PROFESSIONAL RADIO SERVICING TECHNIQUES

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PIONEER HOME STUDY RADIO SCHOOL

NRI

★ THIS IS YOUR FIRST SPECIALIZING LESSON ★

STUDY SCHEDULE NO. 36

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. The Customer's Complaint ....Pages 1-10

Let the customer talk, because he can often give you valuable clues to the location of the trouble, and because *his* complaints are the ones you are expected to clear up. To help you to recognize various complaints when described by the customer or when you are checking receiver performance yourself, we take up here in detail the identifying characteristics of each of the ten common complaints encountered in radio work.

☐ 2. Basic Defects in Radio Receivers ....Pages 10-19

A radio receiver generally fails because of a simple defect in just one part. Locating this defective part takes at least 90 percent of a Radiotrician's time on the average job. The actual repair or replacement is usually a simple matter once the trouble is found. Here we review just about all of the defects which could possibly occur in each type of radio part, so you will know what to expect in the way of defects when looking for the trouble in a receiver.

☐ 3. Complete Professional Servicing Procedure .....Pages 20-28

The ten steps in repairing a radio receiver the professional way are outlined in this section. Remember them—use them according to the instructions—and you'll save many hours of time in locating troubles.

☐ 4. Answer Lesson Questions, and Mail your Answers to N.R.I.

☐ 5. Start Studying the Next Lesson.

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PROFESSIONAL RADIO SERVICING TECHNIQUES

The Customer's Complaint

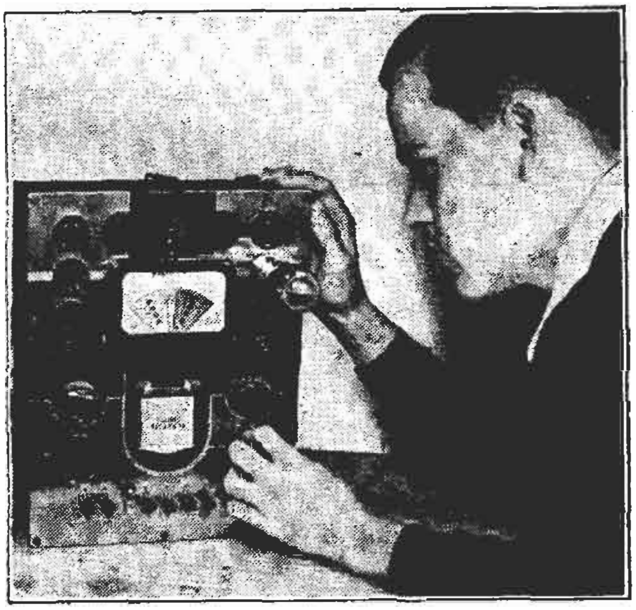
WHEN you as a Radiotrician are called to service a radio receiver which has been in use for several months, it is reasonable to assume that some defects have developed in that receiver. The customer's complaint will be based upon a definite change in the performance of the receiver, and his description of this change in performance can be an important clue to the actual technical defect.

In rare cases, you may be called to service a receiver which has been in use only a few days. Here it is entirely possible that the customer is expecting too much of that particular set. Your job then involves explaining the limitations of various types of receivers.

One thing a Radiotrician must recognize right from the start is that no radio receiver is perfect. Modern receivers are the result of an engineering compromise between desirable technical characteristics, cost and sales-getting features. Thus, good selectivity and exceptionally high fidelity cannot both be obtained at the same time. A communication receiver has good selectivity at a sacrifice in fidelity; a high-fidelity broadcast-band receiver has poor selectivity; the average home radio has a compromise between the two; the large, high-priced home radio may have a special circuit and an extra control which permits changing the selectivity and fidelity characteristics at will.

A radio engineer or a well-trained musician might object to a receiver having harmonic distortion greater than 5%, yet the average customer would not ordinarily notice a gradual rise in harmonic distortion to 10%. It is only when a circuit defect occurs which garbles speech and music or makes reproduction raspy or unintelligible that the average customer calls a serviceman to eliminate distortion.

► Poor sensitivity is a typical example of a complaint which is sometimes unjustified. A particular receiver may be entirely satisfactory to a person desiring only reception from nearby powerful stations, yet this same set might be inadequate for a rural listener who must depend upon distant stations for his programs. Your job as a Radiotrician is to restore the original performance of the receiver, not to



A portable tester like this is excellent for a new servicing business because it serves equally well for bench work and for testing tubes in homes of customers. Here's a practical tube-testing tip—remove only one tube at a time from the receiver for testing, so you can replace tubes correctly without looking for chassis markings or tube layout diagrams. This rule is particularly important when the set has no markings on tube sockets.

change or improve the factory design. If the receiver itself is inadequate for the customer's requirements, by all means recommend that he obtain a more suitable set for his purpose.

By checking the performance of each receiver which passes through your hands, you will quickly acquire the ability to predict the type of performance each receiver can be expected to give, and will have no difficulty in determining whether or not a customer's complaint is justified.

LET THE CUSTOMER TALK

Ordinarily, about all you will know after a customer phones is that his receiver is not working satisfactorily and that he would like you to fix it. You can often secure additional helpful information from the customer, however, either over the phone or at his home.

First of all, let the customer describe in detail exactly what he is complaining about in the way of receiver performance. The customer may have several complaints, so be sure to let him tell you about all of them. You must remember that people's tastes differ greatly as to what is and is not good in radio reception, and you cannot do a satisfactory repair job unless you know exactly what the customer expects.

Don't ask the customer outright, "What's wrong with the set?" Use questions like these: "How is the set acting now? When did the trouble first start? Did it come suddenly or gradually? Did you notice any other trouble before this really serious one started?"

After securing this information from the customer, turn on the set and check its performance yourself to verify the customer's complaint and to see if there are other clues to the location of the trouble.

If the receiver is dead when you first try it, always check for removed tubes, a disconnected power cord plug, a disconnected antenna or other disconnected leads. Oftentimes people will disconnect wires or remove tubes as soon as trouble develops, in the hope of preventing further damage to the receiver.

Defects like howling, noise, hum or severe distortion are easy to recognize, but they may mask other troubles which existed previously. Furthermore, defects like occasional noise, inability to pick up certain stations, fading, blasting or intermittent troubles are not so obvious and sometimes would not even be noticed by a Radiotrician during an initial check of performance. Considerable time can be saved by allowing the customer to tell how his receiver is misbehaving, hence listening to the customer is an important part of every professional servicing technique. You'll find that most people are willing and anxious to talk, if only you give them a chance and listen respectfully to what they say.

TYPES OF COMPLAINTS

No matter how a customer describes the complaints, you can usually recognize them instantly and place them in one or more of the following groups for purpose of analysis:

1. *Dead receiver.*
2. *Noisy reception.*
3. *Annoying hum.*
4. *Squealing or howling.*
5. *Distortion.*
6. *Low volume.*
7. *Poor sensitivity.*
8. *Poor selectivity.*
9. *Station interference.*
10. *Intermittent reception.*

We will now take up in turn each of these major complaints, and learn what clues to look for in each case in order to recognize and verify the customer's complaint while checking receiver performance. In many instances, we will also take up effect-to-cause reasoning techniques for localizing the trouble in a general way. It should be pointed out, however, that this lesson is just a preview of the entire field of professional servicing. *Later lessons will give you more detailed instructions.*

1. Dead Receiver. The customer may simply say that the set does not play, but even in a dead receiver there may be clues indicating the nature of the trouble. If the pilot lamps light up, you know that the set is receiving power from its source. See if all the tubes light up or get warm. Listen for the low-level hum and weak rushing sounds which are heard on almost any receiver when no stations are tuned in. Hearing these means that the power supply and loudspeaker are very likely good. Also listen for the normal rushing sound usually heard when the volume is turned up with no station tuned in (proof that the stages between the volume control and loudspeaker are good). A popping or clicking sound should be heard from the loudspeaker when the ON-OFF switch is turned on and off quickly after the receiver has been operating for a few minutes; failure to get it can mean a loudspeaker defect, power pack defect, or an a.f. output stage defect.

