CHAPTER 21

PUSH-PULL OUTPUT STAGE

Quick Check.—Place the tip of a plugged-in soldering iron on the control grids of each tube in a push-pull stage. A low growl should be heard from the speaker each time.

Function of the Push-pull Amplifier.—The push-pull amplifier is generally used as the last audio or power stage in a high-fidelity receiver. It receives its signal voltage from the first AF stage, amplifies it, and drives the loudspeaker. This function is similar to that of the second AF stage in the standard receiver.

![Block diagram of a push-pull amplifier.](image)

In addition, the push-pull stage serves in other functions. It makes it possible to deliver large amounts of power to the speaker with low distortion, while using small tubes and low $B$ voltages. Another characteristic of the circuit is the reduction of hum. To summarize, the push-pull stage amplifies at audio frequencies with a large power output and with little distortion and hum.

Basic Requirements of a Push-pull Amplifier.—The theory underlying the operation of the push-pull amplifier can best be explained by means of a step-by-step development. Figure 21–1 is a block diagram showing the requirements of a typical push-pull second AF amplifier. The audio signal from the first AF amplifier is broken up into two voltages of equal magnitude but opposite phase, and they are then fed to the two grids in the push-pull stage. The output from the two tubes is coupled to the speaker.

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A simple method of obtaining the 180-deg phase difference for the two grids, as well as equal voltages, is by means of a center-tapped transformer. Such a circuit is shown in Fig. 21–2. At any one instant, the signal voltage at one end of the secondary will be positive, and at the other end negative in polarity. Since the center tap is grounded, one end of the secondary will be as much above ground in the positive direction as the other will be below ground in the negative direction.

Each of the terminals of the transformer is connected to the grids of the tubes as shown in Fig. 21–3. As a result, the grids are 180 deg out of phase. When one grid is being driven positive with respect to ground by the signal, the other grid is driven equally negative with respect to ground. In the first tube, as a result, plate current will increase; in the second tube, plate current will decrease to the same extent.

A negative bias voltage is obtained in the usual manner, as shown in Fig. 21–4, by connecting resistor \( R-7 \) in the directly heated cathode circuit of both push-pull tubes. The plate currents of both tubes flow through this resistor and establish the bias voltage across it. The grids of both tubes are connected to the negative end of this bias resistor, thereby establishing the same no-signal bias voltage on each tube. Condenser \( C-7 \) by-passes the bias voltage. In some circuits, it may be omitted, since its function is not so important in push-pull operation as it is in a single-tube second AF stage.

The output from both tubes is fed into a push-pull output transformer with center tap connected to \( B \) plus, as shown in Fig. 21–5. It should be noted that the flow of plate current through the two halves of the primary is in opposite directions. But coupled with this condition is another factor. Because one grid is driven more
Fig. 21-4.—A method of obtaining bias voltage for a push-pull stage.

Fig. 21-5.—The output circuit of a push-pull amplifier.
negative while the other is being driven less negative, we have a decreasing current through the first tube and an increasing current through the second one. The combined effect is to add the outputs from the two tubes in the secondary of the output transformer where a considerable voltage is induced. The outputs from the two tubes then drive the speaker.

A splendid characteristic of the push-pull stage is that it reduces or eliminates even-harmonic (primarily second-harmonic) distortion,

![Sine-wave Input](a)

![Even-harmonic Distortion for Tube #1](b)

![Even-harmonic Distortion for Tube #2](c)

**Fig. 21-6.**—The waveform of even-harmonic distortion developed in single-tube amplifiers.

![Output from Tube #1](d)

![Output from Tube #2](e)

![Undistorted Output from the Output Transformer](f)

**Fig. 21-7.**—Waveform showing cancellation of even-harmonic distortion in the output circuit of a push-pull amplifier.

a characteristic of single-tube operation. For sine-wave input, by way of illustration, even harmonics have a tendency to flatten one-half the cycle, as shown in Fig. 21-6A and B. In the second tube of the push-pull amplifier, since the signal is 180 deg out of phase, the distorted curve would look like Fig. 21-6C. These two distorted signals are combined in the output transformer, with a canceling out of the even harmonics, as shown in Fig. 21-7.

Because even-harmonic distortion is reduced or eliminated in a push-pull stage, the tubes may be overloaded somewhat without distortion. This accounts for the great power output from such a stage. For example, maximum undistorted output for a single 6A3 will be 3.2 watts, while a pair of push-pull 6A3 tubes will deliver a maximum undistorted output of 10 watts.
A push-pull amplifier will also reduce or eliminate any hum due to hum ripple fed to its plates. The reason is obvious. Hum ripple from the power supply will be fed to the center tap of the primary of the output transformer. Here it will move in opposite directions through the primary, but (in contrast with signal plate currents through it) will be rising or decreasing at the same time in the primary halves. As a result, the hum ripple cancels out.

An important point should also be considered. Since each tube requires the same signal-driving voltage, practically, as if it were operating alone, the total signal voltage delivered from the first AF stage must be twice as great as for a single tube.

Figure 21–8 now shows the complete transformer-coupled push-pull stage. Transformer T-1 is the push-pull input transformer, which couples the output from the first AF amplifier to the grids of the two tubes in the push-pull second AF stage. For high-fidelity reproduction, the push-pull stage is usually operated in class A or $AB_1$, where the grids are always negative and the tubes always or nearly always pass plate current. Resistor $R-7$ and condenser $C-7$ make up the common self-bias system for the push-pull tubes. Transformer T-2 is the push-pull output transformer. It combines the output from the two tubes and couples them to the speaker.
Resistor R-8 is a center-tapped filament resistor, which gives a stable grid return point.

Transformer-coupled push-pull amplifiers are very common in older receivers and are still used to a minor extent in some modern ones. However, most modern receivers replace the input push-pull transformer with a resistance-capacitive type of coupling in conjunction with a phase-inverter tube.

**Push-pull Amplifier with Phase Inverter.**—Transformers are costly, and it is desirable to substitute for them where possible. Thus, resistance-capacitance coupling between the first AF stage and the push-pull stage would be cheaper and more desirable. But it introduces a new problem. How can we get the 180 deg phase difference of signal voltage fed to the push-pull grids? The practical solution requires the use of another tube, known as a "phase-inverter" tube.

Figure 21–9 is a block diagram of a push-pull stage with a phase inverter. The principle of the phase inverter is that, for any tube, the grid voltage variations are 180 deg out of phase with the plate voltage variations. Hence, the positive signal voltage going to one of the second AF grids is also directed to the inverter grid. The out-of-phase negative plate voltage pulse of the inverter is then fed to the grid of the other second AF amplifier.

Another job that must be performed by the inverter is that of delivering the same voltage to the second second AF grid as that which the first second AF grid receives directly from the first AF stage. With transformer coupling, a center tap to ground neatly takes care of this requirement. When using a phase-inverter tube, some provision must be made to compensate for the normal amplification of the added tube.

Let us examine the development of such a circuit. Figure 21–10 shows one of the push-pull tubes coupled by normal resistance-capacitance coupling to the first AF amplifier. Note that a negative signal fed to the first AF grid produces a decrease in current through R-2. This results in a lowered voltage drop across the resistor and,
Fig. 21–10.—Obtaining a positive signal on one push-pull tube grid from a negative signal on the first AF amplifier grid.

Fig. 21–11.—Applying a portion of the positive output signal of the first AF amplifier tube to the phase-inverter grid.
as a result, a rise in positive voltage on the plate. This rise in positive voltage feeds a positive pulse through condenser C-2 to the control grid of the second AF (A) tube. The first AF tube has thus shifted the signal phase by 180 deg. The grid-leak resistor for the second AF (A) tube is shown as two separate resistors, R-4 and R-6.

To obtain an equal but opposite voltage on the control grid of the other second AF (B) tube, a portion of the positive output voltage pulse of the first AF tube is tapped off from the grid leak of the second AF (A) tube. Then this positive voltage is placed on the grid of a phase-inverter tube. Figure 21-11 shows the circuit described above. The self-bias circuit for the first AF tube, made up of R-1 and C-1, is common to the inverter tube.

The positive signal pulse on the inverter grid causes a rise of plate current through the plate load resistor R-3. The voltage drop across R-3 becomes greater and, as a result, the plate voltage of the inverter drops and produces a negative pulse. This latter pulse is fed by resistance-capacitive coupling to the second AF (B) control grid, as shown in Fig. 21-12. Condenser C-7 and resistor R-7 make up the common self-bias system for both push-pull tubes.

Note that the over-all effect is to place opposite voltages on the
control grids of the two output tubes, a condition that is desired. There still remains the problem of making these two voltages equal in magnitude. The output from the first AF tube is fed to the second AF (A) control grid. If this same output were fed to the inverter grid, the inverter gain would furnish a much larger voltage to the second AF (B) control grid. This is not desirable. Hence, if the gain of the inverter is 20, a tap on the grid leak (R-4 and R-6) is taken so that only \( \frac{1}{20} \) of the voltage across it is fed to the inverter grid. Then, the voltages fed to the grids of the two push-pull tubes will be equal. For example, if R-4 is 10,000 ohms and R-6 is 190,000 ohms, the total resistance in the grid circuit of the second AF (A) tube is 200,000 ohms. Then, since the voltage drop divides in direct proportion to the resistance,

\[
\frac{10,000}{200,000} = \frac{1}{20}
\]

and \( \frac{1}{20} \) of the voltage fed to the second AF (A) tube is fed to the inverter grid. Here the voltage gain of 20 gives the same input voltage for both push-pull grids.

There are many other methods for obtaining the necessary phase inversion. In each, the principle is the same, but the tubes and circuit constants vary widely. Figure 21-13 shows a 6SQ7 functioning as the first AF driver tube and another 6SQ7 functioning as the phase inverter. In this case, the driver follows a 6H6 diode detector and AVC stage. The two 6SQ7 tubes might have been combined in a single twin triode 6SC7.

A popular method often used is to employ a 6SQ7 diode detector, AVC, and first AF amplifier, as in the standard receiver, and then to use the triode section of another 6SQ7 as the phase inverter to feed the second push-pull grid.

Figure 21-14 shows a typical push-pull amplifier. Note that the IF amplifier, diode detector, and AVC circuit are combined in a single 6SF7 tube. The twin triode 6SC7 combines the functions of first AF amplifier and phase inverter. The signal from the detector is tapped from the volume control (R-13) and fed to the grid of the first AF section of the 6SC7 tube. The output from this driver is fed by resistive-capacitive coupling to the control grid of the lower 6V6-GT output tube. The grid leak for this latter tube is made up of resistors R-19 and R-20. The combined resistance of these two is 480,000 ohms. The tap between the two furnishes 10,000/480,000 or \( \frac{1}{48} \) of the voltage to the grid of the inverter section of the 6SC7 tube, the gain of which is 48 under these operating conditions. The output of the inverter is then resistive-capacitive coupled to the control grid of the upper 6V6-GT output tube. In this way, equal
Schematic Circuit

Fig. 21-14.—Schematic diagram of the Stromberg-Carlson No. 920 receiver.
but opposite signal voltages are obtained for the control grids of the two output tubes. Note condenser $C-31$ across the primary of the output transformer ($L-14$). Its function is to reduce the tendency of the push-pull stage to fall into oscillation.

NORMAL TEST DATA FOR THE PUSH-PULL AMPLIFIER

Signal Check for Normal Stage Operation.—The signal check for the stage is shown in Fig. 21–15. The signal generator is adjusted to give an AF signal, and the attenuator is set for maximum output.

![Signal Check Diagram](image)

**Fig. 21–15.—Signal check of a push-pull amplifier.**

The signal-generator ground lead is connected to the receiver chassis and the "hot" lead is connected through a 0.1-mfd/600-volt condenser in turn to the plate terminals of each second AF tube. If the signal generator has sufficient output, the audio note will be heard faintly each time in the speaker. The "hot" lead of the generator is then shifted to the control grid terminal of each tube. The signal-generator note should be heard in the speaker at a much greater volume, owing to the gain of each of the tubes.

For greater speed in checking, the quick check given at the beginning of this chapter may be reliably substituted.

To determine if the inverter is functioning, the "hot" lead of the
signal generator is shifted to the inverter grid, and the attenuator is adjusted for less output. The signal-generator note should be heard clear and loud in the speaker.

**Standard Circuit.**—We shall consider the circuit shown in Fig. 21–16 as the standard circuit for a push-pull amplifier. Normal voltage and resistance data will refer to this circuit.

Fig. 21–16.—Schematic diagram of a typical push-pull amplifier.

**Normal Voltage Data.**—The normal voltage data given in the accompanying table refer to Fig. 21–16.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pin</th>
<th>Voltage (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Either 6V6 control grid to ground</td>
<td>Pin 5</td>
<td>0</td>
</tr>
<tr>
<td>Either 6V6 plate to ground</td>
<td>Pin 3</td>
<td>240</td>
</tr>
<tr>
<td>Either 6V6 screen to ground</td>
<td>Pin 4</td>
<td>250</td>
</tr>
<tr>
<td>Either 6V6 cathode to ground</td>
<td>Pin 8</td>
<td>19</td>
</tr>
<tr>
<td>Inverter plate to ground</td>
<td></td>
<td>100–170 volts</td>
</tr>
<tr>
<td>Inverter grid to ground</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Inverter cathode to ground</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
Normal Resistance Data.—The normal resistance data in the following table refer to Fig. 21–16.

