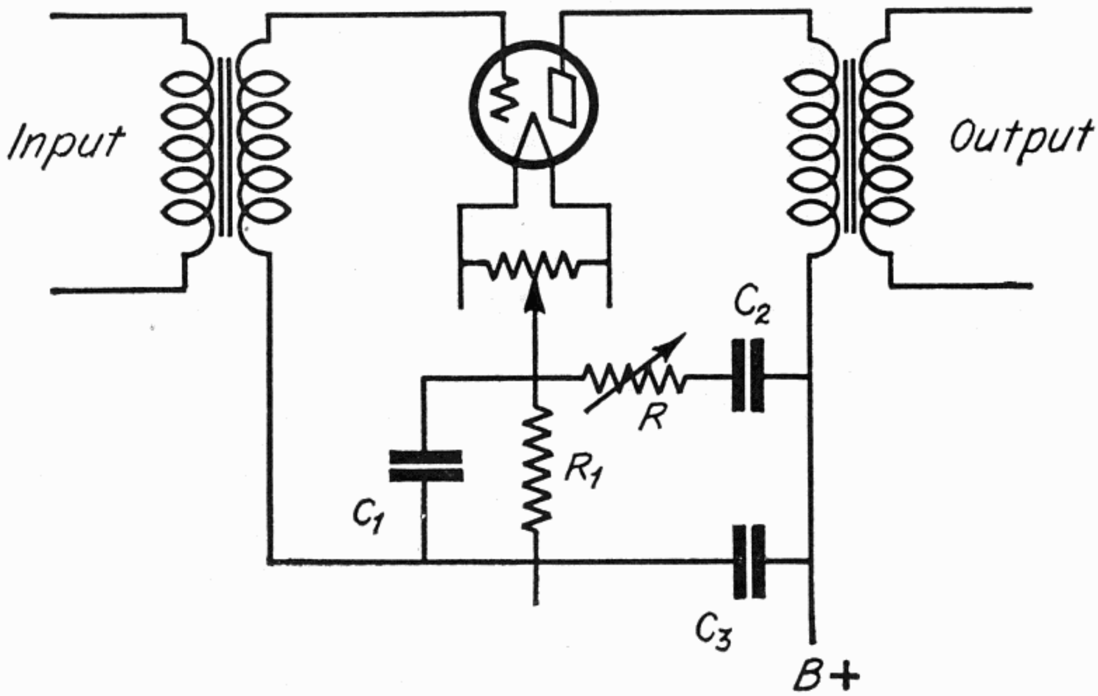


FIG. 12

1. Check the speaker first in accordance with instructions given later on "Speaker Hum."

2. Check the power supply system as already described in the section on "Hum Traced to the Power Supply."

3. Check the receiver proper by going from stage to stage as follows:

Short circuit the grid of the power tube to ground. If hum is present, it is coming in on the power stage and this stage should be carefully examined, checking points as will be explained later. If hum is not present the power stage is O.K. and the hum is originating in a preceding stage. Remove the short circuit from the power stage grid and short circuit the first A.F. stage grid. If the hum is heard, the trouble is in the first A.F. stage which should be gone over carefully. If hum is not heard, the first A.F. stage is O.K. and the trouble is in another stage. Remove the short from the first A.F. grid and short the detector grid. Proceed in this way until the circuit causing the trouble is found.

If hum is heard only when the set is tuned to a station, it is reasonable to assume that it is a modulated hum and a defect is to be expected in the R.F. system.

Be careful at all times when making connections and changes to open the power line switch so as to avoid any danger of shock. If a special part is to be examined, it should be disconnected from the circuit and the power switch opened when change is being made.

THE SOURCE OF HUM IN A STAGE

By substituting a pure D.C. source it is possible to tell where in a particular stage the hum is, that is, whether in the filament, grid, plate, screen grid or cathode circuit.*

Suppose a certain receiver develops a hum and we want to know definitely from which part of the circuit the hum originates. We proceed to use a D.C., preferably from a battery, in place of the source of current in the receiver of each individual tube circuit. By the stage by stage method, let us say hum was located in the output circuit. Disconnect the A.C. filament supply to the output tubes and operate the filaments from a storage battery in conjunction with the proper regulating resistance.

