Chapter 8

Customer Complaints

If a guitar amplifier is dead, the problem is relatively simple. Find the bad component and replace it. Procedures mentioned previously can be used so that the troubleshooting can be done in a logical manner, using a minimum of time. Probably more difficult to service are the cases where the amplifier is working, but not in a satisfactory fashion. There is a strong tendency here to proceed in a hit-or-miss fashion, substituting a tube here or a component there, in the hopes of finding a cure. Don't do it; the whole secret to speedy servicing is an orderly search for defective parts.

Often the owner gives valuable clues to the nature of the problem when he describes what is wrong. Listen carefully to him, and, if possible, verify what he says by listening to the amplifier while he is present. The player's ears are sensitive to the sound of an instrument in a way the serviceman can never be; even so, you can't do much to repair an instrument if you can't hear what is wrong.

Some of the common customer complaints are listed in the following sections along with suggestions for finding the source of the trouble.

DISTORTION

One of the worst problems in all audio amplifiers is distortion. This simply means that the amplifier isn't putting out what goes into it. An amplifier must never *change* the shape of the signal fed into it—it must only make the signal bigger. If the amplifier changes the waveshape of the note, there is distortion. If an amplifier tube operates on any but the linear part of its curve, troubles develop. Fig. 8-1 shows how this works; if the stage is properly biased, the output signal is exactly the same shape as the input. If bias is wrong, then the signal is changed—clipped or otherwise distorted. It is possible even to get a frequency-selective form of distortion; some notes are amplified clearly, others are distorted. (This is a simplification of what actually happens, but it's good enough to illustrate the problem; it can be fixed.)

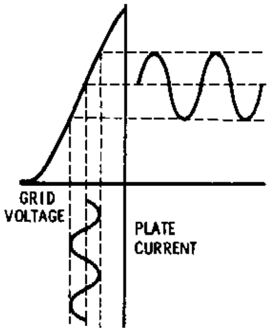
You must work on the assumption that the guitar and amplifier were practically distortion-free when new, and try to make them work as well as they did then. This means finding all of the parts that have drifted off tolerance and replacing them, replacing all tubes that have weakened or developed grid emission, replacing all leaky capacitors, and so on. If you take a stage at a time, you can gradually get the amplifier back to normal.

Probably the most frequent cause of distortion is leaky coupling capacitors between stages. This has been covered previously, but don't overlook it.

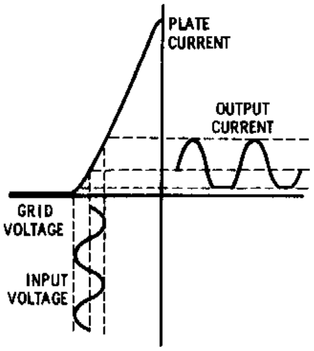
Using an Oscilloscope to Find Distortion

About the only instrument that makes it easy to find distortion is the oscilloscope since the ear is pretty unreliable for obvious reasons. However, if a pure signal is fed to the input of a stage and something else comes out, then there is distortion in that stage. Fig. 8-2 shows how this works.

Here, a pure signal (W1) is fed to the input, and the same signal is undistorted at the output of the next two stages (W2 and W3). However, look at the output of stage 3 (W4). Something has happened here. This pinpoints the source of the distortion; something is very definitely wrong in the third stage.



(*A*) *Output not distorted.*



(*B*) *Output distorted.*

Fig. 8-1. Transfer curves showing signal amplification.

To find the cause of the trouble, start checking parts. First, replace the tube, because it is the easiest. Then, check the operating voltages, paying particular attention to the grid bias voltage. Most RC-coupled stages are very simple; there is actually nothing to them but three resistors, two capacitors, and the tube. If there is distortion in a stage, one of these parts must be bad.

Transistor amplifiers are checked in exactly the same way. Feed in a known good signal to the input, check its waveform *before* it starts through the amplifier, then simply follow it through the whole signal path. At the point where it is being distorted, you'll see it. Clipping is probably the most common cause of distortion in solid-state amplifiers.

Clipping is due to incorrect bias; this in turn can be caused by a bad bias resistor, a leaky electrolytic coupling capacitor, or, and possibly the most frequent cause, a transistor which has developed too much leakage. This is something that *cannot* be checked in-circuit, because of the components which are connected across the transistor. Take it out, and check it with a good transistor tester.