<table>
<thead>
<tr>
<th>Resistance Description</th>
<th>Resistance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second AF (A) plate to second AF (B) plate</td>
<td>300–500 ohms</td>
</tr>
<tr>
<td>6V6 cathodes to ground</td>
<td>200 ohms</td>
</tr>
<tr>
<td>Either 6V6 control grid to chassis</td>
<td>250,000 ohms</td>
</tr>
<tr>
<td>Inverter plate to B plus</td>
<td>250,000 ohms</td>
</tr>
<tr>
<td>Inverter grid to chassis</td>
<td>7,000 ohms</td>
</tr>
<tr>
<td>Inverter cathode to chassis</td>
<td>1,000 ohms</td>
</tr>
</tbody>
</table>

TROUBLES COMMON TO THE PUSH-PULL AMPLIFIER

The troubles common to a push-pull amplifier are similar in many ways to those of the single-tube second AF stage as described in Chap. 10. Only those troubles that apply to the push-pull amplifier will be discussed.

Troubles Common to the Output Transformer.—The output transformer primary may open. As a result, one plate is open and no plate current flows from that second AF tube. The voltage drop across the common self-bias resistor becomes less, and the bias for the other second AF tube becomes too small. As a result, the operative second AF tube distorts the signal badly. The distorted signal will also be weak because only one tube is functioning. A voltage check will show no plate voltage on one second AF tube. Finally, an ohmmeter check will confirm the condition.

An open output transformer secondary is not usual. When it does occur, the output signal will produce no sound from the speaker. For a defective transformer, an exact replacement is recommended. Where such a replacement is not possible, a universal push-pull output transformer may be used. Care must be taken to obtain proper impedance match between the second AF tubes and the voice coil of the speaker. The transformer should be about the same size as the original in order to assure proper wattage dissipation. And the feedback connection, if present, must be properly connected. The reader is referred to the replacement notes on output transformers in Chap. 10 for a more detailed explanation.

Troubles Common to the Tubes.—The second AF tubes may become weak or inoperative. The result would be very similar to that of an open output transformer primary. The operative second AF tube will be improperly biased. The sound from the loudspeaker would be weak and distorted. Replacement with a good second AF tube clears up the condition.

Troubles Common to the Coupling Condensers.—The coupling condensers C-2 and C-3 may become leaky. As a result, a positive voltage will be placed on the control grid of the second AF tube to
which it is coupled, causing bad distortion. Replacement with a condenser of similar capacity will remedy the defect. Make sure that the voltage rating is as great or greater than the original.

The Inverter.—The operation of the inverter is almost always foolproof. Only when its coupling condenser $C-3$ becomes leaky does trouble arise. This has been described in the preceding section.

Troubles in the inverter tube or its associated circuit will also affect the first AF tube and be found in a check of the first AF stage. When the inverter is a separate tube, it operates in a manner very similar to the first AF tube. A complete analysis of the first AF stage is given in Chap. 11.

![Circuit diagram of a typical transformer-coupled push-pull amplifier.]

**Fig. 21-17.—** Schematic diagram of a typical transformer-coupled push-pull amplifier.

### CIRCUIT VARIATIONS OF THE PUSH-PULL OUTPUT STAGE

**The Transformer-coupled Push-pull Stage.—** In some receivers, the first AF stage is transformer-coupled to the push-pull output stage. No phase inverter tube is required, since phase inversion and equal-magnitude voltages are obtained by means of the input transformer whose secondary is center-tapped to ground. Figure 21-17 shows a typical circuit of this type.

Transformer $T-1$ is the push-pull input transformer. It couples the output from the first AF tube to the grids of the two tubes in the push-pull second AF stage. The secondary of the transformer is
center-tapped, and the tap is connected to ground. This grounded
tap makes the voltage fed to the grid equal but opposite in polarity
with respect to ground.

Resistor $R-7$ and by-pass condenser $C-7$ make up the common
self-bias system for both push-pull tubes. For a pair of 6A3 tubes,
$R-7$ should be a 850-ohm, 5-watt resistor. Condenser $C-7$ is about
5 mfd/150 volts. In some cases, as described previously, this con-
denser may be omitted without harmful effects.

Resistor $R-8$ is a center-tapped filament resistor. Its purpose is
to furnish a stable plate- and grid-return point. It is a wire-wound
resistor of from 50 to 75 ohms. An alternative to this resistor is to
bring the grid and plate returns to a center tap of the heater second-
ary of the power transformer.

The output transformer $T-2$ is similar to that of the phase-inverter
type of push-pull stage. It differs only to the extent that the output
tubes are triodes rather than beam-power tubes.

The troubles common to the circuit described above are similar,
where applicable, to those for a resistance-coupled push-pull stage.
Signal check for stage operation is also similar. Replacement notes
for the output transformer are also applicable.

In addition, the input-transformer secondary may open. As a
result, one of the grids will receive no signal voltage and have an
open or zero bias. The tube will draw a heavy current and upset
the bias for the other second AF tube. Hum and distortion of
signal in the speaker will result. An ohmmeter check will confirm
the condition. An exact replacement of the transformer is recom-
mended.

The input-transformer primary may open. Both tubes will then
give normal results on the signal check, but no note in the speaker
when the 400-cycle signal is placed on the first AF plate. There
will be no plate voltage on the first AF tube. An ohmmeter will con-
firm the open. Again an exact replacement transformer is recom-
mended.

Where an exact replacement is not obtainable, reference to a
transformer catalogue will help to obtain a proper replacement
transformer. The transformers are listed by the tubes that they
couple.

Resistance data for the transformer-coupled push-pull circuit are
as follows:

Each grid to ground ........................................ 1,000–2,000 ohms
Each plate to $B$ plus ........................................ 150–250 ohms
Heater-resistor center tap to ground ....................... 850 ohms
Voltage data for the circuit are as follows:

Grid to heater-resistor center tap ........................................ 68 volts
Each plate to ground .................................................. 250 volts

**High-fidelity Loudspeakers.**—To obtain full advantage of the elimination of distortion in a receiver with push-pull output, many manufacturers use high-fidelity loudspeakers. This setup usually consists of two loudspeakers with different response characteristics. One responds especially to the high frequencies and is known as a "tweeter." The other responds especially well to the low frequencies and is known as a "woofer."

![Diagram](image)

**Fig. 21-18.**—A high-fidelity loudspeaker system.

A typical circuit using this speaker system is shown in Fig. 21-18. The lower frequencies of audio signal are fed to the woofer voice coil and are blocked by the reactance of condenser C-8 from getting into the tweeter voice coil. On the other hand, higher audio frequencies meet little opposition from the condenser and feed through the tweeter voice coil.

Condenser C-8 has an approximate capacity of 4 mfd. It is a paper condenser and, since it is in a low-voltage circuit, rarely causes trouble.

The speakers in a woofer-tweeter system give the same troubles as those found with dual speaker systems, where both speakers are similar. Service notes on speakers are found in Chap. 9 on loudspeakers.
SUMMARY

Test for normal operation of the push-pull output stage.

Place the tip of a plugged-in soldering iron on the control grids of each tube in the push-pull stage. A low growl should be heard from the speaker each time.

Diagram of a typical push-pull output stage.

A diagram of the standard circuit for a push-pull amplifier is given in the accompanying figure.

Normal voltage data.

The normal voltage data given in the accompanying table refer to the figure.

<table>
<thead>
<tr>
<th>Voltage Reference</th>
<th>Voltage Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Either 6V6 control grid to ground</td>
<td>Pin 5</td>
</tr>
<tr>
<td>Either 6V6 plate to ground</td>
<td>Pin 3</td>
</tr>
<tr>
<td>Either 6V6 screen to ground</td>
<td>Pin 4</td>
</tr>
<tr>
<td>Either 6V6 cathode to ground</td>
<td>Pin 8</td>
</tr>
<tr>
<td>Inverter plate to ground</td>
<td></td>
</tr>
<tr>
<td>Inverter grid to ground</td>
<td></td>
</tr>
<tr>
<td>Inverter cathode to ground</td>
<td></td>
</tr>
</tbody>
</table>
Normal resistance data.

Second AF (A) plate to second AF (B) plate ........................................ 300–500 ohms
6V6 cathodes to ground ................................................................. 200 ohms
Either 6V6 control grid to chassis ................................................. 250,000 ohms
Inverter plate to B plus ............................................................... 250,000 ohms
Inverter grid to chassis ............................................................... 7,000 ohms
Inverter cathode to chassis ......................................................... 1,000 ohms

### Service Data Chart for the Push-pull Amplifier

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Abnormal reading</th>
<th>Look for</th>
</tr>
</thead>
<tbody>
<tr>
<td>No signal from the speaker</td>
<td>Plate voltage of both tubes = 0. Screen voltage of both tubes = 0</td>
<td>Trouble in the power supply. See Chap. 8.</td>
</tr>
<tr>
<td></td>
<td>Plate voltage of both tubes high</td>
<td>Open self-bias resistor R-7</td>
</tr>
<tr>
<td>Poor tone quality</td>
<td>Plate voltage of one tube = 0. Plate voltage of other tube normal</td>
<td>Open primary of output transformer</td>
</tr>
<tr>
<td></td>
<td>Plate voltage of both tubes low. Screen voltage of both tubes normal</td>
<td>Shorted cathode by-pass condenser C-7. Shorted or leaky coupling condensers C-2 and C-3.</td>
</tr>
<tr>
<td></td>
<td>Voltages normal</td>
<td>Defective second AF tubes</td>
</tr>
<tr>
<td></td>
<td>Plate voltage of one tube is higher than the plate voltage of the other</td>
<td>Defective second AF tube. Open grid resistor in either tube</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open output filter condenser of power supply. Open grid load resistor of either second AF tube</td>
</tr>
<tr>
<td>Motorboating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For further defects refer to standard single-tube second AF stage in Chap. 10.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
QUESTIONS

1. A receiver is brought in for repairs, the complaint being "no reception." A voltage check shows that the plate voltages of both tubes in the push-pull amplifier are high. What is likely to be wrong? How would you check for it?

2. A receiver is brought in with the complaint, "The tone is not as good as it used to be, and the receiver seems weaker." In the push-pull amplifier, the voltage from plate to ground for one tube is normal, but is zero for the other tube. What is the defect? How would you confirm the condition?

3. A receiver is brought in for repairs with poor tone. The plate voltage of both push-pull tubes is low, although the screen voltages are normal. What are the likely troubles? How would you check for each?

4. The receiver of Fig. 21–14 requires a new output transformer and an exact replacement is not available. Use the universal output transformer chart of Fig. 10–11 for reference and choose (a) the type of transformer that should be used (wattage), (b) the secondary taps that should be used.

5. The receiver of Fig. 21–13 has poor tone quality. A voltage check shows a low plate voltage and a slight positive indication on the grid of one of the push-pull tubes. What is likely to be wrong? How would you check for it?

6. A receiver using a transformer-coupled push-pull stage is inoperative. A voltage check shows normal readings for the push-pull stage, but a plate voltage of zero for the first AF tube. What is likely to be wrong? How would you check for it?
CHAPTER 22

ALIGNMENT OF A SUPERHETERODYNE RECEIVER

What Is Receiver Alignment?—The average superheterodyne receiver has seven or more tuned circuits, each of which has to be in resonance at its proper frequency for best operation of the receiver. When they are not in resonance, the receiver responds with a loss of sensitivity and selectivity to an extent depending on the degree to which the tuned circuits are out of resonance. The procedure for bringing these circuits to resonance at their operating frequencies is called "alignment."

Best alignment procedure for any particular receiver is an individual process. In each case, it is best to follow the exact method of alignment recommended by the receiver manufacturer in his service notes. Nevertheless, all methods are sufficiently similar to permit the presentation of a generalized procedure for use where specific service notes are not available. The purpose of this chapter is primarily to present such a generalized procedure.

The alignment procedure presented will be that to be used for a standard superheterodyne receiver operating in the broadcast band. Where special receiver variations occur, such as multiband receivers or broad-band high-fidelity receivers, alignment notes have been given in the sections where such variations were described. They will not be repeated in this chapter.

In most receivers, alignment adjustment for tuned circuits is performed by varying small semivariable condensers in parallel or in series with the main tuning condensers of the tuned circuits. These condensers are known as "trimmers" when in parallel, and as "padders" when in series. They remove or add capacitance to the main tuning condenser, as the case may be. In some cases, as in wave traps or IF transformers, the trimmers are across the coils, and no other condenser is present.

In many modern receivers, the alignment adjustment is performed by varying the position of powdered-iron core plugs in the coils of the tuned circuits. This procedure varies the inductance and therefore the resonant frequency of the tuned circuit. These are known as "permeability-tuned coils." Regardless of whether the adjustment screw varies the capacitance or the inductance of the tuned circuit, the alignment procedure remains the same.
When Does a Receiver Require Realignment?—The serviceman is often confronted with the question of whether or not to realign the receiver. He must be guided by the symptoms of trouble, by his own purposes, and by a few general rules.

A receiver with a complaint of lack of sensitivity or selectivity, or oscillation, may be in need of realignment. However, other factors may cause the same complaint. These include weak tubes, open by-pass condensers, etc., which must first be investigated. Be sure that the receiver is perfect in all other respects before resorting to realignment, which need not be performed unless it is necessary.

Alignment can be used as a service tool to find the cause of trouble in a receiver. For example, when the signal check shows a broad, weak response at an off-frequency setting, the circuit involved may be out of alignment. Then, when the associated trimmer is adjusted and fails to give a peak response, the indication is trouble in that circuit, rather than in alignment. Further investigation will show an open by-pass condenser, an open coil, or something similar. If adjusting the trimmer causes an improvement in response, the indication is that the alignment is at fault, and the receiver should be completely realigned.