If the hum is due to the filament supply, it will now be made evident by humless reception. If hum is still present further tests are required. Short the grid bias resistor and connect a "C" battery into the grid return circuit, equal to the bias furnished by the biasing resistor. Next connect a series variable high resistance in the plate circuit to reduce the plate voltage to the regular value. (When the grid bias resistor is removed from the circuit the plate voltage rises and will be equal to the original plate voltage, plus the grid voltage.) If the hum is

* If from experience it is known that a certain type and make of receiver will normally give humless reception, when hum shows up the most practical scheme is to look for defective parts. The procedure given in the present section is very valuable in the design or assembly of radio receivers, or the elimination of hum in receivers which you know from experience do not give humless reception. When the exact source is found, then a more effective part may be used or one of the hum neutralizing methods may be employed.

originating in the grid circuit, it will now be eliminated. If not, we must now check the B supply.

A voltage from B batteries is now connected in place of the regular power pack voltage and a resistance is connected between the disconnected B– and B+ of the power pack of the receiver to consume current that would have been taken by the tube under test. This is done to prevent a rise of voltage throughout the receiver due to the removal of the load put on the power pack by the output tubes. The value of this resistance

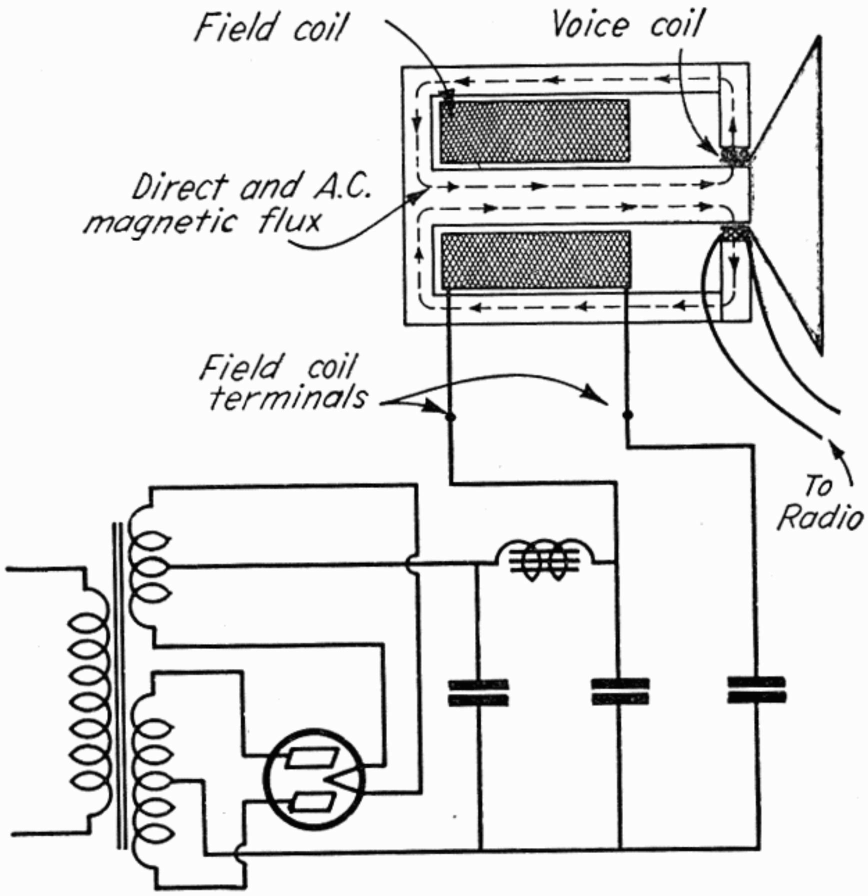


FIG. 13

can be obtained by measuring the plate current and voltage with suitable meters. R of course will be equal to $\frac{E}{I}$

If batteries to supply the new plate voltage are not available, a hum free B eliminator or the B section of a good power pack may be used. However, if possible, use batteries as they will not create the slightest hum.

The stage by stage elimination might indicate that hum is in the first audio stage. Proceed to connect batteries in place of the potentials ordinarily supplied by the receiver. Be sure that the filament resistance is of the proper value when using it to reduce the voltage of the storage battery. Suppose the first audio tube is of the '26 type which requires for its filament 1.5 volts and 1.05 amperes. If the storage battery is of the 6 volt type, the resistance necessary to reduce the voltage to the proper value is found from the equation:

$R = \frac{E - e}{I}$ where R = resistance
E = voltage of battery
e = voltage at which tube must operate
I = current

In this case:

$$R = \frac{6 - 1.5}{1.05} = \frac{4.5}{1.05} = 4.28 \text{ ohms}$$

The ordinary rheostat will not continuously carry this current so be sure to obtain one of the proper current capacity.