In the case of an all-wave receiver, try to tune in stations on two or more of the ranges. If reception occurs on any band, then the trouble is in the preselector or oscillator section for the dead ranges.

Even simple listening tests like this can yield valuable information from a dead receiver. For example, a low-level hum heard all the time the set is on, associated with a popping sound when the power switch is manipulated, means that the main power pack is functioning. Absence of all of these symptoms is an indication that the power pack is dead, the last a.f. stage is dead, or the loudspeaker is defective.

► Other combinations of symptoms will give other conclusions as to the source of trouble, once you have learned to analyze the customer's complaint and verify it by checking the performance of the receiver yourself. Truly, a thorough check of receiver performance is an important part of professional servicing techniques.

2. Noisy Reception. A certain amount of noise is always present both in amplitude and frequency-modulated receivers, in phonograph amplifiers and in public address amplifiers, even when the units are operating properly. The same phenomenon of noise is present in television receivers, though here it appears as white spots on the screen rather than as sound. The constant quest of design engineers for a high signal-to-noise ratio is evidence that noise is a real problem in any system of radio reception or sound amplification.

If it were not for noise, distant broadcast band reception would be limited only by the gain of the receiver, and it would be unnecessary to have high-power transmitters.

Noise is a Radiotrician's problem only when it becomes greater than is normal for the particular system in question. Here again, considerable judgment is required to determine whether or not the amount of noise is normal. By checking performance of good receivers whenever you have an opportunity, you will quickly learn how much noise to expect from various types of sets with various types of antenna systems.

Noise which is due to something entirely outside of the receiver is called *external noise,* to distinguish it from *internal noise* which is due to a receiver defect or to limitations in receiver design.

External Noise. Spark-producing devices like motors, generators, vibrators, diathermy apparatus, household electrical appliances with moving contacts, electro-medical devices, ignition systems in automobiles, and oil burner electrical systems all produce a type of interfering noise which is often called *man-made* static. Manufacturers of electrical equipment are today turning out units which produce a minimum of noise interference. Special noise filters are available for apparatus which is producing excessive noise interference, and their installation is covered elsewhere in the Course.

Noise-reducing antennas on receivers will reduce the effects of external noise signals, so whenever the source of noise is something beyond your control (streetcar motors, elevator motors in buildings, and power stations are examples), you should consider noise-reducing antenna systems.

In addition to man-made interference, we also have nature's source of noise, consisting of electrical disturbances produced by local or distant electrical storms and by lightning discharges. Natural noise is known as atmospheric disturbance or static. In a broadcasting system employing amplitude modulation, little can be done to reduce the effects of atmospheric disturbances. With a good frequency modulation receiver, however, radio reception can usually be enjoyed right through the strongest local electrical storms.

Internal Noise. Noise originating inside a radio receiver can be due either to an actual circuit defect or to certain unavoidable and natural characteristics of radio tubes and circuits.

A poor connection in a receiver can produce a crackling noise which interferes with reception and is hence a justifiable customer complaint. Jarring of the receiver or tapping on certain parts will usually increase the intensity of this noise. Your job as a Radiotrician is to locate and correct the faulty connections or locate the faulty part which is the cause of this type of internal noise.

Circuit noise exists because of the erratic motions of free electrons in conductors. These movements increase with temperature, hence the effect is called *thermal agitation.* The electron movements produce small voltages in conductors. When these voltages are in the input stage of a receiver, they are amplified thousands of times by the high-gain tubes in modern receivers, and the result is a characteristic rushing noise.

In addition, we have in every radio tube another type of noise which is known as the "shot effect." It is due to the irregular movement of electrons from the cathode to the plate inside a vacuum tube, a movement which is often compared to the falling of sand or raindrops on a tin roof.

Tube and circuit noises together produce a noise signal which is only a few microvolts at the most, except possibly in the frequency converter tube where it is much higher. This internal noise is a sort of hissing sound. It is most evident when the set is tuned off a station and the volume control advanced for maximum loudness, for the a.v.c. system is then set for maximum r.f. gain, and the a.f. system is getting the entire output of preceding stages.

To make sure that signals will override noise originating in the frequency converter tube, receiver design engineers place an r.f. amplifier stage ahead of the converter whenever cost and design considerations permit. This extra stage makes distant reception more enjoyable. Without an r.f. stage in a super, the noise in the frequency converter would be the chief factor limiting distant reception.

When confronted with a customer's complaint of noisy reception, determine first whether you have an internal or external noise problem. The simple procedure for determining this quickly is given elsewhere in the Course.

3. Annoying Hum. If you listen intently, you will ordinarily be able to hear hum from the loudspeaker of any receiver operating from an a.c. power line, from a vibrator-type power supply, or from a motor-generator set. Keeping this normal hum below the level at which it becomes objectionable is an important design problem.

In high-fidelity receivers which reproduce sounds as low as 30 cycles, considerably more hum reduction is required than in midget or table model receivers which do not reproduce much below 150 cycles. In any receiver, the hum should be only barely audible, and listeners in the same room should not be conscious of its presence during a program.

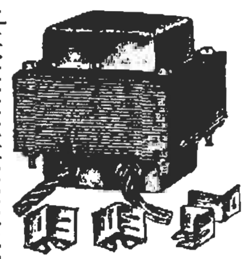
There are a number of receiver defects which can cause the amount of hum to increase considerably. Thus, the hum level may increase gradually as the electrolytic filter condensers in the power pack dry out, or when one half of the rectifier tube has considerably lower emission than the other half. On the other hand, the hum level may rise suddenly due to failure of a filter or by-pass condenser, or development of cathode leakage in a tube. Hum may become so intense that it overrides broadcast programs, or may be annoying only when tuning between stations.

Hum is one trouble which definitely irritates the listener. The longer he listens, the more offensive the hum becomes and the more critical he becomes of hum.

4. Squealing or Howling. In the days of regenerative receivers, it was normal for a set to squeal and to cause squeals in nearby receivers during tuning. This type of set is fortunately almost extinct now, but modern receivers may still squeal or howl when certain defects occur in circuits or parts.

Squealing due to external sources is rather rare today. There is little chance that the carrier signals of two broadcast stations will beat with each other to produce a squeal, because all stations are assigned frequencies not likely to produce interference and are required to maintain operation on assigned frequencies with a high degree of accuracy.

Occasionally, an experimental regenerative receiver or the oscillator circuit of a superheterodyne will radiate a signal and produce an audible squeal in nearby receivers. You can recognize this external squeal source by its intermittent nature and by the fact that its frequency varies as the offending set is tuned.



Example of a universal-mounting power transformer for radio receivers.

Internal sources of squealing are more numerous, and are covered in detail elsewhere in the Course. You may encounter squeals due to troubles inherent in the process of frequency conversion in a superheterodyne receiver. As a general rule, the number of tuned circuits in a receiver, its basic design and its i.f. value determine just how much of this trouble will occur. Also, squealing may be due to oscillation caused by an open by-pass condenser or misplaced connecting lead. The defect may be in the r.f., i.f. or a.f. system of the receiver, or can even be due to an open output filter condenser in the power pack.