As a general rule, when a coil or condenser, which is part of one of the many tuning circuits within the receiver, is replaced, realignment should become a routine step. This rule is important because the replacement will rarely have the same value as the original unit.

Alignment of a superheterodyne receiver involves the adjustment of the tuning circuits of three main units within the receiver. These are the IF stages, the local oscillator, and the RF stages. The order presented is the order in which the units should be realigned.

Equipment Used for Receiver Alignment.—When a receiver is aligned properly, it gives maximum output for any signal introduced at any point within the receiver. The equipment required, therefore, for alignment is that necessary to introduce a signal into the receiver and that necessary to measure the output for maximum.

To introduce a signal, the signal generator is a prime requirement. It furnishes any frequency needed at high or low magnitude. As indicated in Chap. 7, where RF signals are delivered to the receiver, as at the antenna, RF amplifier, mixer, and oscillator stages, a 0.00025-mfd/600-volt condenser should be connected in series with the “hot” lead of the signal generator. Where IF signals are delivered to the receiver, a 0.1-mfd/600-volt condenser should be used.

When the receiver being aligned is of the loop-operated type and no antenna post is provided, the signal-generator output is fed into
the loop of the receiver, as shown in Fig. 22-1. A two-turn loop, with a 6-in. diameter, is constructed with hookup wire, and the ends are connected to the output terminals of the signal generator. This improvised loop is then placed in close proximity to the loop antenna of the receiver. The strength of the signal fed to the receiver can be adjusted by varying the distance between the two loops, or by adjusting the signal-generator attenuator.

The second requirement is a resonance or output indicator. The purpose of this device is to give not a numerical output value, but an indication of maximum output, regardless of its numerical value at that point. When a tuned circuit is at resonance, the output indicator will read maximum.

The resonance adjustment for most tuned circuits is screw-controlled. The head is usually slotted for screw-driver adjustment. Sometimes the head is hexagonal in shape, with or without a slot. Therefore, all that is required for adjustment is an aligning wrench or a screw driver. However, an ordinary screw driver should not be used. All resonant circuits in a receiver are quite sensitive. The capacity introduced by the metal shank of an ordinary screw driver throws off the true resonant point when the screw driver is removed. To overcome this difficulty, alignment screw drivers of polystyrene or bone fiber have been made which eliminate the capacity effect. Socket wrenches for adjusting hexagonal screw heads or nuts are also available in nonmetallic materials.

Another interesting alignment tool is the tuning wand. It consists of a fiber rod with a band of brass at one end and steel at the other. Insertion of the brass end into a coil reduces its inductance; insertion of the steel end increases its inductance. When a tuned
circuit is in resonance to a signal from the signal generator, insertion of either end of a tuning wand into the coil should throw the circuit out of resonance. As a result, the output indication decreases. If one end of the wand increases and the other end decreases the output indicator, then the tuned circuit is not in resonance and must be aligned.

![A tuning wand](image)

**Fig. 22-2.—A tuning wand.**

**Connecting an Output Indicator.**—If a receiver to be aligned is equipped with an electron-ray tuning-indicator tube, the tube gives a satisfactory indication of when a circuit is tuned to resonance, and no other output meter is needed. Maximum output is indicated when the “eye” closes to the greatest extent. In this case, the signal-generator output need not be modulated.

![Connecting an output indicator for alignment](image)

**Fig. 22-3.—Connecting an output indicator for alignment.**

Various other methods of obtaining an indication as to when resonance is reached may be used. Probably the most satisfactory method is to feed a modulated RF or modulated IF signal to the receiver, and to measure the output at the speaker with an AC voltmeter. The AC voltage range on the service multimeter may be connected as shown in Fig. 22-3.

The purpose of the condenser marked “0.1 mfd/600 volts” is to insulate the meter from the DC plate potential of the second AF
tube. The condenser offers low impedance to the audio signal voltage. The latter is the modulation note of the signal generator—in most cases about 400 cycles per second. The relative output-signal strength is then obtained from the reading of the meter.

**Strength of Signal Input.**—When the output indicator described above is used, it is extremely important to utilize as little output from the signal generator as is necessary to give a reading. The reason for this is the operation of the AVC circuit. When a large signal is introduced to the receiver and a tuned circuit is adjusted for resonance, as the circuit is detuned, the AVC voltage that is developed will drop. As a result, the controlled stages will have increased gain in an effort to keep the signal output of the receiver constant, and no drop in output at the output indicator will be seen. When a very small signal input is used, the AVC circuit will not become operative, and the controlled tubes will operate at maximum gain. As a result, with detuning, the output indicated on the indicator will drop, and the AVC circuit will not be functioning to raise the output to the constant level. The detuning will therefore be evident.

The standard output of 50 mw for receivers will require a signal input that is small enough to be below the level at which AVC action will interfere with alignment adjustments, and should therefore be used for this operation. Fifty milliwatts corresponds to an output-meter reading of 16 volts for the average receiver when the connections of Fig. 22–3 are used.

**Receiver Adjustments When Aligning.**—When a receiver is aligned, its controls should be set in such positions as to give maximum gain. Below is a list of the positions for maximum gain. Of course, when a receiver does not have one or more of the listed controls, the serviceman will not make those settings.

*Volume Control.*—Turned on full.

*Tone Control.*—Set to the minimum bass position.

*Fidelity Control.*—Set to low fidelity, or maximum selectivity position.

*Sensitivity Control.*—Set to maximum sensitivity.

The tuning dial should be set up to the frequency required and indicated in the alignment procedure.

**Location of IF Trimmers in a Receiver.**—Before attempting alignment, the serviceman would be wise to check service notes for diagrams showing the location of trimmers and padders. If such diagrams are not available, the following suggestions will be helpful.
The IF trimmers are usually located in the IF cans. Figure 22-4 shows a common arrangement. Look for the detector, IF, and converter tubes, and visualize the block diagram of the superheterodyne receiver. The second IF can is between the detector and the IF tubes. The first IF can is between the IF and the converter tubes.

![Diagram of a typical small receiver showing trimmer locations.](image)

*Fig. 22-4.—Layout diagram of a typical small receiver showing trimmer locations.*

Manufacturer's instructions always advise the adjustment of the trimmers of the secondaries of the IF transformers before those of the primaries of the IF transformers. The location of which is primary and which is secondary is not easily determined. However, it does not matter too much which we adjust first, since the alignment of them is repeated.

Sometimes, the IF cans look like those in Fig. 22-5. Here, only one adjustment screw is visible from the top of each can. This arrangement is common for permeability-tuned IF transformers.

![Diagram of a six-tube superheterodyne receiver.](image)

*Fig. 22-5.—Layout diagram of a six-tube superheterodyne receiver.*
The top adjustment screw will be for either the primary or secondary of the IF transformer. The adjustment screw for the other half of the transformer extends from the bottom end of the IF can and is adjusted from the underside of the chassis.

**Location of Oscillator Trimmers and Padders.**—The two controls for the oscillator-tuned circuit are the 600 or low-frequency paddler, and the 1,500 or high-frequency trimmer. If the tuning gang condenser is of the variety with cut plates for the oscillator section, as in Fig. 22-4, the oscillator trimmer may be easily located. Receivers using this type of condenser usually are not equipped with a 600 paddler.

When the condensers of the tuning gang all look alike, as in Fig. 22-5, the oscillator section can easily be found as follows: Tune in a station and touch the stator plates of each condenser section. When the antenna and RF sections are touched, reception will be little affected. But touching those of the oscillator section will detune the receiver. The trimmer mounted on this oscillator section is the high-frequency oscillator adjustment. The 600 paddler will be located close to this oscillator section.

Some receivers do not use a paddler condenser, but a permeability-tuned oscillator coil instead. The alignment procedure is the same in either case. The oscillator coil is usually close to the oscillator section of the gang tuning condenser. The permeability adjustment is usually located in the top of the coil, which is so mounted as to make the screw accessible from the top, side, or rear of the chassis.

**Location of RF, Antenna, and Wave-trap Adjustments.**—Trace the antenna wire to the antenna coil. The wave trap will be close to the antenna coil. The antenna coil will also lead to the antenna section of the condenser tuning gang. This locates the antenna trimmer. The RF trimmer is the only one to be located. It may be found by tracing the stator lead to the mixer coil.

When the receiver is of the multiband type, the IF trimmers are identified as before. The RF trimmers, however, are usually mounted on the coil assemblies rather than on the gang condenser. This makes the location of the trimmers somewhat more difficult, but it can be done.

Figure 22-6 shows the layout of a two-band superheterodyne receiver. All the coil cans, RF and IF, look alike. However, the second IF can is between the detector and the IF tubes. The first IF can is between the IF and the converter tubes. The oscillator coil can is in one line with the rear gang condenser section and the converter tube. The 600 paddler is between the gang condenser and the oscillator coil. The RF coil can lines up with the center section of
the 3-gang condenser, and the antenna coil lines up with the front section of the gang condenser and the RF tube. Somewhere between the antenna lead and the RF coil can, the wave trap will be found. In Fig. 22–6, the wave-trap adjustment is the trimmer near the antenna post. It can be confirmed by tracing the antenna wiring. The only thing left is to determine which trimmer on each coil is for the broadcast band and which is for short wave. This is not too difficult. Start the alignment procedure with the adjust-

![Fig. 22–6.—Layout diagram of a six-tube two-band receiver.](image)

ment of the IF amplifier in the usual way. When the first coil trimmer adjustment is reached, set the receiver for broadcast reception and give either trimmer a half turn. If it has no effect, return it to its original position. The other trimmer is the broadcast coil trimmer. To verify, give it a half turn and note the effect.

Adjusting a Trimmer to a Peak Response.—When making a trimmer adjustment, turn the trimmer screw back and forth slowly on each side of the peak output position. Note the peak position reading. The final adjustment is always one of tightening the screw, stopping at the peak response.

Sometimes, when the alignment tool is removed from the adjusting screw, the response falls below the peak obtained while the tool was in position. This effect occurs because the weight or capacity of the tool affects the trimmer capacity. When this happens, make the final tightening adjustment to the peak position, and tighten the screw an extra fraction of a turn. When this is done, the output meter reading will fall below the peak reading, but it should return to peak when the tool is removed.
In some receivers, peak response position occurs at the low-capacity setting of the trimmer condenser (when it is wide open), as shown in Fig. 22-8. A trimmer should not be left with this type of adjustment since, in this position, the spring tension of the top plate is at its weakest. Any jar or vibration, like that from the speaker, will cause the upper plate of the trimmer to vibrate, with accompanying noise and microphonics. When peak response position is at minimum capacity, remove the adjustment screw and bend the top plate back, as shown in Fig. 22-9. Microphonics will thereby be eliminated.

**Determination of the Intermediate Frequency of a Receiver.**—Before attempting to align the IF trimmers, the serviceman must know the intermediate frequency for the particular receiver to be aligned. This information is always found in the manufacturer's service alignment notes, or on the schematic diagram.

Where the usual information is not available, the serviceman can assume that the intermediate frequency is probably 455 kc, if the receiver is of modern vintage. The IF amplifiers of the past few years have been designed to peak at some value between 440 and 480 kc. If, because of lack of information, a receiver designed to peak its IF amplifier at 465 kc is aligned at 455 kc instead, no great harm will have been done. The receiver will operate normally and satisfactorily,
although the tracking of the tuning dial may be slightly off.

If the serviceman is entirely uncertain of the intermediate frequency, he can determine it approximately by connecting the "hot" lead of the signal generator to the mixer grid. Then, by rotating the signal-generator frequency control from 500 to 150 kc, he can see at what frequency a response is heard. Usually, a misaligned receiver is not too far from its correct setting and a broad response, with possibly two peaks, will be obtained. For example, if a receiver shows a broad response centering at approximately 270 kc, it may safely be assumed that the receiver was originally designed to operate at 260 kc, the nearest commonly used intermediate frequency. The most commonly used intermediate frequencies are 175, 260, 455, and 465 kc.

When the procedure just described is used, it is important to make sure that the oscillator of the receiver is made inoperative. If the receiver oscillator is operating, there will be many squeals and responses heard, depending on the position of the receiver tuning control. The oscillator is made inoperative by placing a short across the oscillator tuning condenser.

It is also important in the procedure to make sure that the receiver is not responding to a harmonic of the signal-generator output. This unwanted response can be avoided by starting the search for the intermediate frequency at the high-frequency end of the IF spectrum, that is, at 500 kc. Then, when a receiver shows a response at 460 kc, the serviceman should expect another weaker response at 230 kc, the second harmonic of which is 460 kc. Still another very weak response should occur at 153 kc, whose third harmonic is about 460 kc. Were the serviceman to make the check at random frequencies, he might stop at the 230-ke response, assume an intermediate frequency of 260 kc, and try to align the receiver at that frequency, with very poor results.

Aligning the IF Amplifier.—The receiver, signal generator, and output meter are hooked up as shown in Fig. 22-10. The output meter is adjusted for a high-voltage AC range, and connected through a 0.1-mfd/600-volt condenser to the plate pin of the second AF tube. The signal generator is adjusted for a modulated output at the intermediate frequency of the receiver. The signal-generator output is connected through a 0.1-mfd/600-volt condenser to the mixer grid of the receiver. The stator terminal of the oscillator condenser is shorted to the condenser frame. The receiver controls are set for maximum gain. Both the receiver and the signal generator are allowed a warm-up period of 15 min.