In older amplifiers, germanium small-signal transistors were used. These have some leakage; not a lot, just a few microamperes. This is normal (if you have doubts, try a new transistor in there). However, most of the transistors found in later amplifiers will be silicon types, and the normal leakage for these is zero. None at all. So, if you find a silicon transistor showing as little as 10 *microamperes* of leakage, replace it. It's bad. This is particularly critical in power transistors, but can cause trouble in preamplifiers and drivers as well.

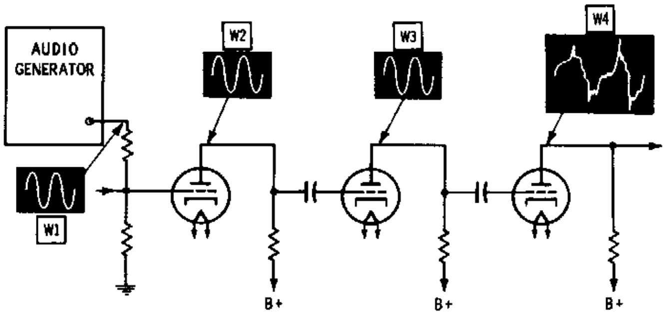


Fig. 8-2. Waveforms at critical points in an amplifier.

As an example of how the scope can help, I once found an amplifier where the complaint was simply "It sounds like . . . !" Feeding in sine-wave signals didn't seem to show anything at all. However, when the guitar was hooked up to the amplifier and a few chords were played at high volume, the trouble was apparent. On the oscilloscope there was a pattern that looked like Fig. 8-3. (Because of the movement in this pattern, it couldn't be photographed, but this is an accurate reproduction.)

Several different frequencies were present at the same time: this caused a rapid movement of the scope pattern. However, by careful observation and juggling of the sweep controls, I finally spotted the

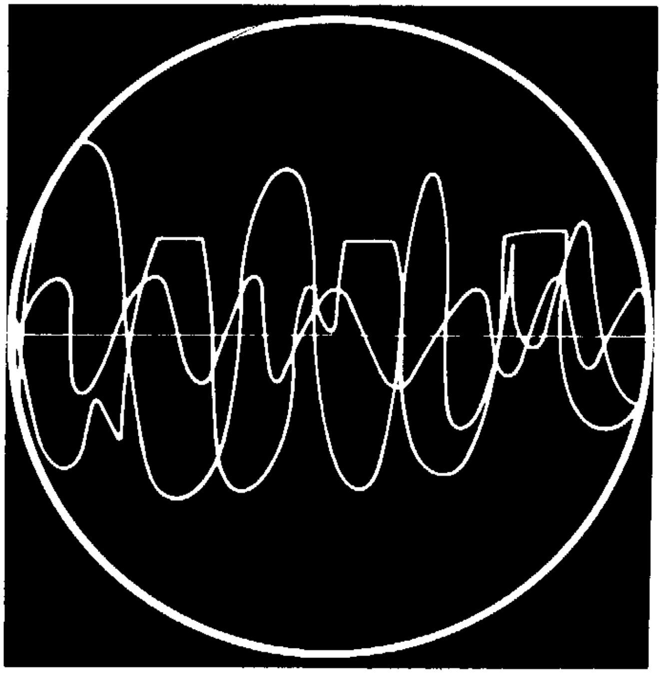


Fig. 8-3. Drawing of an actual scope pattern of a defective amplifier.

trouble; there in the background were several waveforms that were very obviously clipped (flat topped). So, just for luck, (and as a starting point, for I had already replaced several other parts with no results) I changed all of the coupling capacitors, using high-voltage types carefully checked for zero leakage before installation. This cured the complaint.

The distorted waveforms could probably have been spotted by making individual tests at many frequencies, but it was not necessary to go to such lengths. To find a stage that is causing distortion, be sure that your signal generator isn't set for too high an output. This will cause clipping (flat-topping) and severe distortion of the signal from overloading the amplifier.