Defects in the supply circuit filters of an a.f. amplifier, or defective by-pass condensers which are common to two or more screen grids of r.f. or i.f. tubes, can cause a put-put noise which is commonly called *motorboating.*

Loose or flexible elements in tubes or other radio parts, or even a thin, flexible chassis itself can give rise to a variable-pitched howl under the influence of powerful sound waves from the loudspeaker, giving an effect called *microphonics.*

The ability to recognize, localize and remove the cause of squeals, howls, motorboating and microphonics is an important part of the Radiotrician's work if he is engaged in radio servicing.

5. Distortion. When a customer complains that voice or music is muffled, harsh, raspy or unintelligible, you have a definite and justifiable complaint of distortion due to an internal receiver defect.

Equally important cases of distortion, however, are those situations where the customer's complaint is rather indefinite. He may say, *"It just doesn't sound right."* Careful questioning in cases like this will probably reveal that the customer quickly gets tired of listening to the receiver, or reveals that listening for an hour or so gives him a headache or makes him so irritable that he gets up and turns off the set in disgust. Certain amounts of distortion are not noticeable as such by the average person, but an hour or more of listening to distorted reproduction produces a definite reaction.

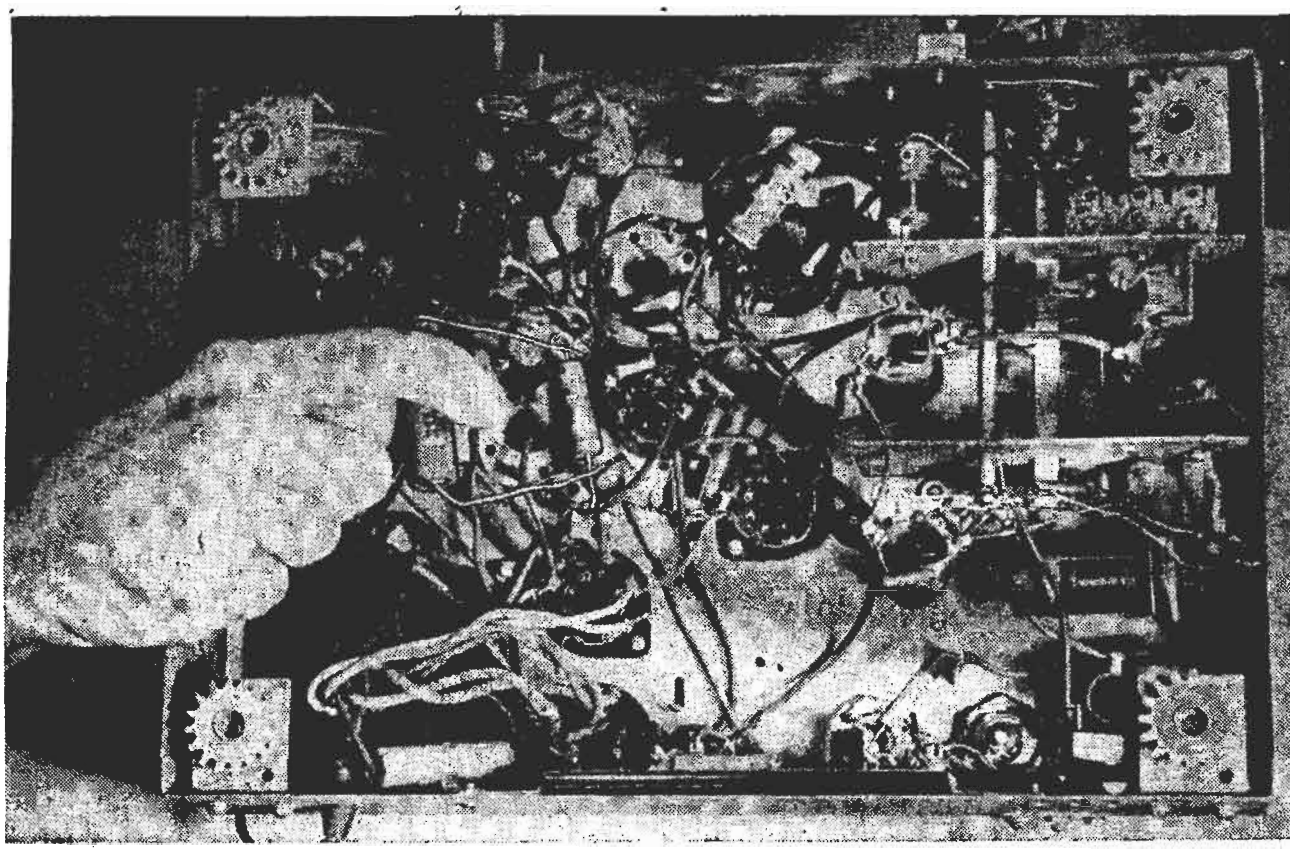
In the case of distortion, it is important to find out whether it occurs on local or distant stations or both, whether it occurs on all bands of an all-wave receiver, and whether it occurs only at high or low settings of the volume control or at all settings. Combining a thorough check of receiver performance with this additional analysis of the customer's complaint is an important feature of radio service work, because it helps to isolate the probable location of the defect.

There will be cases of distortion in which there is nothing you can correct. Thus, selective attenuation of the side-bands from sky-wave signals, or phase cancellation of signals at a location near the skip distance limits, can give distortion.

Distortion may be due to low emission in tubes, gas in tubes, defects in supply circuits which change operating voltages, or opens or shorts in some parts or in wiring.

Distortion can be due to improper alignment, and this in turn may be either the result of normal aging of parts or due to a breakdown in some part. Distortion may exist in the loudspeaker due to a weak field, to complete absence of field excitation, to a broken spider, to a rubbing voice coil, or to a damaged or old cone. It is your job as a radio serviceman to recognize and correct abnormal distortion. In fact, it would be rare indeed, except perhaps in the case of a trained musician, that you would be called at all for distortion which was not definitely abnormal.

6. Low Volume. The average radio receiver is so designed that reception of a fairly powerful local station with the volume control fully advanced and with an antenna of average effectiveness will overload the loudspeaker and perhaps produce rattling. Fortunately, however, the a.v.c. system in a receiver levels out variations in signal strength sufficiently to prevent excessive overloading of the loudspeaker or other stages at normal volume control settings. The average listener rarely advances his volume control fully; he is satisfied to know that the set has sufficient reserve "power" to blast out if he does advance the control.



The quickest and simplest way to check a by-pass condenser suspected of being open is by shunting it temporarily with a good condenser while the receiver is in operation, as illustrated here. It is the general practice to discharge the good condenser after each test, either by holding both its leads against the edge of the chassis for a moment or by touching the leads together.

With the possible exception of certain inexpensive midget sets, modern receivers will give more than sufficient volume for the average room in a home, even for weak local stations and for not-too-distant stations. It takes a little experience to be able to tell whether or not a receiver is delivering a normal amount of volume, but you probably know already what the acceptable volume is for ordinary types of sets.

When the volume is definitely lower than normal both for local and distant stations, but the tuning indicator reacts normally during tuning of stations or you can still tune in the distant stations, you can be quite sure that a defect exists in the audio system. It may be a low-emission tube, low electrode voltages on a.f. tubes, or weak field excitation for the loudspeaker.

When low volume is associated with poor sensitivity (the next complaint to be discussed), so that distant stations cannot be tuned in and the tuning indicator (if present) just barely works when stations are tuned in, look for a defect in the r.f. system.

When local stations come in with adequate volume but both volume and sensitivity are poor for distant stations, you can suspect a poor antenna system. It is easy enough to recognize the defect of low volume, but in applying professional servicing techniques you must go further and investigate every symptom which may help you to isolate the probable causes of the trouble.

7. Poor Sensitivity. A customer would probably describe the condition of poor sensitivity as inability to pick up his favorite distant station. Your first step is to determine whether the trouble is actually poor sensitivity, or whether it is a natural condition.