Hum is most likely to be introduced in the first audio stage so a careful analysis should be made of this stage. Battery voltages should be used for filament, grid, and plate circuits and a resistance should be used to consume the current that would ordinarily be drawn by the tube from the power pack of the receiver as described for the last audio stage.

Many service men prefer to trace hum by supplying battery sources for the operation of the entire receiver. The A.C. filament supply is disconnected from the receiver and the filament voltage supplied from a storage battery. If hum is still present reconnect the filament supply and replace the rectifier and filter system of the power pack with a battery. This proves conclusively whether or not the rectifier system is the origin of the hum. Hum should be absent. Then the stage by stage method may be used to trace the exact locality.

If you are tracing a modulation hum, you should employ a signal generator, preferably without A.F. modulation, connected to the input of the receiver. Now every stage except the R.F. stage under test should be operated by batteries. If hum appears, it is due to modulation in the stage operated from the A.C. supply.

In a manufactured receiver hum is most likely due to circuit defects, because the engineers of the manufacturers have more than likely eliminated the original normal hum by design. Therefore, from your analysis you will have determined precisely from which circuit the hum originated and almost invariably it will be due to a circuit or part defect rather than a design defect.

THE HUM IN THE DYNAMIC SPEAKER

The dynamic speaker is capable of introducing a considerable amount of hum in a radio set of its own accord. The reason for this will be apparent when we consider the circuit of the dynamic speaker as shown in Fig. 13. The dynamic speaker consists of a large magnetic field coil, which is excited by direct current supplied either by the rectified current from the power supply unit of the radio set, or by rectified current from a special speaker rectifier. In either case the current through the field coil is not a pure direct current, but contains a certain amount of alternating current. Consequently, the magnetic field in the air gap of the dynamic speaker is not a pure direct current magnetic field, but also contains a small amount of alternating magnetic lines. The moving coil of the dynamic speaker is situated

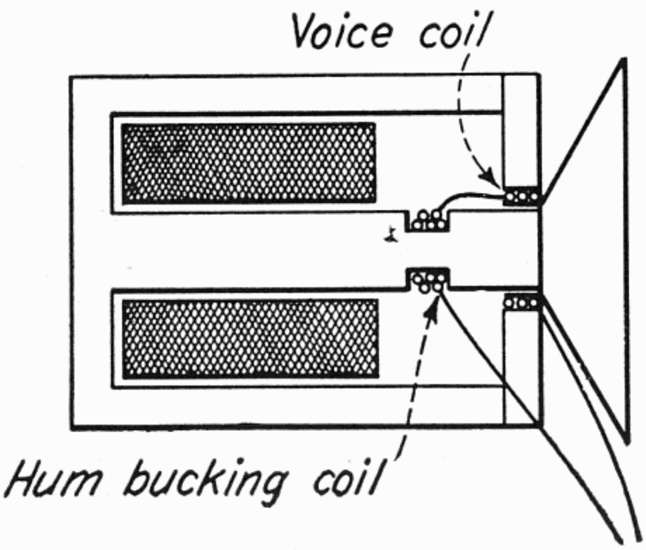


Fig. 14

in this air gap, and therefore, is influenced by the magnetic lines of the field coil. The alternating magnetic lines introduce a voltage into the moving coil and the result is a hum.

Another reason why the dynamic speaker sometimes introduces hum is that the output transformer of the dynamic speaker may be mounted in such a way that the alternating field from the power transformer, associated with the power pack or from the special rectifier system for the speaker, links with it. Consequently an alternating voltage will be induced in the output transformer which may be heard as hum.

To determine whether the speaker is contributing hum directly it is merely necessary to excite the speaker by means of its regular source with the primary of the matching transformer shorted so as to eliminate receiver hum. The hum that is heard now in the speaker is due to the speaker itself or the output transformer. The next plan is to excite the field winding of the dynamic speaker with pure D.C. and determine if the hum is reduced.