The signal-generator attenuator is adjusted to give an output as
low as possible, with the modulation note heard faintly in the speaker of the receiver. Either trimmer in the output IF can is then adjusted for the loudest note from the speaker. The attenuator is then reduced until the note can just be heard again. Then the other trimmer in the second or output IF can is adjusted for the loudest note from the speaker. The procedure is repeated for the two trimmers in the input or first IF shield can—first reducing the output to a faint note and then adjusting the trimmer for a maximum note.

The alignment is then repeated for the four trimmers in turn, starting with either trimmer in the second IF can. This time the output meter setting is reduced to the 50-volt AC range. The attenuator is reduced to give a reading of about 5 volts, and each trimmer is adjusted for peak voltage reading. If the output meter shows a reading over 30 volts while any one trimmer is aligned, the attenuator setting of the signal generator is reduced again, and the adjustment continued.

When all four trimmers have been readjusted to give peak response on the output meter, the IF alignment is complete.

Setting the Receiver Tuning-dial Scale Adjustment.—The next step in the alignment procedure is to adjust the receiver tuning-dial pointer. The most common adjustment is to rotate the gang condenser to maximum capacity (plates fully engaged) position. Then set the dial pointer to the last calibration mark on the low-frequency end of the dial scale, as shown in Fig. 22–11.

Aligning the Oscillator Circuits.—After the IF trimmers have been adjusted, there remain the oscillator and RF or antenna adjustments. Normally, the oscillator will have two adjustments: the high-frequency trimmer and the 600 paddler. However, when a receiver uses cut plates in the oscillator section of the tuning gang condenser, and no 600 paddler, the adjustment of the oscillator circuit is relatively simple. The remainder of this section will give
the alignment procedure for such an oscillator circuit, and it will be
followed by the RF and antenna circuit adjustments. The section
after that will present the alignment procedure for an oscillator
stage with a 600 padder.

The short (used in the IF alignment) is removed from the oscilla-
tor section of the gang tuning condenser. The signal-generator
output lead is shifted to the antenna post of the receiver, and a
0.00025-mfd/600-volt mica condenser is added as the dummy
antenna in series with the generator output lead. The output meter

![Diagram](image)

**Fig. 22-11.—Setting the dial pointer.**

is switched to a high-voltage AC range. The receiver is tuned to a
quiet point on the tuning range, between 1,500 and 1,700 kc. The
receiver controls are kept at the maximum gain positions.

Now, the signal-generator frequency control is adjusted to deliver
the same frequency as that shown on the receiver tuning dial, let
us say 1,500 kc. The oscillator trimmer is then loosened all the way
and tightened carefully until the signal is heard. This adjustment
is very critical. When it is reached, the signal-generator output is
reduced, and the output meter is switched to the 50-volt AC range.
Then the trimmer adjustment is repeated for peak voltage output.
If the reading goes down after removing the aligning tool, follow the
procedure suggested in the section on adjusting a trimmer (page 420).

**Adjusting the RF and Antenna Trimmers.**—There remain now
only the RF and antenna trimmer adjustments. The signal-genera-
tor dial is turned to 1,400 kc. Then the receiver is tuned for max-
imum or peak response at or near 1,400 kc. The generator attenua-
tor is reduced to give a low reading on the output meter, and the
mixer trimmer is adjusted for peak response on the meter. If an antenna trimmer is present, it is then adjusted for peak response. Alignment of the receiver is now complete, except for the adjustment of a wave trap, if present.

Adjusting the Oscillator and RF Circuits When a 600 Padder Is Present.—The alignment procedure is somewhat different when a 600 padder or permeability adjustment is present for alignment at 600 kc. The signal-generator output is fed to the antenna of the receiver through a 0.00025-mfd mica condenser, acting as a dummy antenna. The generator is adjusted for a modulated output at 600 kc. Then the receiver is tuned to 600 kc, and the 600 padder is adjusted for peak response.

Then, the receiver is tuned to a quiet point near the high-frequency end of the dial. The signal generator frequency control is adjusted for the same frequency as that shown on the receiver tuning dial. The high-frequency trimmer on the oscillator section of the gang condenser is then carefully adjusted for peak response. This last adjustment is critical. In making it, the trimmer screw should first be loosened and then slowly tightened until the note is heard. The attenuator is then reduced for a low reading on the output meter, and the adjustment repeated for peak voltage on the output meter.

The next step comprises the RF and antenna trimmer adjustments. The oscillator is set to 1,400 kc. The receiver tuning knob is tuned back and forth near 1,400 kc and left at the position of greatest response. The RF and antenna trimmers are now adjusted for peak response, as described previously.

Alignment of the oscillator circuit is not yet complete. The gang tuning condenser must be rocked at 600 kc on the tuning dial, and the 600 padder adjusted for peak response. This rocking procedure is described in the next section.

Rocking the Gang Tuning Condenser at 600 Kc.—In the rocking procedure, performed step by step, the receiver and signal generator are both tuned to 600 kc, and the 600 padder is readjusted for peak response. The attenuator is then set to give an output meter reading of 16 volts. The signal, of course, is being fed to the antenna.

The receiver is then tuned slightly higher than 600 kc, such as 605 kc. The signal generator, however, is left at 600 kc, and the 600 padder is readjusted for peak response. If the output meter reading increases above the previous reading of 16 volts, the maneuver is repeated until a maximum voltage is obtained. If the output meter reading does not increase, the receiver tuning condenser
is rocked in the other direction; that is, the receiver is tuned slightly lower than 600 kc, such as 595 kc, and the 600 padder is adjusted. The output is noted. If there is an increase, the condenser is rocked still lower, the padder is adjusted again, and the peak output is noted. The rocking and padding adjustments are made and repeated until maximum output is reached.

The adjustment of the high-frequency oscillator trimmer is then checked at 1,500 kc for peak response at the high-frequency end of the broadcast band.

**Adjusting the Wave Trap.**—The last step in receiver alignment is adjustment of the wave trap. The signal generator is connected to the antenna and ground of the receiver, the “hot” lead fed through a 0.1-mfd/600-volt condenser. The generator is then adjusted to give a strong response at the intermediate frequency of the receiver, say 455 kc. The receiver is tuned to 1,000 kc, approximately the center of the tuning range. Then the wave trap is adjusted to give minimum response in the output meter. The receiver is now completely aligned.
### SUMMARY OF ALIGNMENT PROCEDURE

1. Set receiver controls for maximum gain.
2. Connect ground lead from signal generator to receiver chassis (or B minus in the case of an AC/DC receiver).
3. Connect output meter to plate pin of second AF tube and chassis.
4. Allow signal generator and receiver to operate for 15 min as a warm-up period before aligning.

<table>
<thead>
<tr>
<th>Signal generator</th>
<th>Receiver</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency setting, kc.</strong></td>
<td><strong>Dummy antenna, mfd</strong></td>
<td><strong>Generator “hot” lead to receiver terminal</strong></td>
</tr>
<tr>
<td>455 or IF</td>
<td>0.1</td>
<td>Mixer grid</td>
</tr>
<tr>
<td>600</td>
<td>0.00025</td>
<td>Antenna</td>
</tr>
<tr>
<td>1,500</td>
<td>0.00025</td>
<td>Antenna</td>
</tr>
<tr>
<td>1,400</td>
<td>0.00025</td>
<td>Antenna</td>
</tr>
<tr>
<td>600</td>
<td>0.00025</td>
<td>Antenna</td>
</tr>
<tr>
<td>1,500</td>
<td>0.00025</td>
<td>Antenna</td>
</tr>
<tr>
<td>455</td>
<td>0.1</td>
<td>Antenna</td>
</tr>
</tbody>
</table>

**Notes:**

1. Short oscillator section of gang tuning condenser.
2. Align IF trimmers in the following order:
   a. Detector input trimmer (secondary of second IF transformer).
   b. IF plate trimmer (primary of second IF transformer).
   c. IF grid trimmer (secondary of first IF transformer).
   d. Converter plate trimmer (primary of first IF transformer).
   e. Repeat the adjustment of the trimmers in the same order.
3. Rock the tuning condenser during this adjustment as follows: Turn the rotor of the gang condenser back and forth and adjust the 600 padders until a peak is obtained.
4. This step is a check to see whether the previous adjustment of the 600 padders has affected the setting at the high-frequency end. If the high-frequency trimmer requires considerable readjustment, the 600 padders must also be readjusted by repeating the previous step.
5. Adjust for minimum output.
CHAPTER 23

SURVEY OF THE SERVICING PROCEDURE

The preceding chapters of this book have analyzed each stage of the receiver and discussed troubles that might arise from defective components within each stage. The emphasis has been primarily on defects that produce no reception or weak reception.

However, when a defective receiver is brought in for servicing, the defective stage is not usually self-evident. It is therefore necessary to present an over-all servicing procedure for tracking down troubles. In addition, other defects, like hum, distortion, motorboating, modulation hum, noise, and intermittent operation, which have been treated incidentally, require an over-all approach. It is the purpose of this chapter to present such an inclusive procedure for all the defects listed.

SERVICING PROCEDURE FOR NO RECEPTION

When the complaint is “no reception,” the trouble may be caused by breakdown of almost any component throughout the receiver signal chain. For the beginner or servicing apprentice, a routine check of tubes, followed by a routine voltage check, is a good approach. But it is too time-consuming for the more experienced serviceman, who will begin with a routine signal check. The following steps represent the more experienced approach:

1. Check the Power Supply.—The serviceman will ask himself various questions with respect to the inoperative receiver. Do all the tubes in the receiver light or warm up? Is there any sign of unusual overheating? Is the hum excessive? Does B plus measure its normal 200 to 300 volts? If the answers to these questions are those applicable to a normal receiver, he proceeds to the next stage. If not, there is trouble in the power supply and it must be found.

The causes for lack of receiver reception originating in the power supply are listed below:
Open line fuse.
Defective line switch.
Defective line cord.
Open power transformer primary.
Dead rectifier tube.
Open filter choke (speaker field).
Filter choke winding that shorts to chassis.
Shorted filter condensers.
Short in the B plus line.
Open voltage divider resistor.

2. **Check the Speaker.**—If the power supply checks perfect, the speaker comes up for inspection. To check its normal operation, momentarily unseat the second AF tube. If a loud click is heard in the speaker, the latter is not the cause of inoperation, and the serviceman goes on to the next check.

If the click is not heard, the speaker may be defective in some respect. Possible causes for inoperation originating in the speaker or associated circuits are
- Open speaker voice coil.
- Open speaker voice-coil leads.
- Open output transformer primary.
- Dead second AF tube.

3. **Check the Second AF Stage.**—If the speaker is perfect, the serviceman proceeds to check the second AF stage. A plugged-in soldering iron is applied to the signal grid pin of the second AF tube. If a low growl is heard in the speaker, the stage is all right, and the next stage is checked.

If the growl is not heard, the trouble is in the second AF stage, which is then subjected to a voltage and resistance check to localize the cause of the trouble. Causes of lack of receiver reception originating in the second AF stage are as follows:
- Dead second AF tube.
- Open output transformer primary.
- Shorted plate by-pass condenser.
- Open cathode self-bias resister.

4. **Check the First AF Stage.**—With all previous checks showing normal conditions, the serviceman proceeds to check the first AF stage. When a plugged-in soldering iron is touched to the ungrounded end of the volume control, a very strong growl should normally be heard in the speaker. If it is heard, the serviceman may go on to check the next stage in the signal chain.

If the growl is not heard, the cause of no reception is in the first AF stage and its associated parts. Such possible causes are
- Dead first AF tube.
- Open coupling condenser in the grid or plate circuit.
- Open volume control.
Volume-control lug shorting to chassis.
Short in grid wiring (shielding).
Open plate load resistor.
5. Check the Detector Stage.—The detector stage is the next check when all previous check results are normal. A modulated signal at the intermediate frequency of the receiver is fed to the grid of the IF tube. If the signal-generator modulation note is heard in the speaker as the generator frequency control is wobbled around the intermediate frequency, the detector is all right. The serviceman then goes on to check the IF amplifier stage.

If the modulation note is not heard, the trouble is in the detector stage or the IF tube. Possible causes of receiver inoperation here are:
- Dead IF amplifier tube.
- Shorted grid circuit in the IF tube.
- Open or shorted plate, screen, or cathode in the IF tube circuit.
- Defective output IF transformer:
  a. Open windings.
  b. Shorted trimmers.
  c. Leads shorting to the shield can.
- Defective detector tube.
- Open volume control.
- Misalignment of the IF transformer.

6. Check the IF Stage.—When the modulated signal-generator output is fed to the control grid of the IF tube and its note is heard, indicating normal detector operation, the "hot" lead is shifted to the mixer grid of the converter. If the note is now heard at greatly increased volume, the mixer and IF amplifier are functioning. The serviceman then proceeds to check the oscillator of the converter.

If the signal-generator note is not heard when the "hot" lead is applied to the mixer grid, the following factors may be defective:
- Dead mixer (converter) tube.
- Shorted mixer grid circuit (tuning condenser).
- Shorted or open plate, screen, or cathode circuits in the mixer circuit.

Defective input IF transformer:
  a. Open windings.
  b. Shorted trimmers.
  c. Leads shorting to the shield can.
- Misalignment.