Ask if the customer has picked up that distant station regularly before, both summer and winter, with that *same receiver* and *same antenna system* in exactly that *same location.* For example, a New Yorker moving to Washington may complain of inability to get New York stations, yet his set was never capable of giving good distant-station reception.

If questioning indicates the possibility that the receiver is defective, check its pick-up performance by trying to tune in one or more distant stations on the receiver. Judge the sensitivity according to the manner in which the stations come in, making due allowance for the time of day and season of the year. Memorize the frequencies of several near-distant stations which can be picked up regularly in your locality with a good receiver, so you can tune them in quickly when checking the sensitivity of a receiver.

If a receiver fails to give adequate volume on distant stations when used with an antenna known to be in good condition, then poor sensitivity is definitely the complaint, and is probably due to a circuit defect. It should be noted that the customer will generally complain of low volume rather than poor sensitivity, although both troubles are present when the defect is in the r.f. system.

Complaints of poor sensitivity are often not justified. For example, a customer may complain that a station 500 or more miles away came in clear and loud one day, but the next day was weak or could not be heard at all. This may be an entirely normal condition which is not the fault of the receiver; the trouble can be due to variations in conditions up in the stratosphere.

Complaints of poor sensitivity may also be due to normal variations in radio reception with changes in season. Reception is generally far better in winter than in summer, and better at night than during the day for broadcast band stations. This is a situation which most people recognize, but you will still encounter customers who will welcome an explanation of these peculiarities of radio.

You thus see that a radio serviceman is more than a trouble shooter and repairman. He must have a broad general knowledge of radio, covering the broadcasting system as a whole and covering basic design features. He should know, for instance, that a receiver with limited r.f. gain but high audio gain produces extremely loud signals on local and semi-local stations, but does not bring in distant stations.

8. Poor Selectivity. When the customer complains that a powerful local station prevents him from receiving a distant station on a nearby frequency, you have the condition of poor selectivity. It may be a condition inherent in receiver design, or it may be due to a circuit defect.

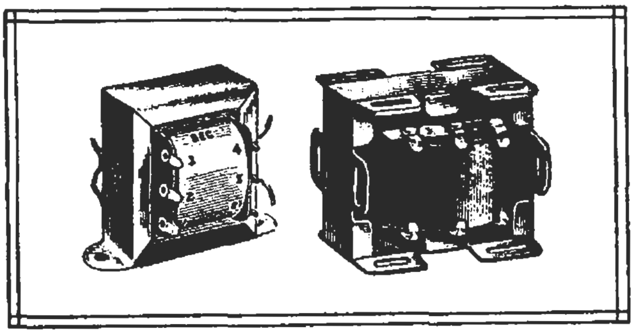
A leaky tuning condenser, a damp coil, conductive dirt on tube sockets, or dirt elsewhere in r.f. circuits can definitely produce poor selectivity. These defects lower the Q factors of resonant circuits, thereby lowering the sensitivity and selectivity of the receiver. In extreme cases the symptom of low volume may also be present.

On the other hand, poor selectivity may be due to the natural characteristics of the superheterodyne circuit employed, coupled with some local receiving condition. It may be the result of several stations operating on nearly the same frequency, with atmospheric conditions particularly favorable for reception of the more distant of the two stations, so that both came in at the same time.

Whenever a customer's complaint of poor selectivity is found to be due to atmospheric conditions, an explanation in non-technical language will satisfy and please the customer in most cases.

It is obvious that in this brief presentation of the complaints of low volume, low sensitivity and poor selectivity, we can merely mention only a few of the causes. Remember that all these troubles are taken up in greater detail elsewhere in your Course. They are mentioned here only to stress the need for more than casual recognition of the customer's complaint. The value of a thorough check of receiver performance cannot be stressed too highly in this study of professional servicing techniques.

9. Station Interference. There may be as many as 40 or 50 low-power stations operating on some frequencies. Under certain favorable atmospheric conditions, some are bound to interfere with each other, so that two stations having the same frequency are heard at the same time. This type of interference usually occurs at the high-frequency end of the broadcast band, because most of the low-power stations are crowded together here. You can recognize troubles of this sort by the fact that they occur only for a few stations, not for all signals received. Nothing can be done about it.



Examples of universal output transformers. Order one designed for use with the output tube or tubes in the set, and other specifications will usually take care of themselves.

When interference is due to a code station operating at or near the i.f. value of the receiver, or is due to image interference or to harmonics of the oscillator beating with a high-frequency station, a wave trap which is tuned to the frequency of the interfering station will give a solution. Many sets have a built-in wave-trap circuit.

10. Intermittent Reception. When a complaint exists for a short period of time and then corrects itself, you have the trouble known as *intermittent reception*. As one example, a tube filament can break in such a way that it opens after being heated for a short period of time, causing a dead receiver, but makes contact after the filament has cooled off. Reception is thus alternately good and bad, with the cycle repeating itself at regular intervals.

A break in a connecting wire inside or outside a part can cause intermittent reception. Thus, the internal connection between the pigtail leads and the metal foil of a paper condenser may break due to a strain during assembly of the condenser or during the wiring of the receiver. The break may be such that any vibration or heat in the chassis will cause a temporary open circuit. A loud portion of a program from the loudspeaker may break the connection, and jarring of the cabinet may restore the connection. Heat may likewise intermittently make and break such a defective contact.

In addition to being intermittently dead, the set may intermittently have any of the other receiver complaints, depending upon the location of the defect. Thus, if the condenser in question happens to be a screen grid by-pass condenser, the break will normally cause intermittent *oscillation*. If the condenser is a plate-grid coupling condenser in an audio amplifier, the complaint could be intermittent *weak reception* or *dead reception* during those intervals when the condenser is open.

Just imagine how many open connections you could have in the various coils, condensers, resistors, transformers, loudspeakers and tubes in a radio receiver. Imagine further the number of possible shorts, partial shorts and leaks which could occur. Combine these with the condition whereby the defect lasts only for a short period of time, perhaps vanishing as soon as you touch the set, and you have intermittent reception—a type of complaint which taxes the ingenuity of radio servicemen to the utmost.

In the customer's home, it should suffice to confirm the customer's complaint that an intermittent exists, and secure as detailed a description as possible of the exact nature of the trouble during the duration of the intermittent defect. It is well to do this, because the intermittent defect may not appear immediately when you turn on the receiver and check its performance. Find out whether the trouble is intermittent dead reception, intermittent hum, intermittent oscillation, etc. Knowing which one it is, you can localize your search to those defects which will produce the type of complaint observed.

Another valuable clue to an intermittent defect is the rate at which the set becomes intermittent and the regularity of the trouble, so be sure to ask the customer how often the trouble occurs. Intermittent troubles which recur at a more or less regular rate are due to heat, whereas troubles which occur at irregular intervals are due to vibration of poor connections.

In general, if an intermittent trouble does not reveal itself in ten or fifteen minutes while you are in the customer's home, it is best to check over the antenna, ground and power cord systems to clear them of suspicion, then remove the chassis and take it to your shop for further observation.

Basic Defects in Radio Receivers

A radio receiver is essentially an electrical assembly of tubes, resistors, condensers, coils, transformers, a loudspeaker, switches and connecting wires.

To emphasize the large number of parts which make up an average radio receiver, we made a census of the parts and connections in a typical modern seven-tube, two-band a.c. superheterodyne. (We used the Philco Model 41-230.) We found:

7	tubes
19	resistors
31	condensers
20	coil windings
42	socket connections
136	connections of parts
255	items total.

A defect in any one of these parts can produce one or more of the receiver complaints just studied. But this total is by no means a true indication of the number of defects we can have in an average receiver. Take tubes, for instance—in a typical pentode tube there can be over two dozen defects. Resistors and condensers can also cause a wide variety of troubles.