The average audio signal generator can put out several volts of signal; even a high-output phonograph cartridge, used with a frequency test record, can do the same thing, so, make sure that you are not overloading the input. A voltage divider set up like that shown in Fig. 8-4 will help out. By using a pair of resistors, one 50,000 and one 950,000 ohms, you can get a 50-millivolt output. This is a good average input from a guitar pickup and should not cause overloading. To make sure, test with the scope at the plate of the first stage—the preamplifier tube. If there is any clipping due to too much input signal, it will probably show up there. For the final test, plug in the guitar itself and have the owner play a few chords on it while you watch the scope screen. To get best results in this test, always use a low-capacitance probe on the scope input. This will give the lowest loading on the high-impedance circuits you are working with.

You can also make stage-by-stage gain checks with the scope when troubleshooting weak amplifiers. Feed in the signal at the input. Set the signal-generator output for a clean sine wave. Now, put the scope probe on the grid of the preamp tube. Set the vertical gain of the scope so that the signal takes up a certain number of squares on the graticule (the calibrated screen on the scope). It doesn't make any difference how many as long as you remember. The best way is to make the signal cover a small number of small squares—say 5. Now move the probe to the plate. If this stage has a gain of 10, your pattern will be 10 times as high—50 small squares.

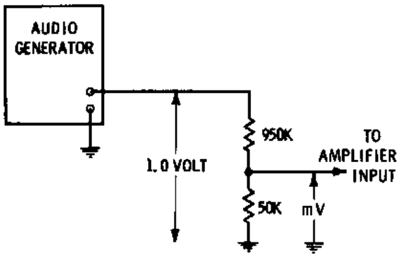


Fig. 8-4. Voltage divider to reduce generator output.

Many scopes have calibrated step attenuators. You can start by setting the attenuator to X1 for the first measurement. If you move it to X10 on the second and get a pattern of the same height, then this stage has a voltage gain of 10. Stage gain varies with tube types, voltage, and several other things. The preamp stages usually have very high gain, somewhere up around 15 to 25, while following amplifier stages may run between 10 and 15 as an average. As a rule, if a stage has low gain, you will be able to spot it even if you do not have the exact gain figures for that particular amplifier. If you get a gain of 10 to 15, that's probably pretty good. The tube manual will often give you a figure in the "typical characteristics" charts that you can use for a given tube.

Fig. 8-5 shows waveforms and stage gains for an imaginary amplifier. The signal always has the same shape, but the amplitude (height) increases. Even small amplifiers can have amazingly large amounts of actual voltage gain. When you remember that some amplifiers begin with a signal of only about 0.050 volt and wind up with perhaps as much as 50 volts, you can see that an overall voltage amplification of 1000 times is not unusual.

OSCILLATION, HUM, AND MOTORBOATING

Now and then you will find an amplifier that is oscillating. This means that the amplifier has some kind of internal feedback (the cause of all oscillation). There are several different kinds:

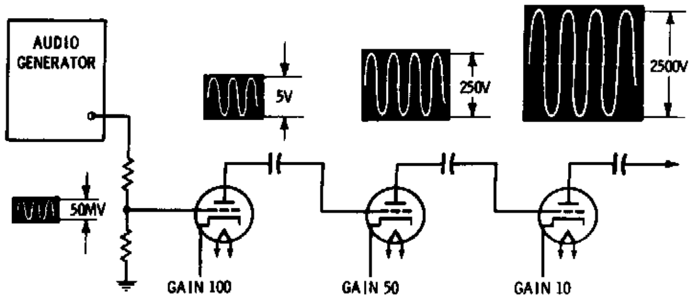


Fig. 8-5. Possible waveform values and stage gains.

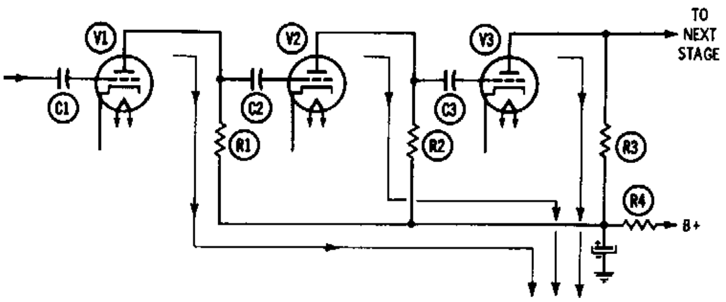


Fig. 8-6. Normal signal paths to ground.