A number of methods have been utilized for correcting speaker hum. In general, if the speaker is a finished product of a manufacturer, it will be difficult to incorporate the changes necessary to reduce hum. However, the methods employed are as follows:

A:—Fig. 14 shows the use of a hum bucking coil in detail. A groove is cut into the pole piece of the electromagnet close to the end near the moving coil. In this groove there are wound

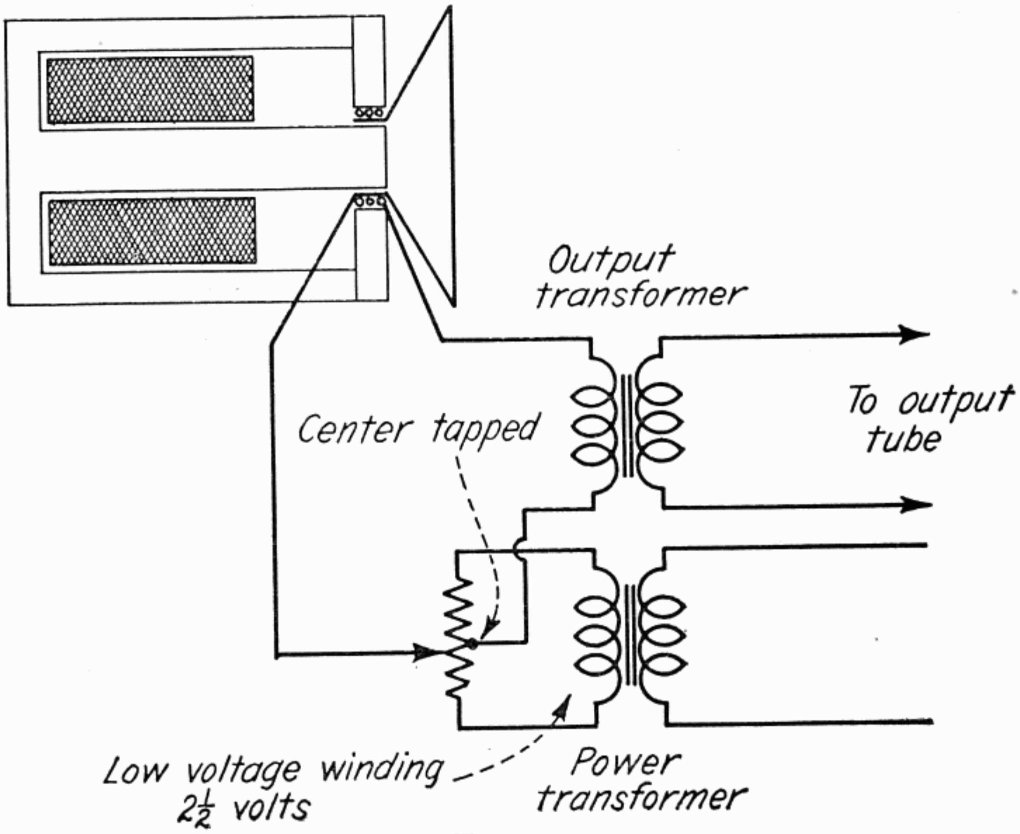


Fig. 15

a few turns of cotton covered wire in a direction opposite to the moving coil winding. This coil is connected in series with the voice coil and the output coil of the output transformer. When connected in one direction the hum is considerably reduced and when connected in the other direction, no change is noticed. The principle involved here is that the hum coil also has induced in it a hum voltage like the voice coil, but by connecting it in the proper direction, these two hum voltages balance out, resulting in a reduction of hum.

B:—The second method employed also involves the principle of balancing out hum. It is illustrated in Fig. 15. A potentiometer with a fixed center tap is connected across one of the low voltage windings in the power transformer and a portion of the voltage across this potentiometer is applied to the voice coil of the dynamic speaker. In this way a small alternating voltage is introduced in the voice coil. By moving the slider up and down along the potentiometer, its voltage may be varied until the right value is found for balancing out the hum which is present in the speaker. With one terminal connected to the center of the potentiometer, it is possible to move the slide toward either side of the center of the potentiometer, and in this way we can get A.C. voltages of the proper phase to balance out the speaker hum voltage. This method may be applied to any dynamic speaker. If a center-tapped potentiometer is not available, solder a lead to the lower center position of the resistance coil in a standard potentiometer.