7. Check the Oscillator Circuit of the Converter.—After the signal-generator output is fed at the intermediate frequency of the receiver to the mixer grid and its note is heard, the receiver dial is adjusted to 600 kc. The signal-generator frequency control is then
wobbled back and forth around 600 kc. If the note is now heard at about the same volume as the former modulated IF signal, the oscillator circuit is functioning, and the serviceman proceeds to the next check.

If the modulation note from the generator which is set to 600 kc is not heard, the oscillator circuit is inoperative. Possible causes are

- Defective oscillator (converter) tube.
- Open oscillator coil (either winding).
- Open or shorted oscillator anode by-pass condenser.
- Open oscillator anode dropping resistor.
- Short or resistance in the oscillator section of the gang tuning condenser.
- Defective oscillator paddle condenser.
- Defective oscillator grid condenser.
- Defective oscillator grid resistor.

8. Check the Mixer Circuit of the Converter.—If the oscillator is functioning normally, the “hot” lead of the signal generator is shifted to the control grid of the RF tube, or to the antenna if there is no RF stage. The receiver is tuned to 1,400 kc, and the signal generator is wobbled back and forth around 1,400 kc. If the modulation note is heard at increased volume, the mixer circuit is functioning.

If the note is not heard, the trouble lies in a component between the RF grid (or antenna) and the mixer grid, and these might be

- Dead RF tube.
- Shorted RF control grid circuit (tuning condenser).
- Open or shorted plate, screen, or cathode circuits in the RF stage.

9. Check the RF Input Circuit.—If the signal-generator modulation note is heard when the hot lead is connected to RF grid but there is no reception from the antenna, the trouble must be in the antenna coil or leads. Possible causes in this regard are

- Antenna lead shorting to chassis.
- Open connection between antenna and antenna coil.
- Open or burned antenna coil primary.

A 2-point Check of a Superheterodyne Receiver.—As the serviceman gains in experience, he develops shorter methods of procedure which reduce the time consumed. Such a short cut is the 2-point servicing procedure for checking an inoperative superheterodyne receiver.

If visual inspection does not disclose the source of the trouble, the tip of a plugged-in soldering iron is applied to the ungrounded end of the volume control. This is the beginning of the AF signal
chain. Normally, a strong growl from the speaker should be heard. If it is not heard, the trouble is in the audio amplifier (first AF, second AF, and speaker) or the power supply, and they are checked stage by stage for the specific defect. If the strong growl is heard, this one check clears the first AF stage, the second AF stage, the speaker, and the power supply of blame for the receiver inoperation.

The serviceman then moves on to the second check point. This is the mixer grid of the converter. A modulated test signal at the intermediate frequency of the receiver is fed to this mixer grid. The normal response is the modulation note of the signal generator in the speaker. If this note is not heard, the trouble is in the IF amplifier or the detector stage. The signal-generator output is increased and the frequency control is wobbled around the intermediate frequency to see if the receiver is misaligned. If the response is still not heard, the test signal is fed to the IF grid to localize the defect further.

If the normal response is heard when the modulated IF test signal is fed to the mixer grid, the IF amplifier and detector stages may be presumed to be functioning. The signal-generator frequency control and receiver dials are set to 600 kc in order to check the oscillator circuit of the converter.

The normal response in this latter check is the signal-generator modulation note from the speaker. If it is not heard, the oscillator circuit is not functioning. A voltage check of the converter stage is then made.

If the normal response is heard, the defect must be before the converter. A check of the RF amplifier stage and the antenna circuits is now in order.

By this short 2-point check, the signal channel may be quickly analyzed into three blocks, which are checked over all before resorting, if necessary, to stage-by-stage checking.

**SERVICING PROCEDURE FOR WEAK SIGNALS**

The defects that cause weak reception are different from those which result in no reception. However, the servicing procedure that localizes the stage in which the defect lies is the same signal check just outlined for the complaint of no reception. The main difference in the two checks is the receiver response to the generator signal.

For a dead receiver, all signal checks result in a normal speaker response until the defective stage is reached. At that point, the receiver will give no response. For a weak receiver, all signal checks give a normal response until the defective stage is reached. At that
point, the receiver will give a weak response, as shown by a loss or no
gain over the last normal check before this check.
Many factors within the receiver may result in weak response.
These are tabulated below:
1. Weak tube in any stage.
2. Short in the power transformer winding.
3. Short in the filament wiring.
4. Jammed voice coil in the speaker.
5. Weak excitation circuit for the speaker field.
7. Open cathode by-pass condenser in the second AF, IF, con-
verter, and RF stages.
8. Open AVC by-pass condenser.
10. Open plate by-pass condenser in the IF, converter, and RF
stages.
11. Open antenna coil.
12. Resistance in the gang tuning condenser.
13. Poor wiper contact in the gang tuning condenser.

SERVICING PROCEDURE FOR HUM

A common receiver defect is a hum level that is so high that it
mars normal receiver reception. This section will describe the type
of hum that appears all over the receiver dial.

Checking the Power Supply.—When a receiver is being serviced
for the complaint of an abnormally high hum level, the most com-
mon defect that causes this condition is the breakdown of the power-
supply filter condensers. This is usually due to the aging of these
condensers.

The first step, therefore, in trouble shooting for hum is to connect
a substitute condenser across each of the power-supply filter con-
densers in turn. If the hum level is reduced as a result, the defective
filter condenser is replaced. The filter choke of the power supply
must also be checked for a short that results in inadequate filtering.

Tubes as a Source of Hum.—If the filter condensers check perfect,
a good second step is to replace the tubes with new ones, one at a
time. Tubes often introduce hum, especially the AF tubes. Such
hum results from heater-cathode leakage through their insulation,
capacitive coupling between the heater and other electrodes, and
emission from the heater to other electrodes or vice versa. Although
elimination of hum from these sources is primarily a design problem,
replacement of tubes with new ones may reduce the hum level.
Grid Circuits as a Source of Hum.—Another possibility for hum is an open grid circuit in any stage of the receiver. This type of hum results from a build-up and discharge of signal at the open grid at a rate that may be close to the power-supply hum, and is mistaken for it.

The next check in hum elimination, therefore, is a continuity check made with an ohmmeter of all grid circuits.

Previous Service Work as a Source of Hum.—If the cause of hum still proves elusive, the next check is to see if previous service work may not have introduced the trouble. For instance, replacement of part of a speaker may have resulted in the reversal of polarity of the hum-bucking coil. Or the wiring may have been disturbed with resulting poor lead dress, particularly in the region of the detector and first AF tube. The diode-plate leads, volume-control leads, and first AF grid leads must all be short. They should be dressed close to the chassis and away from the filament or other wiring that carries 60-cycle current.

Tracking Down Elusive Hum.—The suggestions made above should locate most of the common causes of hum. Occasionally, an elusive cause will escape the normal procedure that has been suggested. In such a case, the receiver must be examined stage by stage.

To do this, remove all the receiver tubes, except the rectifier. Since it is dangerous to operate a power supply without any load, a heavy-duty 5,000- to 10,000-ohm/25- to 50-watt resistor should be connected as a load from $B$ plus to ground. Then turn the receiver on and listen for hum. If hum is present, it is due to some factor that was overlooked in the power supply, and it must be carefully sought for.

If the hum level is normal, insert the second AF tube and remove the power-supply resistor load. If the hum now is heard, it is due to some defect in the second AF stage. If the hum level is normal, insert the first AF tube and listen for hum. In this way, the tubes are reinserted, one stage at a time, until the offending stage is reached. Then the components of only one stage need be carefully checked to find the defect.

In the case of an AC/DC receiver, where tube heaters are in series, tubes may not be removed, as above. The stages must be made inoperative in another manner. A short from the second AF grid to ground makes everything before this point inoperative, so far as their effect on the speaker is concerned. Any hum present limits the defect to the power supply or second AF plate circuit. If the hum level is normal, the short is shifted to the first AF grid
and ground. This adds the first AF plate circuit and the second AF grid circuit to the part of the receiver being checked. Thus, in shifting the short to ground from grid to grid of the various tubes, more and more parts of the receiver that will affect the speaker are brought in for check until the point of hum is located.

Once the tube-removal procedure or grid-grounding procedure has localized the stage in which hum originates, nothing in this stage should be overlooked in the careful recheck. On some remote occasions, a new tube that replaces a bad one may have a similar defect that still results in hum. If all else in the hum-producing stage has been found to be good it may be necessary to replace the old tube with several new ones before the hum disappears.

Another possibility in the careful recheck of a stage is the possibility of leakage between sections of a by-pass condenser block. For example, a line filter condenser or a condenser connected to a heater lead will carry alternating current. If they are part of a block, leakage to other condensers in the same block may introduce hum.

Normally, condensers are checked for opens, shorts, leakage, and intermittent opens. None of these checks requires the removal of the condenser from the circuit. However, in making a careful recheck of a stage, the condenser lead must be opened, and a substitute condenser connected in its place. This procedure will take care of leakage between sections of a block.

**Summary of the Causes of Hum in Receivers.**—The causes of hum in a receiver may now be summarized for quicker use.

1. Open power-supply filter condensers.
2. Defective tubes (cathode-heater leakage).
3. Open grid circuit.
4. Reversed speaker hum-bucking coil.
5. Closeness of audio grid leads to wiring carrying 60-cycle current.
6. Leakage between sections of a by-pass or filter condenser block.
7. Shorted filter choke.

**SERVICING PROCEDURE FOR NOISY OPERATION**

When a receiver is brought in with the complaint that it is noisy, the condition is one of hissing and crackling sounds that are extraneous to the desired station signal. Noise may result from any one of a great number of causes, including noise pickup by the antenna, a noisy power line, and noise produced by defective units within the receiver itself. The first two are installation problems. A procedure for handling them is given in Chap. 17.

**Determination of the Receiver as the Source of Noise.**—The
serviceman must be able to determine by check if the noise results from some defect within the receiver. This check is best handled on the service bench, where noise from antenna and power line pickup is either absent or, at least, is a factor whose normal level is known.

To determine if the receiver itself is the source of noise, the antenna and ground connections to the receiver should be removed, and the antenna and ground terminals of the receiver connected together by means of a short link. Then, if the receiver is turned on and noises are heard in the speaker, especially when the receiver is jarred, the noise is due to a defective component within the receiver.

**Causes of Noise within a Receiver.**—The components in a receiver that usually cause noisy operation are as follows:

1. Noisy tubes (loose elements).
2. Corrosion in coil windings:
   a. RF transformers.
   b. IF transformers.
   c. Audio transformers.
   d. Speaker fields.
3. Speaker defects:
   a. Rubbing voice coil.
   b. Torn paper cone.
   c. Loose rim.
4. Poor connections.
5. Noisy volume control.
7. Conductive dirt in vital spots (like sockets).
8. Tuning condensers (shorts and poor wiper contacts).

**Locating the Source of Noise in a Receiver.**—Several of the causes of noise within the receiver have already been presented in previous chapters. Chapter 9 gives the checks for the speaker defects that cause noise, and these checks may be used in noise analysis. Probably, replacement with the bench test speaker will disclose this source. In Chap. 14, the noisy tuning condenser is described. In Chap. 11, defective volume controls are described. Both of them are common sources of noise and are easily identified as the sources, since the noise comes on when the controls are adjusted. A procedure for cleaning tuning condensers is given in Chap. 14. A noisy volume control should be replaced as described in Chap. 11.

A good procedure to follow when hunting for the source of noise is similar to that used in checking for hum. Remove all the tubes, except the second AF tube and rectifier tube. In the case of the AC/DC receiver, connect a short between the second AF grid and ground. Tap the tube and other components in the second AF stage and listen
for noise. If the noise is heard, all connections and components in the second AF stage and power-supply stage are checked until a poor joint or defective component is found. If the noise is not heard, the second AF and power-supply stages are probably in good condition. The first AF tube is then added, or the ground connection is moved to the first AF grid. Then components in this stage are checked as before. If they prove satisfactory, the procedure is repeated for each stage in the receiver until the troublesome stage is found. The search within the defective stage must be thorough and not overlook any odd and unusual condition of a component.

As each tube is replaced or made operative, it should be slightly jarred by tapping the radio sharply. When this is done, a noisy tube will become more noisy. Then replacement with a new tube followed by the jarring test will tell if the tube was at fault. In some cases, simply replacing one tube at a time with new ones and tapping the receiver sharply will locate a noisy tube.

The stage-by-stage analysis may show a noisy stage. If the defect is due to corrosion in coil windings, jarring the radio will not affect the noise. In this case, the defective winding can be found by an ohmmeter check. Good windings in RF and IF transformers normally measure less than 100 ohms; a corroded winding usually measures several hundred ohms. The resistance measurement of AF transformers and chokes also increases when they are corroded.

Often, unsoldered or poorly soldered connections, or bits of solder or other conducting dirt, may be the cause of noise in a stage. They may be difficult to locate because they may be in an out-of-the-way place. Such defects may cause intermittent noise or intermittent operation. Jarring the receiver usually increases the noise when those defects are the cause. An extremely careful search must be made for them.

If the procedure localizes the IF amplifier as the source of noise, remove the IF transformers from their shield cans for a careful inspection. Even though an ohmmeter check shows freedom from corrosion, the leads from the coils to the trimmers, which lie along the shield can, may vibrate into contact with the can, producing noise. Inspect the leads and route them so that they cannot possibly touch the shield can.