1. Low-frequency oscillation is usually accompanied by a fairly bad hum. It is called motorboating from the "plup-plup-plup" sound it makes, something like an old motorboat (not a high-speed outboard).
2. High-frequency oscillation can sometimes be so high in pitch that the human ear cannot hear it —up around 20,000 or 25,000 Hz. It is also called ultrasonic oscillation. You cannot hear the oscillation itself, but you can hear the effects. It will cause the amplifier to have a very bad distortion.

Feedback

All oscillation is caused by a feedback. Amplifier circuits have many common connections such as the plate voltage supply circuit shown in Fig. 8-6. Only the plate circuit and grid circuit is shown, for that is all that is necessary. When there is a common plate supply circuit like this, it must be very well bypassed. A big electrolytic capacitor is put across the power supply from the B+ line to chassis or ground.

What does this do? In the plate circuits of all amplifier tubes there is a signal current flowing. It is taken off at the plate and fed to the grid of the following stage through the coupling capacitors (C1, C2, and C3). However, the rest of the current flows down through the plate resistors (R1, R2, and R3) and back to the B+ supply; it has to in order to make a complete circuit. Actually the signal is of no further value as soon as it leaves the plate of the tube; it must get to ground without creating any problems. The signal is alternating current, or to be more correct, it is a pulsating dc, like the plate current in all tubes. For convenience, the current is treated as if there were both ac and dc in the same circuit.

To get rid of the ac component, a big capacitor is connected from the B+ line to ground. This has a very low resistance to ac, so the B+ is at ac ground potential. There should never be any ac components on B+ lines. You can see from Fig. 8-6 that the signal currents flow down the load resistors and then through the low resistance of the capacitor to ground where they are lost. What happens if the capacitor opens up or develops a very high resistance (high power factor)?

This is different. Instead of any easy path to ground, the signal now has a very high-resistance path to ground if any at all. As you can see in Fig. 8-7, under these conditions the signal currents go everywhere. Instead of being dissipated harmlessly in the chassis, they can flow back up into other circuits. For example, the signal from tube V3 can get back into the plate circuit of tube V2, where it is promptly transferred through coupling capacitor C3 back to the grid of tube V3. The phase shifts in this feedback path are complicated, but it suffices to say that somewhere in there the signal manages to get back to a grid in exactly the right phase to cause in-phase regenerative feedback. The stage then goes into violent oscillation.

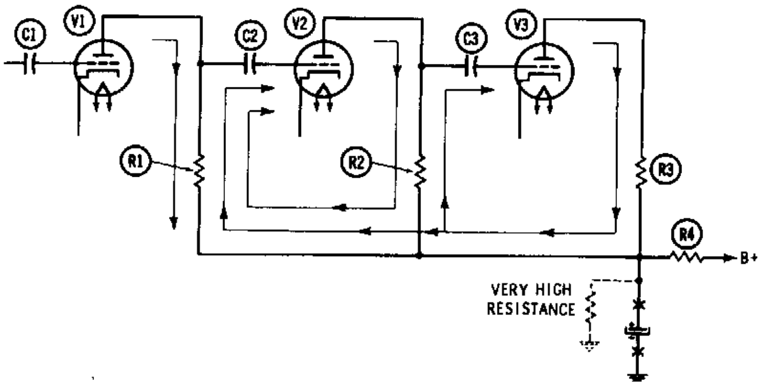


Fig. 8-7. Signal paths when bypass capacitor opens.

The scope is the best "weapon" for checking on this. Touch the scope probe to each of the dc power supply connections. You should never see anything but a nice "straight dc line." The presence of any signal on dc power supply lines shows that this circuit definitely does not have the absolute zero impedance that it must have if the amplifier is to work without feedback.

If one unit in a multiple-section electrolytic has gone bad, always be sure to replace the whole thing. The conditions inside the can which caused this one to fail will cause trouble in the others, in a very short time.

HEAT-SENSITIVE RESISTORS

A common trouble is the amplifier that "sounds all right when I first turn it on, but sounds awful after it works for a while," or "gets weak as it gets hot." This is some kind of *thermal* trouble; it is caused by some part in the amplifier getting hot and changing in value. The most common thermal troubles are resistors, although now and then a capacitor will do the same thing. A common example of this is the amplifier that won't work while in the cabinet, but when taken out on the bench for service, works for hours. This is because the amplifier chassis is better ventilated out in the open and stays cooler.