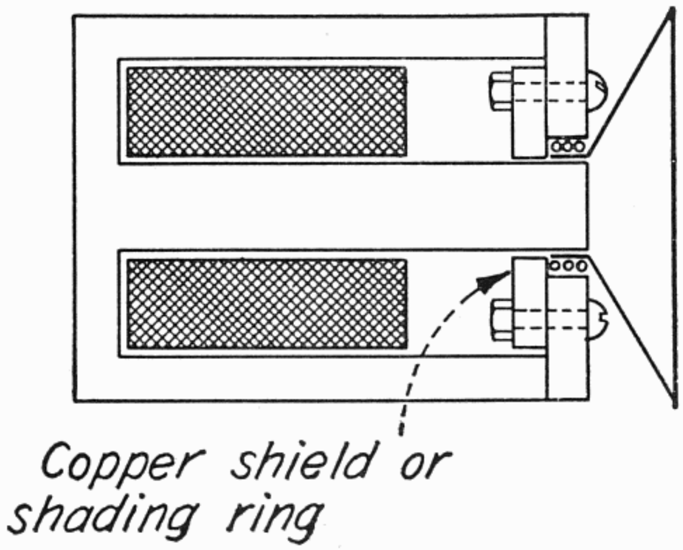


FIG. 16

C:—The third method commonly employed by manufacturers is to place a heavy copper shield between the moving coil and the field coil. This heavy copper shield is shown in Fig. 16. Its effect is to shield the voice coil from the alternating currents in the field coil, by setting up in the field magnetic circuit a flux opposite to the A.C. flux produced by the ripple current in the field coil. The shading ring has little effect on the voice coil currents.

A defective rectifier supplying voltage to the speaker field will cause considerably greater hum than that normally present. This is due to the fact that the defective rectifier no longer rectifies properly, and a larger amount of alternating current voltage is applied to the speaker field than is normally the case.

Replacement of this rectifier, whether it is a tube, or a copper oxide type, is the only remedy.

Imperfect rectification due to other causes will also cause speaker hum. For example, a badly unbalanced secondary of the rectifier transformer giving different voltages on each side of the center tap, will cause hum. A dry electrolytic condenser as shown connected in Fig. 17 will greatly reduce hum.

A mechanical hum may be contributed by the dynamic speaker, due to vibration of the laminations in the speaker power transformer. Clamping the laminations tightly, and wedging the coil on the core securely, are the only remedies for this.

As a last resort, speaker hum may be removed by moving

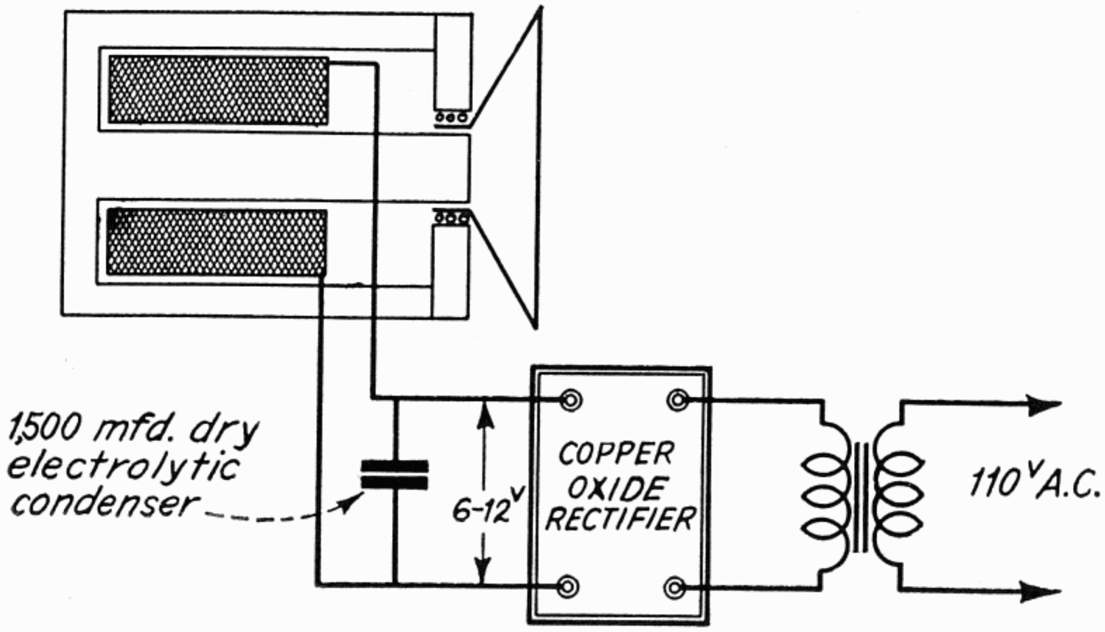


FIG. 17

the speaker back from the baffle (½ to 2 inches). This has the tendency of destroying low frequency response and likewise hum reproduction.