SERVICING PROCEDURE FOR INTERMITTENT OPERATION

Intermittent reception can be divided into two main groups. In one, the radio suddenly clicks off and remains inoperative for a while; then, just as mysteriously, it resumes normal operation. In
the other type, the volume suddenly decreases and then returns to normal a little later. Sometimes, these changes are gradual rather than sudden. This condition is often called "fading."

**Causes of Intermittent Operation.**—Intermittent operation (often accompanied by noise) may be due to intermittent breaks or other defects in the antenna-ground system, which should be carefully checked for breaks, as described in Chap. 17.

In the receiver, many components may be the cause. To tackle the complaint, the serviceman might replace all components likely to cause the trouble, hoping by elimination to remove the cause. Or, he might track down and repair the causative factor. The first procedure is expensive; the second is time-consuming.

The wholesale replacement of suspected receiver components includes

1. All tubes.
2. All by-pass and coupling condensers.
3. Any resistors that dissipate heat and may change in ohmic value as a result, like voltage-divider resistors.
4. The volume control.

In addition, the condenser gang should be cleaned and overhauled. Finally, a thorough search should be made for poorly soldered connections.

**Tracking Down Intermittent Reception.**—In tracking down the cause of intermittent reception, the receiver is allowed to play on the service bench until the fading out occurs. This condition may be hastened by jarring the receiver; or, the receiver may be made to operate inside a packing box to cut off ventilation and produce overheating; or, it might be operated through an autotransformer connected to the power lines, so that it operates under the condition of an abnormally high line voltage.

Then when the receiver fades out, any accompanying symptom, like noise or squeal, will be of aid in locating the trouble. If the receiver stays out, it is serviced as though it were a dead or weak one. If reception is resumed before any conclusive evidence has been reached, the serviceman waits for the next fade-out, or attempts once again to induce it.

**SERVICING PROCEDURE FOR MODULATION HUM**

"Modulation" hum is the name applied to a hum that is heard together with the station voice or music only when a station is tuned in. The hum level is normal at an off-station position on the tuning range. This type of defect in receivers is also called "tunable" hum.
Causes of Modulation Hum.—The most common cause for this condition is an open line filter condenser, or inefficient grounding of the receiver. When a receiver is checked at the service bench for a complaint of tunable hum, the first step is to operate the receiver on a station where the hum is very noticeable. No ground lead should be connected to the receiver, since the home installation may not use one. Then connect a condenser of similar capacity across the line filter condenser and listen for a reduction in the hum. If this step is not effective, try connecting the condenser from the other side of the line to the chassis, as shown in Fig. 23–1.

![Diagram of additional line filter condenser connected to reduce modulation hum.]

Fig. 23-1.—Procedure for reducing modulation hum.

If the modulation hum still persists, the next likely cause is leakage or capacity effects from the heater to other elements in the RF or converter tubes. The next step, therefore, is the substitution of tubes, known to be good, for the RF and converter tubes.

SERVICING PROCEDURE FOR SIGNAL DISTORTION

Distortion in a receiver results in poor tone quality from the loudspeaker. It is usually due to the overloading of some stage in the receiver by a signal that is too large for the stage to handle.

Causes of Receiver Distortion.—It is unusual for the signal to be too large. The common difficulty is that the stage operation has deteriorated to a point where it cannot handle a signal of normal strength.

The usual difficulty is trouble in the grid-bias circuits, which is found by voltage analysis. The speaker, of course, is another possible cause of poor tone. This condition is checked by substituting the bench test speaker for the receiver speaker.
A more complete list of possible causes of receiver distortion is given below.

1. Rubbing speaker voice coil due to
   a. Off-center voice coil.
   b. Warped speaker cone.
   c. Off-center speaker field gap.
2. Shorted cathode by-pass condenser in the second AF stage.
3. Changed value of second AF bias resistor.
4. Open grid leak in the first or second AF stage.
5. Open volume control.
6. Defective tubes.
7. Shorted or leaking audio coupling condensers.
8. Shorted or leaking AVC by-pass condensers.

Less frequent causes of poor tone quality are those resulting from previous replacement of defective parts. These include a mismatch resulting from the replacement of a speaker or output transformer; a replacement plate circuit by-pass condenser in the second AF stage that is too high or low in capacity, resulting in too high or low a response; rarely, side-band cutting resulting from the use of an IF replacement transformer with extreme selective characteristics. In the latter case, the side-band cutting may be reduced by slightly mistuning each IF trimmer, broadening its response characteristic.

**SERVICING PROCEDURE FOR MOTORBOATING**

Motorboating is a defect in a receiver that results in a put-put noise similar to the exhaust of a motorboat. The most common cause for motorboating is an open output filter condenser in the power supply. The only other common cause is an open grid circuit in any of the stages of the receiver.

**Removing Motorboating in a Receiver.**—A servicing procedure for this defect in a receiver is to bridge the output filter condenser in the power supply with a test condenser of similar capacity and to see if the trouble is eliminated. If this proves ineffective, the serviceman proceeds to make an ohmmeter check of all grid circuits, looking for an open. In this regard, it should be remembered that AVC decoupling filter resistors are part of their grid circuits. They must not be overlooked, even though they rarely open. The most common opens occur in the grid-load resistors of the first and second AF stages.

**SERVICING PROCEDURE FOR SQUEALS AND OSCILLATIONS**

There are many types of squeals and howls in a receiver, all of which are classified under the general term of “oscillation.” Their
causes are many and varied and call for different servicing procedures.

Chirps or Birdies.—First, there is the type of squeal or birdie that appears to spoil reception from only one or two stations. This is probably image-frequency interference. A procedure for handling these is given in Chap. 16.

Microphonic Noise.—There is another type of howl known as “microphonic” noise. It usually starts on a loud signal, or when the radio is jarred, and builds up to a strong howl that drowns out all reception. It can be caused by loose elements in a tube or by vibrating tuning condenser plates. The howl is started by either the jarring of the receiver or the vibration resulting from a loud signal from the speaker. The loose elements begin to vibrate rapidly and introduce sustained high-pitched AF notes into the tube.

When a receiver with microphonic howl is serviced, the receiver is operated at low volume. Each tube in turn is greatly tapped. When the offender is reached, a “bong” is started which soon dies out, since the speaker volume is too low to sustain the vibration. Any tube in the receiver may be the cause of the microphonic howl. However, the detector first AF tube is the most common offender.

If a check of the tubes discloses no defect, the tuning condenser should be investigated. Microphonics due to the tuning condenser are usually found in small receivers, where the speaker and tuning gang assembly are in close proximity, or in large receivers designed for and operated at high-volume levels. In both cases, original design takes care of the condition by mounting the tuning condensers or the chassis, or both, on a rubber suspension. Sometimes, even the speaker is mounted on rubber to dampen vibrations. It is only necessary thereafter to check the mounting provisions to see that the rubber has not become old and cracked, or that the suspended mounts are still floating freely.

Squeals over the Major Part of the Receiver Tuning Dial.—Another type of squeal is the one that occurs over the entire tuning range of the receiver or a large part of it. If this squeal is affected somewhat by tuning, the defective component is usually in the RF or IF portions of the receiver. If the squeal is unaffected by tuning but is affected by the operation of the tone control, the defective component is probably in the audio end of the receiver. However, these considerations are not of too great consequence, since the servicing procedure is the same for both conditions.

Squeals of either type are usually caused by regenerative coupling. The latter is usually caused by poor contact between a shield and the
chassis or by the opening of a by-pass condenser. The service procedure is suggested by the cause. Shields are checked for their contact to the chassis. Ohmmeter checking is inadequate, since even a small resistance contact (too small to be read on the ohmmeter) may still cause inadequate shielding. The best procedure is to clean and tighten all shield-ground contacts. Where a tube shield has been inadvertently discarded, it should be replaced by the serviceman. This shielding is especially important in the case of a high-gain tube like the IF amplifier.

Open by-pass condensers are checked by bridging a test condenser across each by-pass condenser in the receiver. It is important when making these checks to short the terminals of the test condenser after each condenser is checked.

A test condenser of about 0.1 mfd can be used for all RF by-pass condensers, even though the condenser being tested differs considerably from that capacity. The substitution box described in Chap. 23 is very convenient for rapid testing of this type. The audio bypass and the power-supply filter condensers should not be neglected in this test.

Sometimes, the broad squeal is due to an error that crept in during previous service work. Disarranged or poorly dressed leads may come about in the replacement of an IF or RF transformer. Or, an inverse feedback winding from the secondary of an output transformer may have been reversed during the replacement of the transformer. In the former case, the leads may couple with other parts of the receiver and deliver regenerative feedback. In the latter case, a reversed inverse feedback winding may deliver regenerative feedback, rather than degenerative feedback. As a result, an audio oscillation is set up.

Poorly dressed wiring may be checked by moving the suspected wires with a bakelite rod, while the receiver is oscillating. A change in the squeal indicates that the wire is at fault. Generally, the grid and plate leads are the “hot” leads and should be routed close to the chassis and direct to their connection points without crossing each other or coming close to other wiring.

The reversed inverse feedback winding may be checked for by reversing the primary or secondary wires of the output transformer and by observing if there is any improvement.

A summary listing of factors that might cause broad squeals and oscillations follows:

1. Open power-supply output filter condenser.
2. Open second AF plate by-pass condenser.
3. Reversed feedback winding (after output transformer has been replaced).
4. Open shielding.
5. Incorrect lead dress.
6. Open AVC by-pass condenser.
7. Open screen by-pass condenser in the RF, IF, or converter stage.
8. Open plate decoupling by-pass condenser in the RF, IF, or converter stage.

AIR CHECK OF A RECEIVER

The final step in servicing a receiver is first to check that the original complaint has been removed, and then to check the receiver in all respects for normal operation. This final check is known as the "air check."

To make the air check, the receiver is connected to an antenna and turned on. The tuning dial is rotated to a nonstation position, and the hum level is noted for normal operation.

At the same dial position, the volume control is rotated from minimum to maximum, in order to determine if it is noisy. The same is then done for the tone control, if present.

Then the dial is rotated to the low-frequency (550-kc) end, the volume control is set for a moderate volume level, and the dial is rotated toward the high-frequency (1,500-kc) end. The stations are checked off as they appear. This procedure checks the dial calibration and the sensitivity of the receiver. All stations that the serviceman knows are normally picked up in his locality should be picked up by the receiver being checked. Failure to receive any of them indicates a weak receiver. Good judgment should be used by the serviceman in this test. Obviously, a sensitive superheterodyne receiver with an RF stage and two IF stages should pick up more stations than a receiver with no RF stage and only one IF stage.

As the stations are picked up, the selectivity of the receiver may be determined by the dial space that each station covers, especially the strong local stations. If a strong local station stretches over 30 kc of the dial, the receiver selectivity is poor and should be checked. Misalignment is indicated.

Tone quality is most easily checked by listening to speech rather than to music. Clear, crisp, intelligible speech is a sign of good tone quality, especially for the high audio frequencies. Then turn to some symphonic music program, and listen for the response to the low frequencies.

The next check is for the power handling of the receiver—from
whispers to the limit that the speaker will take without rattling. This will not be much for a small speaker. But a large speaker in a high-fidelity receiver ought to be capable of roaring with good tone quality.

The course over the tuning dial will disclose whistles, birdies, and squeals. The serviceman must be on the alert for these effects. A sharp slap on the receiver will show up any noisy conditions.

The final step is the check of the operation of any other controls on the receiver, like fidelity controls, phonograph switches, push buttons, and short-wave operation.

CASE HISTORIES OF DEFECTIVE RECEIVERS

At this point, it is advisable to examine the work of a practical serviceman making repairs on the bench. The following tabulations are the actual case-history records made by a serviceman with wide experience.

Case 1. Complaint: Receiver is dead.

1. Applied AF signal to first AF grid................................................. Normal.
3. Applied IF signal to mixer grid................................................. No response.
4. Replaced mixer tube................................................................. Receiver operates normal.
5. Air check...................................................................................... O.K.

Case 2. Complaint: No reception.

1. Signal to first AF grid................................................................. Normal.
2. IF signal to second IF grid........................................................... No response.
3. Replaced second IF tube.............................................................. Receiver operates normal.
4. Checked:
   Sensitivity.................................................................................... O.K.
   Selectivity...................................................................................... O.K.
   Quality............................................................................................. O.K.
   Dial mechanism................................................................................ Worn.
5. Replaced dial belt.

Case 3. Complaint: Noisy and fading.

1. Jarred receiver while playing...................................................... Very noisy.
2. Lightly tapped tubes and components........................................ Noise all over chassis.
3. Replaced tubes one at a time and tapped.................................... No effect.
4. Continued tapping to find place of greatest effect. Tapping of condenser drive mechanism sometimes caused fading.
5. Opened condenser cans and the coil to condenser connections.
6. Ohmmeter check of each condenser, and tapped each................................. One condenser could be tapped from open to dead short.
7. Inspected that condenser......................................................... Stator rod almost touched the chassis.
8. Insulated stator rod.
9. Checked condenser for short .............................................................. None.
10. Reassembled radio and tried ........................................................... No noise, no fading.
11. Realigned.
12. Checked performance ................................................................. O.K.

1. Removed radio from car.
2. Checked $B$ voltage ................................................................. None.
3. Checked filter for short ............................................................. None.
4. Checked buffer condenser ........................................................... Short.
5. Replaced buffer condenser ......................................................... Receiver operates.
6. Checked:
   Sensitivity .............................................................................. O.K.
   Selectivity .............................................................................. O.K.
   Quality .................................................................................... O.K.
7. Replaced in car.
8. Checked for motor noise ............................................................... O.K.