To find such troubles quickly, apply heat. One trick is to cover the amplifier chassis with a cardboard box, cutting off all ventilation (with it out of the regular cabinet, of course) and letting it run until the trouble shows up. Then take the box off very quickly and make tests of voltages, stage gains, etc., until you find the offending stage.

Once the stage is located, you can apply heat to individual parts by holding the tip of a soldering iron on them. You can tell very rapidly whether a given part is causing trouble. If any doubt remains on a resistor for example, take it completely out and hook an ohmmeter across it. Note the resistance reading and then heat it up, If the resistance changes more than about 5%, it is a good idea to replace it. Several resistors in the same stage, or the same amplifier, may be changing in value, so don't stop when you find the first one.

Some resistors will go up in value—most of them do, in fact. However, now and then you will find one that goes down. This makes no difference; if it changes in value at all, it is definitely bad and should be replaced.

Tubes will sometimes short out. When they do, a very heavy current is drawn through resistors in their circuits. This may overload and overheat resistors to such an extent that they will become thermals. Look for signs of overheating and charring, or a bad discoloration of the color-code paint. A good color to check is red; if the resistor has been overheated, the red stripe will turn a brownish-grey.

NOISY CONTROLS

Guitar amplifiers use standard carbon-element variable resistors for volume and tone controls. After a certain length of time, these controls get very noisy. If they are not worn too badly, they can be repaired by spraying contact cleaner into the body of the control. This washes away dirt and dust and cleans the sliding contact that is responsible for most of the noise. The standard test is to turn the amplifier on, turn the control rapidly up and down, and listen to the speaker. If the control is still noisy, you will hear it. In this case, replace it.

Worn controls must be replaced. The most common control used in these circuits is a standard audio taper of whatever resistance is needed. The 1-megohm control is often used, but you will find everything from 0.5 megohm to 2.5 megohms in use. These are not too critical; you can replace a 0.5 megohm with a 1 megohm if you have to, and there will not be a lot of difference in the performance. Exact duplicate replacements are best, of course.

FOOT-OPERATED CONTROLS

Because the guitarist's hands are usually pretty full, some instruments have foot-operated volume controls like that shown in Fig. 8-8. This is a standard volume control mounted in the foot-pedal assembly so an up or down movement of the foot raises or lowers the volume. It is connected into the amplifier circuits through a shielded cable and plug. These are usually wired in such a manner that the panel volume control is disconnected automatically when the foot control is plugged in.

In some a rack and pinion gear arrangement is used to move the control. Others have a cable-drive arrangement that does the same thing by means of

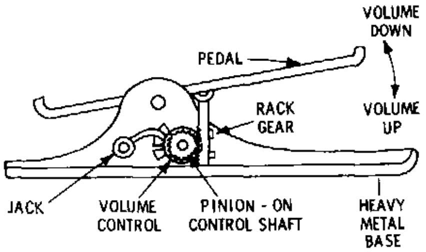


Fig. 8-8. Foot-operated volume control.

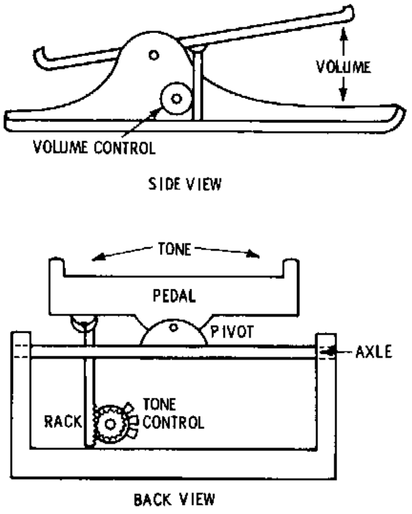


Fig. 8-9. Foot-operated tone and volume control mechanism.

winding a cable around the volume-control shaft. Slack is taken up by a spring.

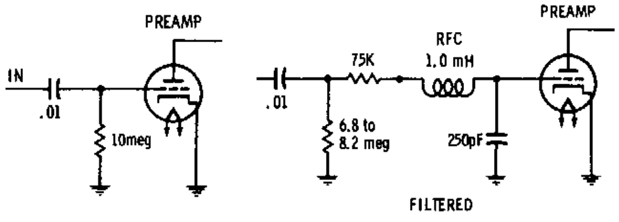
In a more elaborate version, straight up and down movement of the foot controls the volume, while rocking the foot from side to side controls the tone. A typical unit is shown in Fig. 8-9. The same basic hookup is used here to get the control action; there is just more of it. In one other application of the foot control, a simple on-off switch operates the vibrato on amplifiers equipped with this feature. Tremolo and reverberation circuits are often fitted with foot-operated switches too.