TUBE HUM

The tube is frequently at fault when hum is involved. Defective tubes or improper operation of tubes may cause hum. Under the section on "Filter Systems" we discussed hum caused by the rectifier tube. This section will be devoted to other tubes in the set.

A.C. tubes in general, and the '26 type tube in particular, must have proper voltages applied to them for minimum hum. Fig. 18 shows how the hum from a '26 type tube varies with plate current. This shows that for least hum, tubes should be operated at a specific plate current. This means that a definite grid bias and plate voltage must be used. These values are given by the set maker. Circuits should be checked to see that tubes are operating at rated voltages.

Absence of bias in any tube will generally cause hum. An open grid circuit makes the tube more sensitive to electrostatic induction from the rectifier tube. Sometimes it may result in oscillation which will usually accentuate the hum. Absence of grid bias may be due to any of the following causes:

1. Open grid bias resistor. A continuity test will show this.

2. Open R.F. secondary.

3. Open A.F. secondary.

4. Open grid leads.

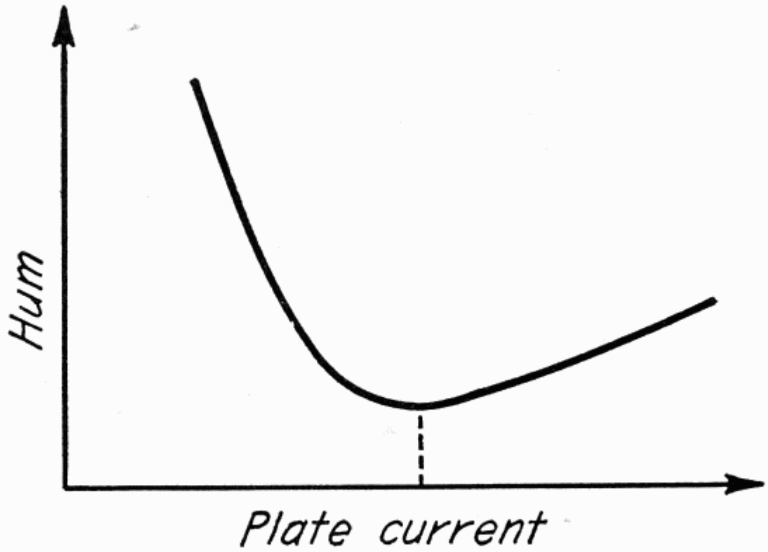


FIG. 18

5. Defective bias resistor or by-pass condenser.

6. Open plate return.

Circuit tests and visual observation will show up these faults. Where the fault is internal, the unit should be replaced. But if the open is at the terminals, it may be repaired.

The major common defects in tubes that cause hum are:

1. Gassy tubes. This is evidenced by a blue glow and haze, due to gas present in the tube or a leaky tube. The tube should be replaced after checking to see that the operating voltages are right.

2. Heater leads shorting to cathode. In the '24, '27, '35 and '51 types of tubes of some makes, the heater leads may lean over and touch the cathodes. This results in shorting out the tube bias and causes hum. A new tube should be tried.

3. Microphonic tubes. Such tubes have loose elements in-

side and are sensitive to vibrations and other disturbances. Such a tube may actually exaggerate any hum present. The best remedy here is to interchange it with some other tube in the set or use a new tube.

4. Sensitive detector tube. Some tubes have exceedingly high sensitivity as detectors. They may not make better than average R.F. amplifier tubes, but they have good detector sensitivity. As a result they are more sensitive to electrostatic pick-up of A.C. voltages which may be carried by neighboring circuits. Here, as in the case of the microphonic tube, the best thing to do is to interchange the detector tube with some other tube in the set if less hum at the sacrifice of sensitivity is desired.

HUM DUE TO REGENERATION

A receiving set in a regenerative or oscillating state is always more sensitive to any kind of disturbance than one which is stable. This is due to the fact that the sensitivity of the receiver increases as regeneration increases. For example, it is well known that a single tube regenerative set is very difficult to operate on A.C. on account of its tendency to exaggerate any A.C. ripple which may be present.

Regeneration may occur in both the audio and radio circuits. In all cases, the causes and remedies for the regeneration are the same as those given in the text on "Internal Noise." As far as hum is concerned, it should be remembered that if the hum arises in the audio stages, it is present irrespective of the presence of the R.F. carrier.