Case 5. Complaint: AC/DC receiver, intermittent reception.
1. Checked performance ................................................................. O.K.
2. Left playing ............................................................................. Died in $\frac{1}{2}$ hr. No tubes lit.
3. Checked tube filaments ................................................................. 50L6 open.
5. Checked performance ................................................................. O.K.
6. Left playing .............................................................................. O.K.

Case 6. Complaint: No signal.
1. Signal to first AF grid ................................................................. No response.
2. Checked second AF plate voltage ................................................ None.
3. Checked second AF screen voltage .............................................. None.
4. Checked voltage across rectifier ............................................... High.
5. Checked speaker field ................................................................. Open.
6. Replaced speaker.
7. Checked performance ................................................................. O.K.
CHAPTER 24

THE SERVICE BENCH

Much has been written about the radioman’s service bench, and trade journals have sponsored contests for the best ones. Photographs of the winners have shown beautiful specimens. But in many cases, some of the tools indispensable to the serviceman seem to be lacking, or are perhaps in the back room. It is quite true that the customer must be impressed by an orderly setup, but this does not mean that the service bench must look as though nothing ever happened on it. Instruments and tools must be readily available, and ample working room must be provided. Therefore, this chapter will concern itself with the bench for work, not the one for show alone.

Physical Make-up of the Workbench.—Dimensions and constructional details will not be given, since these depend largely on the available space and the individual’s preferences. The information given is in the form of general suggestions to fit a particular need.

The most important consideration is the available space, since the bench usually fills up one wall or one corner. Regardless of other dimensional considerations, a minimum clearance of 2 by 4 ft for working space should be provided. This area can accommodate even a large chassis, with its speaker, loop, power-supply chassis, etc. The bench top should be made of wood or other insulating material. Metal trim should be avoided because of the danger of short circuits.

Behind and above the working area, the serviceman can install shelving and panels for meters, manuals, replacement parts, etc. To the right of the working area should be the soldering-iron stand and a bench vise. If space permits, a bench grinder is another useful appliance to have available. Both the vise and the grinder should be installed as far from the working area as possible, to minimize the possibility of getting metallic filings in a receiver on the bench. Figure 24–1 shows an arrangement for a bench top 6½ ft by 3 ft.

The height of the working area should be such as to be comfortable for the serviceman—either standing at his work or sitting on a high stool; about 40 in. is a good average. Tall men may prefer a bench top an inch or two higher than this.
Below the working area should be suitable knee space. Flanking it, there can be drawers for tools. The back of the knee space, near the wall, can be built up with shelves for large materials that are infrequently used, such as a storage battery and charger. The tool drawers should be set back about 4 in. from the front of the bench top. Directly beneath this top, in the knee space, a strip of wood containing electrical outlets should be mounted. This same strip can have a small drawer in it for frequently used small hand tools and test leads.

A good place for another strip of outlets is directly below the meter shelf. This same strip can contain connections for the shop antenna and test speaker, as well as the resistor and condenser substitution box. A shelf above the meter panel can accommodate manuals and trade literature. Space on each side of the test panel can be used for drawers to hold small parts.

Below the test instruments is a convenient place to mount spools of hookup wire and solder. These can be mounted and made to unwind on a dowel stick.

Figure 24-2 shows the front view of such a service bench. The test instruments should be mounted at about eye level, 60 in. or more from the floor, depending on the serviceman’s height. These should be, as a minimum, those necessary for service work: the signal generator, the multimeter, the bench test speaker, and the resistor and condenser substitution box. Signal generators have been described in Chap. 6; multimeters, in Chap. 4. These may be of the panel-mounting type. Carrying-case units are equally good and have the advantage of being portable for use away from the bench. They merely rest on a shelf. But, lest they be yanked off, a screw through the shelf or some other easily removed holding device
should be installed. The test speaker and substitution panel, described in this chapter, can be permanently mounted in a test panel.

**The Bench Test Speaker.**—The bench test speaker should be so constructed as to be easily connected to any receiver. Since there are many types of speakers as well as many methods of connections in different receivers, a universally applicable test speaker for any

![Diagram of service bench](image)

**Fig. 24-2.—Service bench—front view.**

receiver is not easy to design. The assembly shown in Fig. 24-3 has been used with considerable success.

The speaker used is a 10- or 12-in. P-M dynamic speaker, capable of handling the output of any receiver. It should be a high-quality speaker, since it will be used to check for the cause of poor tone in a receiver and must not have its own poor tone.

The output transformer is of the push-pull type, which permits connection to push-pull output tubes. For use with a single tube output stage, half the winding will match a low-impedance output
tube. The full winding, disregarding the center tap, will match a high-impedance output tube.

When the receiver being tested utilizes a speaker field winding that is wired directly across the rectifier (see Fig. 9–3), no provision need be made for the field at all.

![Provision for Output Transformer and Voice Coil Replacement](image)

**Fig. 24-3.—Bench test speaker.**

![Provision for Speaker Field Coil Replacement](image)

When the field winding is part of the filter or voltage divider circuits (see Figs. 9–2 and 9–4), the original speaker field coil may be used, other connections to the receiver speaker being removed. If it is desired to replace such a field coil for test purposes, it may be replaced by the choke and resistor assembly of the test speaker. The
choke is rated at about 20 henrys and is capable of safely carrying a current of about 100 ma. It should have an ohmic resistance of approximately 400 ohms. The two series resistors are 600 and 1,000 ohms, respectively, and are rated at 20 watts. The choke and resistors, all connected in series, will replace a speaker field of approximately 2,000 ohms.

The speaker, choke, and resistor leads should be cabled and brought to a binding-post strip, mounted under the speaker panel,

and labeled as shown in Fig. 24-4. The binding posts should have a hole through the screw portion for convenience in attaching pin tips.

**How to Use the Bench Test Speaker.**—The use of the test speaker can be illustrated by an example. Assume a receiver like our standard, shown in Fig. 1–1. Assume further, a defect consisting of some shorted turns in the primary of the output transformer. This defect will result in a very weak signal output, since most of the signal will be feeding the shorted turns. On check, the power supply will show normal readings, but there will be either a very weak click or no click when the second AF tube is momentarily unseated. This places the trouble probably in the speaker and would indicate a weak field or a frozen voice coil. Normal power-supply readings
indicate a normal speaker field, which is confirmed by checking the magnetic pull with a socket wrench. The voice coil is then disconnected and the test speaker voice coil is substituted, as shown in Fig. 24–5. The result clears the voice coil, since the output is still weak.

The trouble may now be in the output transformer or the second AF stage. Voltmeter and ohmmeter checks may still show normal readings, since the shorted turns may not materially affect the resistance of the transformer primary. The second AF stage therefore seems to be all right. The test speaker and its output trans-

![Diagram](image_url)

Fig. 24–6.—Checking a receiver output transformer by substituting the bench test speaker.

former are now substituted for the receiver speaker and output transformer. This is done by opening one of the transformer primary leads—plate or B plus, whichever is more convenient. Because the standard receiver uses an output tube that requires a high-impedance load, the test speaker is substituted, as shown in Fig. 24–6. The result is a normal response with the test speaker. This proves that the output transformer is defective and must be replaced.

The test speaker is used to confirm any troubles that seem to point to the speaker, as indicated in Chap. 9. Results with the test speaker should be interpreted with good judgment. For example, when it is used with the usual AC/DC receiver, the serviceman should expect excellent tone and volume as compared with the normal response from the 4- to 6-in. speaker, which is usual for these receivers.
Speaker-plug Wiring.—Speakers, as used in receivers, often have their leads terminated in plugs, which are connected to the receiver chassis. These plugs are usually 4- or 5-point units. The R.M.A. has set up standard methods of connection for these plugs, the more common of which are shown in Fig. 24-7.

Since there is considerable variation and since many receivers do not follow the standards shown, the serviceman should provide himself with several cable and plug assemblies, so that he can connect any receiver to his bench test speaker. These should include a 4- and 5-prong plug with coded leads attached.

Figure 24-8 shows the connections for hooking the test speaker to a receiver using a high-impedance output tube, a 1,000-ohm field coil, and a standard 4-prong plug arrangement.

In general, it is best to check the receiver schematic diagram against the receiver being serviced for speaker pin connections rather than to assume that one of the standard speaker connection diagrams of Fig. 24-7 is being used. A variation, commonly encountered, is the use of the speaker plug as a link that breaks the
Fig. 24-8.—Connecting the bench test speaker to a receiver using a standard 4-prong speaker-plug arrangement.

Fig. 24-9.—Speaker-plug arrangement which opens the B circuit when the plug is removed.
power-supply input if the speaker plug is removed. This is a safety device to prevent damage that might be caused if the power supply were allowed to operate with no load, as would normally happen when the speaker plug is removed. Such a speaker plug connection is shown in Fig. 24–9.

Antennas for the Test Bench.—Every test bench for radio work should be provided with antennas of various types to match conditions in any home or car installation. In this way, servicing problems may be tackled with at least one known factor—antenna efficiency.

There ought to be one good antenna, long and high, for good signal strength and minimum noise pickup. This will give best results with any home receiver. But there is no point in using it with a receiver whose home installation does not have a large, efficient outdoor antenna.

Therefore, the test bench should also be equipped with a short antenna to match conditions where a short indoor antenna is used as the home installation. For this antenna, the serviceman must take cognizance of his own shop conditions. If his shop has a metal ceiling—a common condition—or if he is located on the street floor of a large steel building, a short indoor antenna will not be the equivalent of a short indoor antenna in the average home. Under these shop conditions, signal pickup would be so low and noise pick-up so high with the short antenna that similar reception would not be tolerated by a radio owner. To match the condition of a normal indoor antenna in an electrically quiet residential section, the serviceman may require at least a 20-ft outdoor lead-in wire to be used for his short indoor antenna.

An antenna suitable for testing automobile receivers should also be available on the service bench. Both the long outdoor antenna and the short antenna would provide too much signal for the average automobile receiver, which normally operates with a very short antenna. A good equivalent antenna for an auto radio may be had by clipping the antenna lead to any one of the test points of the bench test speaker. The test speaker cable contains nine wires, which will be 2 to 5 ft long, depending on bench conditions. If this is not satisfactory because of high noise level at the test bench, a flagpole antenna like the one described in Chap. 17 should be tried. The lead between the test bench and the window should be low-capacity shield wire, the shield being grounded only at the auto receiver chassis. Figure 24–10 shows bench connections for the three antenna types.
If the test speaker wiring is satisfactory as an auto radio antenna, the serviceman may be confident that signal pickup and noise conditions at his test bench will also be satisfactory for the operation of loop receivers. If it is not satisfactory, he should realize the limitations of his location and make due allowance when servicing this type of receiver.

All-wave receivers, which use special antenna assemblies, usually have provision for connecting a standard antenna, at least for operation on the broadcast band. A special antenna installation for testing all-wave receivers is therefore unnecessary.

![Diagram of antenna connections](image)

Fig. 24–10.—Panel on test bench showing antenna leads.

The bench, of course, should be equipped with a good ground connection.

**The Resistor and Condenser Substitution Box.**—Often, test procedure calls for the bridging of condensers in the receiver with similar ones to check for hums, squeals, etc. Similarly, a resistor that is suspected of being open is also bridged with a similar part. Sometimes, the serviceman often wishes to short two points in a receiver for test purposes. For example, to localize the starting point of a hum that is not due to the filter circuit, he will short the second AF grid to ground. If the hum ceases, the second AF stage does not cause it, and he will then short the first AF grid to ground, and so on back through the receiver.

It would be convenient to have these shorts, resistors, and con-
densers readily available at the ends of a pair of test prods. This function is served by a substitution box that allows them to be connected to the test prods by turning a switch.

Any number of different condensers and resistors may be used, since the switches may have up to 24 positions. However, too many condensers and resistors would make the switching too slow and cumbersome. A smaller number of clearly marked positions would be more convenient. Of course, this reduces the possible number of resistors and condensers available. But this is no disadvantage, since, in test work, the bridging of a component need not be made with an exact duplicate. For example, when a receiver has an open screen by-pass condenser, the squeal will stop or be materially reduced when the defective condenser is bridged with any condenser with a capacity from about 0.01 mfd and up. Similarly, in checking filter condensers for hum, even a 4-mfd condenser will show considerable improvement over results with an open 20-mfd condenser. Likewise, with resistors, an ohmic value wrong by 100 per cent or more will show a marked improvement in results from those obtained when the resistor is open.

Of course, the actual replacement in the receiver should be made with the correct value. But for test purposes, the number of components and consequent test points on the switch may be reduced for greater convenience.

A 7-point switch should be sufficient for all test work: 3 for condensers, 3 for resistors, and 1 for a short. The schematic circuit of such a substitution box and the uses of each component are shown in Fig. 24-11.

The values of components indicated at the left of the diagram are recommended as a test substitution for any value within the limits
shown at the right of the schematic diagram. A paper condenser is recommended for the filter condenser, although an electrolytic condenser may be used. In this case, the serviceman must observe polarity, as indicated on the diagram. A paper or electrolytic condenser with a rating of 500 volts may be used for test purposes in an AC/DC receiver. However, if a replacement is made, the serviceman must be sure to use the proper voltage rating (150 volts).

It is not recommended that condensers of the order of 0.0005 mfd be used in the substitution box, since the capacity, inductance, leakage, and RF pickup of the leads and substitution box will affect circuits using these low capacities.