In order to get a better over-all picture of the problems encountered in radio servicing, let us now consider in detail the various kinds of defects which can exist in each kind of radio part. We need not consider mechanical defects like broken or crushed parts, since they can be spotted readily during the initial surface inspection of the receiver for obvious defects.

1. Vacuum Tube Defects. A tube tester is an indispensable instrument for any radio serviceman. The following defects occur in tubes and are revealed by tube testers:

Low Emission. Inability of the cathode or filament in a tube to emit the normal number of electrons when heated is revealed by a low (BAD) reading on the meter of the tube tester.

Open Elements. Some types of tube testers will reveal open elements, but this defect can also be identified readily by the action of the circuit. An open filament is readily detected because the tube will feel cold when touched, and no filament glow will be visible. It is always wise, however, to check the tube in a tube tester, because an open in the socket or in a filament lead can cause the same symptoms.

Shorted Electrodes. These are readily detected either with a tube tester, by circuit action, by continuity tests with an ohmmeter, or by voltmeter tests.

Leakage between Electrodes. Cathode-to-filament leakage often occurs in heater-type tubes. The trouble is revealed by most models of tube testers, but is not in itself sufficient cause for discarding a tube. Cathode leakage does no harm when the cathode and filament are both grounded or at the same potential with respect to ground. Leakage is important only when the cathode is ungrounded.

Excessive Gas. A certain amount of gas is present in all tubes, and causes grid current to flow. Only in high-resistance grid circuits is gas objectionable, however. A voltage test across the grid resistor constitutes a satisfactory test for gas, assuming that the preceding grid-plate coupling condenser is not leaky. Gas is one defect not ordinarily revealed by tube testers.

2. Socket Defects. Defects in tube sockets are sometimes visible on inspection, but more often a professional servicing technique is required to isolate the defect. It is quite important to realize that professional techniques are required to locate even simple socket defects such as the following:

Open Prong Contacts. Repeated insertion and removal of a tube from its socket may spread apart the prong contacts so much that they no longer grip the tube prongs. Faulty material used in the construction of a socket will cause the same trouble. When the defect cannot be detected visually, make a continuity check between the bottom end of the suspected tube prong and its socket contact.

Shorted Prong Contacts. Shorts can occur between adjacent contacts on a tube socket, particularly if a number of wires are grouped together on the contact lugs or there is excessive solder. This trouble can be suspected if noise occurs when the tube is wiggled in its socket. The remedy is rearranging of connections to the socket terminals.

Leakage. Dust or a conductive greasy film on the surface of a tube socket will provide a leakage path between socket terminals, with the trouble being most serious in the case of leakage between grid and plate terminals. Brushing the socket with a small, stiff round paint brush or a toothbrush will clear up this trouble and also identify it by restoring receiver operation. Charring of the insulating material of a socket between the high-voltage plate terminal and other terminals may also cause leakage paths. Charred sockets should be replaced.

3. Condenser Defects (Paper and Mica). The method of testing a condenser depends upon the nature of its defect and upon its capacity value.

Shorted Condensers. A short can occur in a condenser if a surge voltage punctures the dielectric, allowing the metal foil on each side of the dielectric to make contact. An ohmmeter will always reveal shorts in condensers. It is usually best to unsolder one condenser lead when making an ohmmeter test for a short in a part.

Leakage. This is the radio man's term for the condition whereby current "leaks" through a condenser due to a greatly lowered resistance between the condenser terminals. This lowered resistance may be the result of internal deterioration of the dielectric, or to an accumulation of conductive dirt on the surface of the condenser between the terminal leads. One condenser lead must usually be disconnected in order to make a leakage resistance check with an ohmmeter, because the leakage resistance value will be comparable to that of parts usually shunted across condensers.

There are many places in receivers where a small amount of condenser leakage is unimportant. An alert Radiotrician will recognize these and not waste time checking leakage in such locations. As an example, leakage in a condenser shunted across a cathode resistor is relatively unimportant. In other positions even a small amount of leakage is bad; thus, leakage in a grid-plate coupling condenser can cause distortion and other troubles. An alert, properly trained radio serviceman never makes unnecessary tests.

Opens. These are common both in paper and mica condensers, and occur particularly at the point where the pigtail leads are bonded to the metal foil inside the condenser housing. The most practical test for open by-pass condensers is simply to shunt each suspected condenser in turn with a good one of approximately the same capacity while the set is in operation.

An ohmmeter test for open condensers is not very satisfactory. A large condenser (disconnected from the circuit) may take a charge from the ohmmeter battery, causing a momentary deflection of the meter pointer, if it is not open. The amount of deflection depends on the ohmmeter range and on the size of the battery in the ohmmeter, as well as the capacity of the condenser. Only condensers above about .05-mfd. give a noticeable deflection, so smaller condensers cannot be checked this way at all. Shunting a suspected condenser with one known to be in good condition is the best test for open condensers.

An open can often be detected by wiggling each condenser in turn while the receiver is operating; noise will occur when the defective condenser is touched. Of course, the capacity test in a condenser tester will reveal an open.

4. Condenser Defects (Electrolytics). Electrolytic condensers perhaps require replacement more often than any other type of condenser used in radio equipment.

Wet electrolytic condensers become ineffective when not used for long periods of time. Modern dry electrolytics are much better in this respect, and will ordinarily give long life if not overloaded by excessive voltage and not dried out by excessive heat. Nevertheless, voltage surges and unusual climatic conditions will cause dry electrolytics to become defective.

Opens. These are rare in electrolytics, but high-resistance joints can sometimes occur internally at the junctions between the foil strips and the contact lugs or terminal leads, due to corrosion. Substitution of a good condenser is perhaps the most practical way to check this.

Shorts. A short will occur in an electrolytic condenser if an excessive voltage of the correct polarity is applied, or if voltage of incorrect polarity is applied for any length of time. In a wet electrolytic, the short will probably heal, but in dry electrolytics it is invariably permanent. An ohmmeter will reveal shorts.

Leakage. All electrolytic condensers have a certain amount of leakage, which is equivalent to a resistance shunted across the condenser. The leakage resistance can be measured with an ohmmeter, and will have different values depending upon the polarity of the ohmmeter connection. The leakage resistance will be larger when the positive terminal of the condenser is connected to the positive terminal of the voltage source in the ohmmeter. This is the correct connection for a check of leakage. Be sure to discharge the condenser by shorting its terminals before reversing ohmmeter leads.

An ohmmeter test gives only a general check-up of the condition of an electrolytic condenser. Better information can be obtained with a capacity tester, or by a simple substitution test. If connecting a good electrolytic in place of the suspected one clears up the trouble, you can be sure the defect has been located.

Poor Power Factor. A perfect condenser would theoretically have a power factor rating of zero, as compared to a power factor rating of one for a perfect resistor. Resistance in series with condenser capacity internally raises its power factor. A condenser with high power factor (approaching the characteristics of a resistor) dissipates energy just as a resistor does, and this produces heat in the condenser. This heat causes evaporation of the solution or chemical paste in the electrolytic condenser, raising the power factor still more and eventually drying out the unit entirely.

A condenser which feels hot to the touch is definitely drying out and has a high power factor. It should be replaced, because it will break down very soon due to the heat.

When you substitute a good electrolytic condenser and this clears up the trouble, you have identified the original condenser as defective.

5. Tuning Condenser Defects. Gang tuning condensers in receivers are particularly susceptible to mechanical damage because they are usually entirely exposed and have moving parts. Their troubles are as follows:

Opens. The mechanical construction of a tuning condenser is such that an open in its circuit is extremely unlikely; if it does occur, it will be at the terminals and can readily be repaired by resoldering. Continuity tests between the connecting leads and the rotor and stator will reveal the trouble.