However, this is not always the case where the radio frequency stages are concerned. A condition may arise here which we termed "hum modulation." If the hum arises in the radio frequency tubes and no carrier is present, the hum may not be heard. This is because the R.F. stages do not amplify audio frequency signals, and hum is an audio signal. However, if a carrier is present, the hum in the R.F. tubes modulates the carrier and this is amplified and detected in the usual manner. This is the reason for hum making its appearance when a carrier is tuned in, and being absent between stations. To make sure that this hum heard when a station is tuned in, is due to the set, it is necessary to tune in to a number of stations. If the hum is present on all the stations, it is safe to assume that the hum is due to R.F. modulation and the causes for the hum should be checked in accordance with the instructions in this book.* If it occurs only on one station, we must be sure that hum modulation is not introduced by causing the first tube to work on its curved characteristic. This may be due to a strong local signal. The only remedy is to use a variable mu tube or insert a wave trap in the antenna circuit to reduce the signal strength of the interfering signal.

1. Neutralization of the receiver.

2. Filter circuit.

3. The A.F. transformer secondary may be improperly connected. Try reversing connections.

4. If modulation hum is present, you can isolate it in a particular stage or stages by using an R.F. signal generator Beginning at the R.F. stage, preceding the detector, couple the signal generator to the input of this stage. Now remove the tube ahead of this one so that no signal can be amplified through the circuit from the antenna system. If hum is now present, it is being introduced in the R.F. stage preceding the detector. If not present, it is due to another R.F. stage or stages and you should continue to couple the signal generator to each R.F. stage until the hum is localized in a particular stage. It is understood, of course, that the signal generator is of the R.F. type and unmodulated.

5. An open in the C bias filter condenser may give rise to oscillation or increased ripple feed from plate to grid. Check condenser for an open.

HUM ORIGINATING IN WIRING

Careless or inadequate wiring in a radio set is a frequent source of hum. The reason for this is that a great many wires in the receiver carry alternating current or filtered current. These wires pass other electric circuits. Around the wires carrying A.C. or D.C. with a ripple component, there will be a magnetic field and an electrostatic field, which may be picked up by other sensitive parts of the set, or which may induce voltages in various parts of the set. These voltages will be ampli-

* The variable mu tubes are especially designed to prevent modulation distortion and the service man has the option of rewiring the receiver to take these tubes, which is rather simple if the set originally used '24 tubes. If the receiver originally used the C bias volume control, no change will be necessary except in some cases increasing the value of the variable resistor. All other methods of volume control should be replaced by this one. Tube change over should not be attempted with A.V.C. receivers. You may try new grid resistors or a 2,000 ohm and .1 condenser filter in the R.F. plate supply to each tube.

fied by the receiver and will appear as hum in the speaker output. For example: the wires carrying the filament current for three or four screen grid tubes and the wires carrying the filament currents for the output tubes, carry currents of the order of 5 to 10 amperes. This is a very large current and may produce, under favorable conditions, large magnetic fields. If these wires pass next to the grid circuit of the detector tube, a small alternating current from these may induce a voltage in the grid circuit of the tube, and the result will be that this voltage will be amplified by the detector and audio amplifier of the receiver and a loud hum will be heard.

Hum due to wiring may be introduced in the following ways:

1. Wires carrying raw alternating current and passing close to the detector grid or to parts of the audio amplifier such as the audio transformer grid leads. This can be detected by visual observation and the correction is simple. The leads should be moved as far as possible from such circuits.

2. Alternating current leads not twisted. Pairs of leads carrying alternating currents such as the two wires feeding the filaments should always be twisted. Twisting these leads reduces hum voltages which may be induced in other circuits. The same applies to the high voltage leads from the secondary of the power transformer.

3. Proximity of the power supply cord to the detector circuit or antenna circuit or to the radio frequency circuit. The power supply carries the 110 volt alternating current voltage. The field from this cord may be great enough to induce voltages in these various circuits and so produce hum. It should, therefore, be kept as far away as possible both in the chassis and outside of the chassis.

MISCELLANEOUS CAUSES OF HUM

A number of miscellaneous causes of hum may be enumerated, some of which are subject to correction and some of which are not.

1. Poor or insufficient grounding. The ground lead should be securely attached to the chassis, and all points intended to be grounded should be checked. On some receivers, grounding the cores of the power transformer and audio transformers helps to reduce hum, and on others it does not. Trial only will show the proper connection.