RADIO-FREQUENCY INTERFERENCE IN GUITAR AMPLIFIERS

As in all other kinds of electronics work, you will find the odd and unusual cases that will drive you crazy! Here is one of them that the author encountered. A string band, using one very large and one medium-sized amplifier, got along fine until they made a radio broadcast from the station itself. In the studio all of the instruments sounded so very peculiar that they finally had to turn off the amplifiers. This, to their surprise, cured the troubles.

The problem was traced to radio-frequency (rf) pickup in the input of the guitar amplifiers. Since studio and transmitter were in the same building, there was a very strong rf field all around them. The transmitter signal was being detected by the grids of the amplifier input stage. This generated a very high grid-leak bias (high negative voltage) and drove the input stages nearly to cutoff. Naturally, this caused a very severe distortion.

The cure was simple. Since the trouble was due to the presence of rf on the grids, a very small bypass capacitor was connected directly from grid to ground at each tube socket. Such a capacitor has a very low impedance at radio frequencies, so it makes a short circuit to ground for them. However, its impedance at audio frequencies is very high, so it doesn't affect the guitar tones. Fig. 8-10 shows how this is done. If the capacitor alone does not entirely clear up this kind of interference, the small rf choke shown can be added in series with the grid.



(*A*) *Original circuit.* (*B*) *Modified circuit.*

Fig. 8-10. Eliminating rf interference.

MICROPHONICS

Microphonics is a word that needs more explanation. Previously it has been said that a contact mike can act as a microphone, picking up extraneous sounds in addition to string vibrations. Trouble very much like this can develop if one of the tubes in the front end (input stages) becomes microphonic—translation, it acts as a microphone. Sound vibrations in the air can cause some of the tube elements to vibrate; this affects the electrical signals passing through it. The general result is a loud BONG when the amplifier chassis is touched or jarred. In bad cases tubes can even cause acoustic feedback, just like putting a microphone too close to a speaker. When the volume is turned up, the amplifier will howl dismally.

There is only one known cure for this—replace the tube. Some early efforts used special rubber-mounted sockets and fiber tube covers to damp out the sound vibrations, but these were pretty unsuccessful. The best cure is the use of specially designed nonmicrophonic tube types, like the 5879 shown in the microphone input circuit of Fig. 2-17. These are built with all elements rigidly held in place so they cannot vibrate when sound waves strike them. This construction keeps the tubes from becoming microphonic.

Transistors are very seldom microphonic because of their construction. However, nothing is impossible in electronics, so you may find a microphonic transistor before you finish reading this book. If you do, the same remedy applies—replace it. Most silicon transistors are comparatively noise-free and so far have given absolutely no trouble with microphonics or other noise effects.

INTERMITTENT AMPLIFIERS

The most infuriating complaint on an amplifier, or on any kind of electronic gear is an intermittent—one that works beautifully and suddenly quits. Then, in the standard intermittent, it starts working again just as if nothing had happened. Usually this happens just as soon as you get it out of the box and start looking for the cause of the trouble. You can hammer on it and do anything you want with it, and it plays on, just like new.

There are ways of dealing with these things. Intermittent operation means one thing—there is a loose connection somewhere. If the amplifier is playing and suddenly stops, only to start again in a moment, something is breaking the signal path. A tube is going dead, a coupling capacitor is opening up, or a resistor is opening and closing.

There are two main kinds of intermittents, physical and electrical. The physical type can be jarred to make it cut in and out. Something in there is mechanically loose—a bad solder joint, broken wire, an intermittent coupling capacitor, a dirty tube socket, etc. The electrical type can be hammered on with no effect; the amplifier simply cuts out when it gets ready to. The latter are the most annoying intermittents, of course.

If you find a physical intermittent, take the amplifier out of the cabinet, set it up on the bench, feed a continuous signal through it so that you can tell when it cuts out, and then tap every part in it. Right now you have no ideas at all as to where this thing is located; it could actually be caused by almost any part in the whole amplifier.