Shorts. Mechanical strain applied to the chassis during handling, warping of the frame of the gang tuning condenser, warping of tuning condenser plates, loosened mounting screws, accidental dropping of the chassis, or tampering with the gang tuning condenser can cause a short between the rotor and stator sections. You can usually identify such a condition by a scraping sound heard when the unit is rotated. To test for shorts electrically, the coil associated with the gang tuning condenser must be disconnected temporarily if it is connected between rotor and stator plates. Shorts usually occur over limited portions of the movable range. Flaky conductive material, such as the metal plating applied to some condensers, can lodge between rotor and stator plates and cause shorts.

Leakage. The high-resistance range of an ohmmeter can be used to detect leakage in gang tuning condensers. The chief cause of this leakage is dust between the rotor and stator plates and on the insulating sections in the unit. The dust can be blown out or wiped out with a pipe cleaner of the type obtainable at any tobacco store.

Poor Contacts. Any resistance at the wiping contacts in a gang tuning condenser or in the stator-mounting screws is rather difficult to measure with ordinary test equipment; as just an ohm or so is appreciable here. Watch for poor wiping contacts serving the rotor section. This is a frequent cause of low sensitivity and poor selectivity, and also of r.f. oscillation. These three symptoms are thus a direct clue to poor rotor contacts in many cases.

6. Trimmer Condenser Defects. Both the air dielectric and mica dielectric types of trimmer condensers are fortunately reasonably free from trouble. Only in rare cases will they become open, shorted or leaky, and they then require testing like any variable tuning condenser. The mica type is subject to capacity changes as a result of changes in temperature or normal aging, but this is usually easy to recognize because it affects the alignment of the receiver. The mica dielectric can crack or flake, causing changes in capacity and eventual shorting of adjacent plates.

A change in capacity is one defect which cannot be located by simple meter tests; you must be able to recognize the effects of capacity changes on receiver performance.

7. Fixed Resistor Defects. As a general rule, low-wattage units (ranging from .1 watt to 3 watts) will be of the carbon or metallized type, and higher-wattage units will have wire-wound construction, oftentimes covered with a ceramic cement. You will occasionally encounter small 1- and 2-watt wire-wound resistors molded in a bakelite housing which resembles that of some carbon resistors, but these wire-wound units will rarely have more than about 5000 ohms resistance.

Resistors which crack or break in any way can usually be spotted visually, so we will concentrate here upon defects which can be located only by tests.

Opens. Overloading of a resistor by sending excessive current through it can burn out the resistance material or cause an open at the point where the wire lead makes contact with the resistance material. You can check for opens in resistors with an ohmmeter.

Shorts. A direct short between the two terminals of a resistor is not at all common. However, it is entirely possible for resistor leads to touch each other, to touch the chassis or touch other parts and give the same shorting effect. Also, resistors encased in metal can short to the metal case anywhere. When not visible to the eye, a short in a resistor can be located with an ohmmeter.

Changes in Resistance. Carbon resistors are particularly susceptible to changes in resistance, whereas wire-wound resistors rarely change. Overloading of a carbon resistor or even continued use at normal temperatures will often cause a marked decrease in resistance, which increases the resistor current and overloads it still more.

Volume control potentiometers should be replaced when they cause noisy operation.

The resistance value can be checked with an ohmmeter in the usual manner. Remember, however, that carbon resistors are generally used at points where a great deal of variation in resistance value is tolerated or where the resistor is operated well under its rated wattage. Normally, variations as great as 20% in resistance value are entirely permissible.

8. Variable Resistor Defects. Variable resistors and potentiometers are far more subject to trouble than fixed resistors. Since they are mechanical in operation, we have wear in moving parts to consider. As a rule, the defect will be readily apparent because rotating of the control knob while the set is in operation will cause noise or intermittent operation. An open volume control will not provide proper control of volume even though it may permit partial transfer of the signal.

Opens. In both carbon and wire-wound controls, movement of the contact arm over the resistance element may eventually wear away the metallic or carbon deposit, or wear down the nichrome resistance wire, creating an open. Loss of spring tension in the movable arm may also give an intermittent or full open.

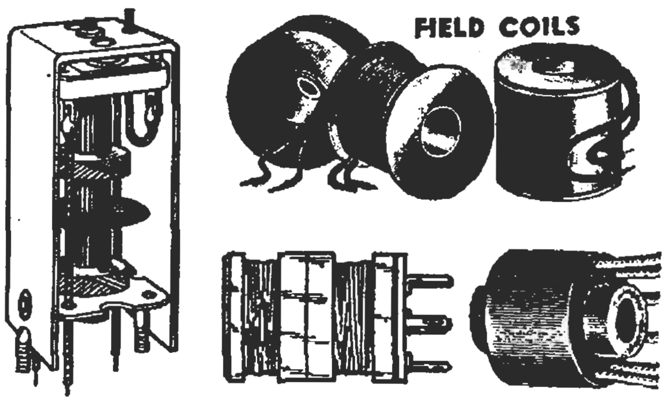
Wearing away of the resistance element reduces its heat-dissipating capabilities, so that a current-carrying control unit may be overloaded by normal current or momentary excessive current after it has worn down. This causes an open by burning out the resistance element. When the defect is not visible, an ohmmeter check will isolate the trouble.

Shorts. As with fixed resistors, shorts are not common. In units where the metal case is "hot" and an insulating bushing is used between the chassis and the mounting bushing of the control, a defective insulating washer or bushing will often create a short to the chassis. To locate a trouble of this sort, you usually have to unsolder all leads, then test between each terminal of the control and the chassis.

Change in Resistance. Wearing off of the carbon or metallized material in a variable resistor or potentiometer will cause the total resistance to increase, but this is not ordinarily of importance. The chief symptom in trouble of this nature will be noise. Manipulation of the control during the initial performance check should reveal this trouble, either by noise coming from the loudspeaker or by failure of the potentiometer to control volume or tone in a normal manner.

9. Air-Core Coil Defects. Here we are concerned with air-core r.f. and i.f. transformers as well as with r.f. chokes. Coils consist simply of copper wire and insulation, but several types of trouble can develop.

Lowered Q Factor. A coil which becomes damp or coated with conductive dirt will develop high r.f. resistance,

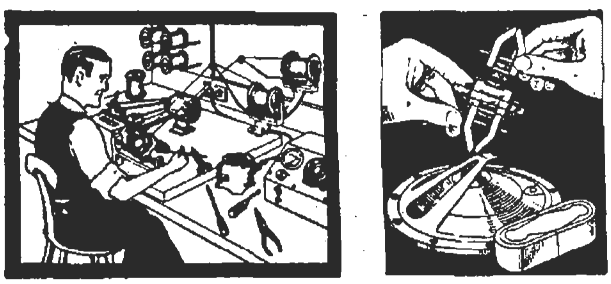


A number of different manufacturers produce exact replacement coils of all types.

which has the effect of lowering the Q factor. This in turn affects the operating characteristics of the stage in which the coil is used. For example, lowered Q factor in an r.f. coil can cause poor sensitivity or poor selectivity even in a properly aligned stage, and can cause low output in an oscillator stage. The Q factor of a coil could be measured with a Q meter, but this information would be of no value unless the normal Q factor and the permissible tolerance in Q factor were known.

Inspection of the coil and temporary adjusting of resonant circuit trimmers are the usual techniques for isolating the trouble to a coil having lowered Q factor. Trimmer adjustments will be sharp for a high Q coil, but quite broad for a low Q coil. Experience in evaluating receiver performance and adjusting tuned circuits will help you to decide when a coil should be baked out or replaced because of lowered Q factor

Shorted Turns. These may develop in all coils, particularly those employing special diamond, basket or bank windings. If a great many turns are shorted out, and the normal resistance of the coil is indicated on the circuit diagram, the defect may be detected with an ohmmeter as an appreciable reduction in coil resistance. Otherwise, the action of the circuit is the only clue to the trouble. For example, in the case of an r.f. coil in a resonant circuit, more capacity will be needed to align the receiver, and both sensitivity and selectivity will be poor even after alignment. We also have the possibility that adjacent coils may touch each other, particularly when wound close together or one over the other. Here an ohmmeter test from one coil to the other will verify the trouble.