2. Grounding one side of the power line through a condenser frequently helps. The power line sometimes acts as an antenna and picks up line noises and hum from neighboring power circuits. These disturbances are transmitted through the set by way of the ground and power supply. The best way to eliminate this source of hum is to filter the 110 volt line, or to use two condensers connected as shown in Fig. 19 rated at 220 volts A.C. and grounded in the center. The audio frequency disturbances picked up by the line are short circuited to ground through the condensers.

3. Room reflections. In many cases the following phenomenon will be observed in a room. As you walk away from the speaker, you will find points where the hum is loud and other

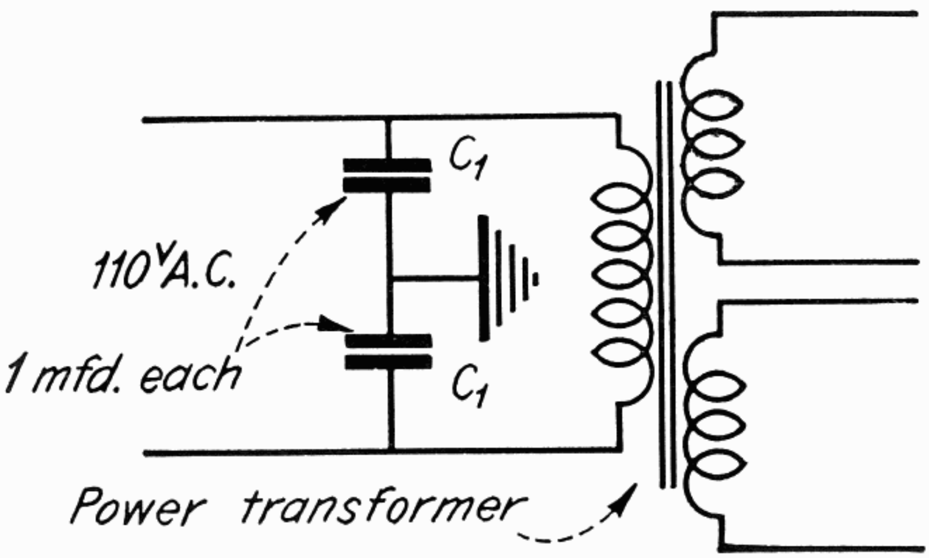


Fig. 19

points where there is no hum. This is due to reflections occurring from walls and ceiling in the room. At some points of the room these reflections reinforce the original hum and therefore at these points the hum will sound loud. At other points the reflected hum will oppose the original hum and at these points the hum will be low or disappear entirely. These alternations of loud and weak hum are called "standing waves." The only remedy here is to try changing the position of the set or speaker to eliminate these reflections.

4. Hum adjuster and center tapped resistors. The hum adjuster and center tapped resistors are used to balance the filament circuits by finding the electrical center. In the case of the hum adjuster, the arm is rotated until that position is

found which gives least hum. A defective hum adjuster will produce hum. The possible defects are:

1. Poorly soldered connections.

2. Arm not making contact. The blade should be adjusted until it makes contact.

3. Oxidized contact. The arm should be sandpapered to clean it of oxides.

In the case of the center tapped resistor, the tap is brought out at the center of the resistance. The voltages from the center to each end should, therefore, be equal. If they are not, the center tap should be moved to the point which gives equal voltages on each side or to the point which gives least hum. Opens or shorts on either side will also throw the balance off and produce hum.

TEST QUESTIONS

Be sure to number your Answer Sheet with *the number* appearing on the front cover underneath the title of this text.

Place your Student Number on every Answer Sheet.

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way, we shall be able to work together much more closely, you'll get more out of your Course, and the best possible lesson service.

1. Why would a poor contact at a plate prong of an '80 type rectifier tube cause hum?
2. If hum appeared in a receiver using a Meissner filter, and was traced to the filter, what defect would you look for first?
3. Explain why hum may appear only when the receiver is tuned to a station.
4. How would you attempt to eliminate hum that was traced to a first audio '26 type tube?
5. Explain the fact that hum originating in a detector stage may be due to its position with respect to the rectifier tube.
6. How can you prove conclusively whether hum originates in the rectifier and filter system of the power pack or not?
7. Show by a diagram how hum in a loudspeaker voice coil can be balanced out.
8. If shorting the grid of the second audio tube causes a hum to disappear, but the hum is present when the grid of the preceding tube is shorted, in what stage is the hum originating?
9. How can hum be introduced into a receiver by unmatched '81 type tubes arranged for full-wave rectification?
10. Why should A.C. filament leads be twisted?