The front panel of the substitution box appears as shown in Fig. 24–12. The seven positions are clearly marked and will be an aid in fast checking. The polarity indication on the test jacks may be neglected, if the 8-mfd condenser is a paper condenser.

In using the substitution box for condensers, the serviceman should establish the habit of shorting the test leads together after each application of the test prods. This is important because the test condenser may become charged with the voltage in a circuit. The condenser may then discharge into another receiver circuit being tested, with disastrous results. To establish this habit, the serviceman might do well by shorting all test leads after use, regardless of the component being used.

**Soldering-iron Service Hint.**—The soldering iron in most common use by a serviceman is a 100-watt unit. To save time, it must be
hot at all times when in use on the bench. However, it will overheat if left connected to the power line and will need constant retinning of the tip. A method for overcoming this difficulty is to leave the iron connected to the outlet at all times when the bench is in use,

![Schematic diagram of a "high-low" soldering-iron outlet.](image)

Fig. 24-13.—Schematic diagram of a "high-low" soldering-iron outlet.

but to place a dropping resistor in series with it. The ohmage of the dropping resistor should be so chosen that the iron will not overheat yet will remain sufficiently hot to solder small joints. Then, if a considerable amount of soldering is to be done or if a heavy joint is to be soldered, a toggle switch is used to short out the series resistor. A 6-ohm/20-watt resistor may be used, as shown in the circuit of Fig. 24-13.

The resistor and switch should be mounted in a conventional 3-in. electrical outlet box to prevent accidental touching of the hot unit. The switch should be labeled HIGH and LOW, to indicate high and low heat, as shown in Fig. 24-14.

![Front view of a "high-low" soldering-iron outlet box.](image)

Fig. 24-14.—Front view of a "high-low" soldering-iron outlet box.

Bench Lighting.—Lighting is important for the serviceman, since a receiver is full of many small and crowded components. It is recommended that large incandescent lamps with wide metal shades be used. If fluorescent lighting is used above the bench, adequate
filters should be installed in them to reduce noise radiation. Even with filters installed, there may be some interference picked up by a loop-operated receiver directly under the lamps.

For convenience, the serviceman can use lamp fixtures with extra-long lead wires. He might thereby raise and lower the fixtures as the needs of a situation demand.
APPENDIX

SYMBOLS AND ABBREVIATIONS

A    Heater or filament circuit
AC   Alternating current
AF   Audio frequency
A-M  Amplitude modulation
amp  Amperes
ant  Antenna
AVC  Automatic volume control
B    Plate circuit
BC   Broadcast
BFO  Beat frequency oscillator
C    Capacitance
C    Grid circuit
CT   Center tap
DAVC Delayed automatic volume control
DC   Direct current
E    Volts (in Ohm's law formulas)
F-M  Frequency modulation
gnd  Ground
h    Henry
I    Amperes (in Ohm's law formulas)
IF   Intermediate frequency
k    1,000
kc   Kilocycles (or kilocycles per second)
L    Inductance
L-C  Inductance-capacitance
ma   milliamperes
mc   Megacycles (or megacycles per second)
meg  Megohms
mfd  Microfarads
mh   Millihenrys
P-M  Permanent magnet
R    Resistance
Ω    Ohms (in Ohm's law formulas)
R-C  Resistance-capacitance
RF   Radio frequency
rpm  Revolutions per minute
rms  Effective value (as of voltage)
SW   Short wave
TRF  Tuned radio frequency
v    Volts
W    Watts
Z    Impedance
RMA COLOR CODE FOR RESISTORS (OHMS)

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<th>2ND DIGIT</th>
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D - TOLERANCE CODE:

- Brown = 1%
- Orange = 3%
- Gold = 5%
- Red = 2%
- Yellow = 4%
- Silver = 10%
- No Color = 20%

For new type only, body color indicates type of resistor, as follows:
- Black = composition, non-insulated.
- Any color, other than black, tan preferred = composition, insulated.
- Dark brown = wire-wound, insulated.
An example will indicate the use of the new type of resistor coding. Assume the following with colors as given:

- A................. Red
- B................. Green
- C................. Orange
- D................. Silver

Decoding, we get

<p>| | | | |</p>
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<tbody>
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<td>A</td>
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<td>B</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>1,000</td>
<td>D</td>
<td>10%</td>
</tr>
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</table>

The resistor has a value of 25 times 1,000, or 25,000 ohms, and a tolerance of ± 10 per cent.

**R.M.A. COLOR CODE FOR FLEXIBLE RESISTORS**

The same color code holds for flexible resistors as for carbon resistors. For flexible resistors the first digit is the body color (A). The second digit is the thick thread color (B). The multiplier is the thin thread color (C).

**OHM'S LAW AND ITS DERIVATIVES**

Where \( E = \text{volts} \), \( I = \text{amperes} \), and \( R = \text{ohms} \),

\[
I = \frac{E}{R} \\
E = I \times R \\
R = \frac{E}{I}
\]

Where \( E = \text{volts} \), \( I = \text{amperes} \), \( R = \text{ohms} \), and \( W = \text{watts} \),

\[
W = I^2 \times R \\
I = \sqrt{\frac{W}{R}} \\
R = \frac{W}{I^2} \\
W = I \times E \\
I = \frac{W}{E} \\
E = \frac{W}{I} \\
W = \frac{E^2}{R} \\
E = \sqrt{W \times R} \\
R = \frac{E^2}{W}
\]
RMA COLOR CODES FOR CAPACITORS (MMFD)

THREE DOT SYSTEM

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SIX DOT SYSTEM
Three-dot System.—Assume a condenser with the dotted colors in the direction of the arrow as follows—red, green, and brown. Decoded, the value is 25 times 10, or 250 micro-

 microfarads, or .00025 mfd. The DC working voltage is 500 volts, and the tolerance is ±

 20 per cent.

Six-dot System.—Assume a condenser with the dots as follows:

A. ....................... Brown
B. ....................... Red
C. ....................... Green
D. ....................... Brown
E. ....................... Silver
F. ....................... Gold

Decoded, the value is 125 times 10, or 1,250 micromicrofarads, or 0.00125 mfd. The tolerance is ± 10 per cent. And the DC working voltage is 1,000 volts.

CHART SHOWING AUTOMOBILE BATTERY GROUNDS

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<td>Terraplane</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Willys</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Mercury</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>

P = battery positive pole grounded; N = battery negative pole grounded.

Note: For 1946, all cars not indicated by N have the positive pole grounded.
### ELEMENTS OF RADIO SERVICING

#### GRAPHIC SYMBOLS

<table>
<thead>
<tr>
<th>RESISTOR</th>
<th>COIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>Air-core</td>
</tr>
<tr>
<td>Tapped</td>
<td>Magnetic-core</td>
</tr>
<tr>
<td>With terminals</td>
<td>Variable coupling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAPACITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
</tr>
<tr>
<td>Variable differential</td>
</tr>
<tr>
<td>Mechanical linkage</td>
</tr>
<tr>
<td>Split-stator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANTENNA SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna</td>
</tr>
<tr>
<td>Counterpoise</td>
</tr>
<tr>
<td>Loop</td>
</tr>
<tr>
<td>Ground</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BATTERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>One cell</td>
</tr>
<tr>
<td>Multicell</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WIRING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal, contact, or pivot point</td>
</tr>
<tr>
<td>Connections</td>
</tr>
<tr>
<td>No connection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWITCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-off</td>
</tr>
<tr>
<td>Multiposition</td>
</tr>
<tr>
<td>Key</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUSE</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>HEATER ELEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MICROPHONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
</tr>
<tr>
<td>Single-button</td>
</tr>
<tr>
<td>Double-button</td>
</tr>
<tr>
<td>Capacitor</td>
</tr>
<tr>
<td>Moving-coil</td>
</tr>
<tr>
<td>Velocity</td>
</tr>
<tr>
<td>Crystal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOUDSPEAKER</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
</tr>
<tr>
<td>Magnetic</td>
</tr>
<tr>
<td>P-M dynamic</td>
</tr>
<tr>
<td>Electrodynamic</td>
</tr>
</tbody>
</table>
### APPENDIX

#### GRAPHIC SYMBOLS

<table>
<thead>
<tr>
<th>PHONE</th>
<th>PICKUP or CUTTING HEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Single" /></td>
<td><img src="image" alt="General" /></td>
</tr>
<tr>
<td><img src="image" alt="Double" /></td>
<td><img src="image" alt="Electromagnetic" /></td>
</tr>
<tr>
<td><img src="image" alt="Crystal" /></td>
<td><img src="image" alt="Crystal" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRystals</th>
<th>SHIELDING</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Detector" /></td>
<td><img src="image" alt="General" /></td>
</tr>
<tr>
<td><img src="image" alt="Piezoelectric" /></td>
<td><img src="image" alt="Individually shielded wires" /></td>
</tr>
<tr>
<td><img src="image" alt="Rectifier (dry-disk) A:C" /></td>
<td><img src="image" alt="Shielded pair" /></td>
</tr>
<tr>
<td><img src="image" alt="Half-wave A:C" /></td>
<td><img src="image" alt="Twin coaxial R-F cable A" /></td>
</tr>
<tr>
<td><img src="image" alt="Full-wave A:C" /></td>
<td><img src="image" alt="Line shielded between A and B B" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermocouple</th>
<th>Thermoelement</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Indirectly heated" /></td>
<td><img src="image" alt="Directly heated" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VIBRATOR</th>
<th>PLUG</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Synchronous" /></td>
<td><img src="image" alt="Nonsynchronous" /></td>
</tr>
<tr>
<td><img src="image" alt="Relay (deenergized)" /></td>
<td><img src="image" alt="Jacks" /></td>
</tr>
<tr>
<td><img src="image" alt="Make" /></td>
<td><img src="image" alt="Break" /></td>
</tr>
</tbody>
</table>

Abstracted from American Standards Association publications Z32.10-1944 and Z32.5-1944. Note that all lines are the same thickness. Leads can come out of symbols any convenient way.

### TUBES

<table>
<thead>
<tr>
<th><img src="image" alt="Filament" /></th>
<th><img src="image" alt="Indirectly heated cathode" /></th>
<th><img src="image" alt="Cold cathode" /></th>
<th><img src="image" alt="Photoelectric coupling" /></th>
<th><img src="image" alt="Gas-filled pool cathode" /></th>
<th><img src="image" alt="Grid" /></th>
<th><img src="image" alt="Deflecting electrode" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Anode" /></td>
<td><img src="image" alt="X-ray target" /></td>
<td><img src="image" alt="Dynode" /></td>
<td><img src="image" alt="Ignitor" /></td>
<td><img src="image" alt="Excitor" /></td>
<td><img src="image" alt="Internal shield" /></td>
<td><img src="image" alt="Single-cavity envelope" /></td>
</tr>
<tr>
<td><img src="image" alt="Double-cavity envelope" /></td>
<td><img src="image" alt="Triode" /></td>
<td><img src="image" alt="Pentode" /></td>
<td><img src="image" alt="Cold-cathode gas diode" /></td>
<td><img src="image" alt="Phototube" /></td>
<td><img src="image" alt="Cathode-ray tube" /></td>
<td><img src="image" alt="Cathode-ray tube" /></td>
</tr>
<tr>
<td><img src="image" alt="Magnetron" /></td>
<td><img src="image" alt="Split magnetron" /></td>
<td><img src="image" alt="Single-cavity velocity-modulated tube" /></td>
<td><img src="image" alt="Double-cavity velocity-modulated tube" /></td>
<td><img src="image" alt="Multiplier phototube" /></td>
<td><img src="image" alt="Ignitron with grid" /></td>
<td><img src="image" alt="Excitron with grid and holding anode" /></td>
</tr>
</tbody>
</table>
TUBES AND THEIR PRONGS

Note: For all cases below, except the 8-prong tube, a spot of bakelite or cross mark is usually placed between the filament prongs, for identification (shown by arrow in diagrams). In all cases, except the 8-prong tube, numbering begins with the prong (viewed from the bottom) to the left of the bakelite spot or cross mark and continues in a clockwise direction.

<table>
<thead>
<tr>
<th>Tube base (bottom view)</th>
<th>Identifying tube prongs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4-prong</strong></td>
<td>The 4-prong tube has 2 large and 2 small prongs. The large prongs (1 and 4) are filament connections.</td>
</tr>
<tr>
<td>![4-prong diagram]</td>
<td></td>
</tr>
<tr>
<td><strong>5-prong</strong></td>
<td>All prongs are the same size. Prong 3, however, has more separation than the others. The filament or heater prongs are 1 and 5.</td>
</tr>
<tr>
<td>![5-prong diagram]</td>
<td></td>
</tr>
<tr>
<td><strong>6-prong</strong></td>
<td>The heater or filament prongs are the heavy ones, 1 and 6.</td>
</tr>
<tr>
<td>![6-prong diagram]</td>
<td></td>
</tr>
<tr>
<td><strong>7-prong</strong></td>
<td>The 7-prong tube has 2 large prongs (1 and 7) to identify the filament connections.</td>
</tr>
<tr>
<td>![7-prong diagram]</td>
<td></td>
</tr>
<tr>
<td><strong>8-prong</strong></td>
<td>Most modern tubes have this type of base. Observe the key slot in the center. Numbering begins from the left of the key slot and continues in a clockwise direction. Heater connections are usually prongs 2 and 7.</td>
</tr>
<tr>
<td>![8-prong diagram]</td>
<td></td>
</tr>
</tbody>
</table>