Several mail order radio supply firms offer a coil repair service which involves rewinding of defective coils when exact duplicate replacements are not available. This service is also available for the coils of magnetic loudspeakers.

Opens. The windings in a tightly wound coil may break due to expansion with temperature, especially at points where the wire passes through the coil form or connects to a terminal. More often, however, corrosion at a terminal will create a high-resistance joint. In a primary coil which carries the plate current of a tube, the direct current may start electrolysis which causes corrosion and an open. Noise will be the first symptom that this condition exists. An ohmmeter test will indicate above-normal coil resistance and high resistance due to corrosion at joints.

10. Iron-Core Coil Defects. Since iron-core coils are used chiefly in audio frequency and power frequency circuits, we are not concerned with changes in Q factor. Actual mechanical defects in the coil windings or failure of insulation between windings are the two chief problems here.

Opens. These are readily detected with an ohmmeter. They can be due to electrolysis, particularly at the terminals of filter chokes where fairly high currents are flowing through joints formed by dissimilar metals. Of course, a sudden voltage surge or continued overloading of a coil with excessive current may melt the wire and cause an open.

Shorts. Shorts between turns due to failure of insulation are not readily detected with an ohmmeter, but it is usually possible to detect shorts between layers of windings because this creates a greater change in resistance.

Shorts in coils are best located by their effect upon receiver operation. For example, if there is a short in a choke coil, normal current will give a lower a.c. voltage drop than normal across the coil, with hum as the symptom. A short in a power transformer will cause overheating, with eventual production of smoke and charring of the insulation, and with lowered output voltage. These same effects will appear when turns are shorted to a grounded iron core and the transformer circuit is grounded at some other point, but the short to the core can also be detected with an ohmmeter.

An odor of burned insulation and a charred appearance is always an indication of a defect in an iron-core transformer. A hot unit without these symptoms does not necessarily mean a defective unit, however; a certain amount of heat is normal in transformers which are handling power. The exact amount of heat varies with different manufacturers and with different transformer uses; some transformers will operate quite cool, while others are designed to operate at the heat limit set up by the Board of Fire Underwriters.

Removal of all of the tubes is an easy way to check a power transformer for shorts; if the smoking and overheating stops when all loads are removed by doing this, you either have a broken-down filter condenser which is drawing excessive current, or you have a shorted tube or some other short to ground in a plate or screen grid supply circuit. If the smoking continues, the transformer itself is defective, or there is a short in the rectifier tube socket or in the transformer leads.

11. Loudspeaker Defects. In addition to becoming defective, loudspeakers are subject to normal wear and aging due to the fact that the voice coil-cone assembly is continually moving during operation. Once a defect has been isolated to the loudspeaker, you have the following possibilities to contend with:

Weak Flux. An open can occur in the field coil of an electrodynamic loudspeaker due to corrosion, electrolysis or over-loading. If the field coil is also serving as a filter choke, as is usually the case, the receiver will be dead. If there is a separate filter choke, there may be enough residual magnetism in the iron core of the loudspeaker to permit operation, but sounds will be weak and greatly distorted. A simple ohmmeter check will reveal an open field coil.

Weak and distorted reception will also occur when the permanent magnet in a p.m. dynamic loudspeaker loses its magnetism. You must remember, however, that there are many other possible defects in a receiver which can produce these same symptoms. The defect should definitely be isolated to the loudspeaker before making extensive tests on the loudspeaker.

Open Voice Coil. The voice coil may open at one of its joints or in the flexible leads which connect it to the output transformer secondary. The voice coil leads are subject to breakage even though extremely flexible, because these leads must connect between fixed terminals on the loudspeaker and rapidly moving terminals on the voice coil. An ohmmeter will detect an open in the voice coil if you first disconnect one voice coil lead from the output transformer.

Grounds. You can have a ground in the field coil, the voice coil or in a hum-bucking coil. Grounds can be found by a simple ohmmeter test between the suspected coil and the frame of the loudspeaker, if inspection of the circuit diagram shows that no ground should exist.

Defective Spider. The flexible material of the spider may become brittle and crack, or may lose its elasticity. When the condition is serious, the symptoms will be a peculiar type of distortion. Visual inspection of the spider will reveal the trouble in most cases.

Sometimes the spider will get loose at the points where it is glued to the cone, causing fuzzy tones. Regluing with cone cement will fix this. Partly loosened dust caps in the center of the cone will cause the same trouble.

Off-Center Voice Coil. As a loudspeaker ages, there is usually a certain amount of entirely normal warping and shifting of parts. Rough handling can cause this same warping and shifting, and the condition becomes serious when the voice coil rubs against the pole pieces.

Iron filings, bits of metal, or hard particles of dirt lodged in the voice coil can cause the same trouble as a shifted spider or other shifted parts.

You can detect a rubbing voice coil by pushing the cone in and out with your fingers when the receiver is turned off, for the vibration due to rubbing will be transmitted to your fingers, and you can hear the grating or scraping sound of the voice coil rubbing against the pole piece. The symptoms of an off-center voice coil are distortion of low notes and buzzing sounds. There is much more voice coil movement at low frequencies than at high frequencies, hence rubbing of the voice coil may distort men's voices without affecting women's voices.

Cone Defects. A cone may become hard and inflexible due to aging and drying out; the result is a rattle and failure to give normal fidelity. The outer edge of the cone, which is glued to the frame, may become loose and cause raspy, buzzing sounds and distortion at low audio frequencies. A cone may become softer than normal due to absorption of moisture, causing distortion. In a few cases the cone may actually crack or tear, causing distortion and giving a defect you can readily see on inspection. Yes, even cone defects require a certain amount of analysis for detection.

12. Defective Connections. Under this classification we have hook-up wire used for connecting together the various parts and tube sockets, and the tie-down terminals used for supporting small parts by their leads. A defective connection is an excellent example of a trouble which may require many minutes to locate even with professional servicing techniques, but which ordinarily can be repaired in a few seconds.

Opens. An open at a joint may be due to poor soldering at the factory in the first place. Remember that soldering, even with most modern production methods, is still a manual operation in which the human element is the predominating factor affecting quality.

As a rule, those entrusted with soldering operations in factories have had considerably more training in soldering techniques than the average serviceman, so opens at soldered joints are more likely to be present in equipment which was previously serviced. Oftentimes a soldered joint which looks good may be held together only by rosin, which is an insulator and hence causes an open. Corrosion and electrolysis at joints may cause opens, partial opens or even intermittent opens.

The procedure normally used to locate opens in wiring involves checking continuity from each tube electrode to the chassis, the rectifier plate or the rectifier cathode. Opens will then be indicated by comparison of ohmmeter readings with resistance values indicated on the circuit diagram.

Once the defective circuit has been isolated, the parts and connecting wires which make up the circuit can be checked with a step-by-step ohmmeter procedure, but more often the serviceman will simply push or pull on each joint in the suspected circuit while the receiver is in operation. The defective joint will cause noise when moved or jarred. Another favored procedure is application of a hot soldering iron to each joint in the circuit, to make the solder flow freely over the entire joint.

Shorts. Connections and bare leads sometimes short to the chassis or to an adjacent connection, particularly when terminal lugs are close together as on tube sockets and terminal strips. Where wires go through holes in the chassis, frayed insulation may allow the wires to touch the chassis and cause a short. In the case of a high-voltage lead such as a plate supply lead, sparks will be observed at the point of contact when the lead is wiggled.