Here is another place to use the process of elimination. Start at the power output tube socket, and tap all of the parts in the signal path—coupling capacitors, resistors, tube sockets, tubes, etc. Use something like a pencil eraser or an insulated tool of any kind. If you get close to the cause of the trouble, you will notice that you hear a pop every time you hit a certain part. This is very apt to be the one you are hunting.

Don't hammer on the whole chassis; this does no good at all. What you must do is tap or jar certain parts without moving the rest of the amplifier in an effort to pin down the trouble to a small area. If you jar the whole chassis naturally you are going to get a response. Take it easy, and hammer gently and selectively.

Dirty or old tube sockets are a common cause of physical intermittents. Put your finger on the top of each tube, and move it around in the socket. If you hear a popping or scratching noise, the tube pins and the socket contacts are dirty. Take the tube out, spray contact cleaner into the socket, and straighten out the pins. Put the tube back in. Push it up and down several times in the socket; this scrapes the corrosion off tube-socket contacts. Now tap it again, and see if the noise has stopped. If it has not, substitute a new tube and try again. The original noise may have been inside the tube itself (a common trouble not too long ago, but not so common now, with improvements in the internal construction of vacuum tubes). Don't replace the tube first in this case; clean up first. You may put in a new tube with clean pins, and throw away a perfectly good tube with dirty pins.

If the new tube doesn't stop the noise, then it must be coming from one of the parts connected to this particular tube. Turn the amplifier over and give these parts a good working over with your hammering tool. Look closely at every solder joint around the socket; some of them may be bad. In printed-circuit amplifiers it is often helpful simply to resolder all connections around that socket; melt each one, apply just a tiny bit of fresh solder, and let it cool. In the early printed-circuit boards this kind of trouble was common, but here again material improvement has stopped a lot of it.

The most annoying type is the electrical intermittent. No amount of hammering will affect it; it just suddenly stops working when it gets good and ready! Of course if it stays out, it is easy to locate the trouble by signal-tracing—but it usually doesn't. Many will cut out, but will come on the moment a test probe is placed anywhere on the circuit.

There are ways of dealing with these, of course. One good way is to connect indicators of some kind to several points in the circuit. For example hook the scope to the grid of an output tube, a vtvm on "ac volts" to the plate of an amplifier tube, and a dc voltmeter to some point along the B+ supply lines. Now, turn the unit on and wait until it cuts out. By checking the reading on each of the indicating instruments, you can get some idea of where the circuit is opening. In this example, if the scope shows that the signal disappeared from the grid of an output tube, but the ac vtvm shows no change in its reading, then you have the defect pinned down to somewhere between those two points. Move the scope one stage closer to where the vtvm is connected, and try again. Eventually you will be able to close in on the thing and find out exactly which part is giving trouble.

Many intermittents are thermal—they show up after the amplifier has been turned on long enough to get thoroughly warmed up. In these cases some part expands physically due to heat and breaks the circuit.

For example, a paper capacitor that has been installed with too much tension on the connecting leads will open with heat; when the capacitor expands, the end of the capacitor is pulled loose and it becomes open, stopping the signal.

To catch a thermal intermittent, put the amplifier on the bench and cover it up with a cardboard box, blanket, or anything that will hold the heat in. Let it get hot and cut out, and then you will be able to find the bad component easily. Try applying heat to suspected parts of any kind with the tip of a soldering iron; this will often cause intermittents to show up.

Some units operate in reverse; they won't work at all until they are thoroughly warmed up. Then they come on very suddenly, and refuse to cut out at all until they are cooled off again. There is a way to deal with this, too. You can get coolant fluid in spray cans at electronic parts houses. This can be sprayed on suspected parts to cool them off, possibly making the trouble show up.

The easiest way, of course, is to cool the amplifier off, and check it by signal tracing while the part is defective. However, this can have its drawbacks. Many chassis will not cool off enough to cut out for a long time after they have started to work. One exasperated technician put an amplifier like this into his deep freeze and really cooled it off. He found the trouble very quickly, too, I might add.

SUMMARY

Servicing guitar amplifiers is not difficult if you use the right methods, and, above all, if you know how the circuits work. A logical method of eliminating first one possible cause and then the next will lead you to the real cause of trouble in the shortest possible time.