Shorts may occur at joints, where the wire is bare and contact with the chassis or some other terminal is more likely. Oftentimes terminal lugs become loose or bent, or excessive solder is used in making connections at the lugs, with the result that a short exists.

When the circuit diagram indicates that a complete circuit is isolated from the chassis, a simple ohmmeter test between that circuit and the chassis will indicate whether or not a chassis short exists.

Leakage between connections is common and may cause trouble in r.f. circuits, but drying out of a moist or damp chassis will usually clear up the trouble. If it does not, new leads or parts will be required.

13. Switch Defects. The contacts of the various switches used in radio equipment may corrode, causing opens or noisy partial opens. Loss of springiness in the movable contact arm can cause the same symptoms and troubles. In addition, connections to the switch terminals may be open, shorted or partially open.

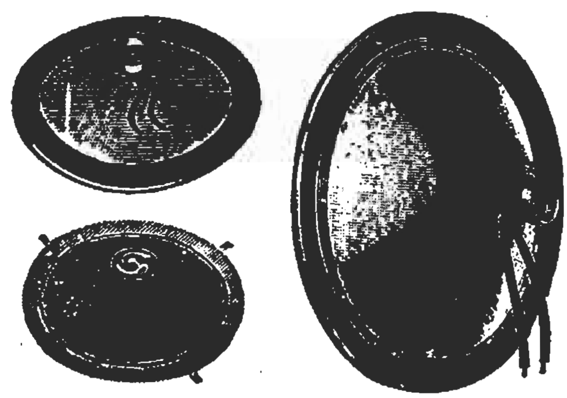
Circuit continuity tests will usually reveal switch defects quickly. It is not at all uncommon for a movable contact arm or for a terminal lug of a switch to break off and cause an open, and here also an ohmmeter continuity test will reveal the defect.

LOCATING DEFECTS

Once the defective part in a receiver is located, any one with a little mechanical ability and a knowledge of soldering can make the necessary replacement or repair in a few minutes. The real work of a Radiotrician is locating the defective part or connection, or locating the cause of the trouble in such cases as improper alignment of tuned circuits.

When the trouble in a receiver is simply a defective part or connection, and unlimited time is available, a person with a little training in the use of a tube tester, an ohmmeter, and perhaps a condenser tester can test each part and connection in the receiver until he locates the defective one.

Of course, the chances are good that the defective part will be located long



Exact duplicate replacement cones are made for practically all loudspeakers.

before running through the entire test procedure for all parts. But even if you were able to average 50 tests per chassis, you can readily imagine what an enormous amount of time is required when using a part-testing technique of this nature.

As a matter of fact, there are many servicemen, without the type of professional training you are now acquiring, who actually do test various parts one after another until they find the defect. With experience they learn that certain parts or connections should be checked first for each type of complaint. They become good guessers unconsciously, without knowing why, but with professional servicing techniques you can locate troubles faster than these men right from the start of your servicing career. Your techniques will work on all sets, whereas testing of parts will tell nothing at all about many kinds of receiver troubles.

Complete Professional Servicing Procedure

The preceding analysis of the many possible defects which can occur in a radio receiver indicates that there are a great many defects which can be detected by checking voltages with a voltmeter or by checking continuity with an ohmmeter. Nevertheless, the time required for such random tests leads to great inefficiency in servicing, and particularly leads to occasional jobs which take way too much time or cannot be fixed at all.

This means that the man who relies only upon a guess-and-try method of testing each and every part in turn will frequently find himself confronted with troubles which defy detection by his testing techniques. After wasting a great deal of time in testing parts, he will be forced to resort to such simple versions of professional servicing techniques as he is able to carry out. If given sufficient time, he may eventually be able to localize the defect, for as a last resort he can begin putting in new parts one by one until he eventually does find the trouble, but what a waste of time such a procedure is!

The professional servicing procedure presented here has as its goal the correction of the receiver defect in the least possible time. This goal eliminates immediately the guess-and-try test methods which are the chief technique of the untrained mechanic. To become a professional radio serviceman—a true Radiotrician—you must master a carefully planned series of professional servicing techniques. These utilize your training, ability and experience to ferret out the trouble in the least possible time.

Ten Steps. A *complete* professional servicing procedure for repairing radio receivers involves a maximum of ten distinct steps, as indicated in Fig. *1*. Success in carrying out Step 3 can, however, make possible the omission of up to five of these steps, and success in Step 4 may permit omission of the next four steps.

These steps are so planned that you will be led directly to the trouble in a logical, step-by-step manner, even when you do not have enough clues to lead more directly to the trouble. As your training continues, however, and as you gain more practical experience, you will soon find Step 3 assuming more and more importance. Thus, you will get a logical, direct approach to the trouble with a minimum of wasted time and effort. As you become more like the thoroughly trained professional, you will learn the short cuts which can frequently be used to save even more time.

Since the professional technique you want to develop involves use of all of these steps, let us now look into these steps in detail, to see just how they are related to each other.

1. Determine the Complaint. This has already been discussed in detail, and can be summed up here in just one sentence: *Find out exactly what the customer expects you to do.*

2. Confirm the Complaint. This involves trying out the set—checking its performance. The things to watch for while checking performance vary with the nature of the complaint, as you learned earlier in this lesson. In general, however, this step involves turning on the receiver, tuning to the dial settings of a few local stations and noting how they come in, then trying out the volume control, tone control, band-changing switch and any other controls with which are present, and noting how the tuning indicator reacts if one is present.

3. Effect-to-Cause Reasoning. When a receiver becomes dead, hums, distorts, howls, oscillates, has inadequate volume, has poor selectivity, has poor sensitivity, or has some other symptom which you have verified by checking receiver performance, there is definitely a *cause* for the observed condition. If you can figure out what that cause is by means of reasoning, it is only logical that you check the likely cause first.

Usually, however, there are a number of possible causes for each type of complaint encountered. To utilize effect-to-cause reasoning efficiently, you must know when to give up checking probable causes and start the next step in the procedure. Once you begin checking every possible cause for an observed symptom, you are really resorting to the guess-and-try methods of the untrained radio man.

► Proper use of effect-to-cause reasoning can be best explained by means of a few examples. Let us take first the case of a dead receiver. You know that a burned-out filament in a tube will ordinarily cause a dead receiver, so isn't it logical to suspect tubes when the symptom is no reception? Since you are eventually going to test the tubes in the receiver anyway, it is quite logical and permissible to test the tubes after you have made sure that the receiver is obtaining power and its antenna-ground system is normal. When tubes are cleared of suspicion, however, you have before you dozens of possibilities because a break anywhere in a signal circuit can cause a dead receiver. This is where you should give up effect-to-cause reasoning and proceed to the next step.

► How about oscillation or howling? You know that an open screen grid-to-cathode (or chassis) by-pass condenser will usually cause a stage to go into oscillation, so it is entirely logical to suspect and check the various screen grid by-pass condensers when oscillation is the symptom. This can be done quickly by the substitution method, placing a good condenser of approximately the correct value across each suspected screen grid by-pass condenser in turn while the receiver is in operation. If none of these tests restore normal performance, however, and there are no associated symptoms to limit the trouble to a particular section, your next move should be an inspection for surface defects, followed by the isolation procedures.

► A leaky input filter condenser will cause distortion, hum, an overheated power transformer and possibly red-hot plates in the rectifier tube. Therefore, if you observe all these symptoms, you would correctly question the input filter condenser. If it is leaking sufficiently to draw excessive current from the high-voltage secondary winding of the power transformer, it will overload this transformer and cause it to heat up excessively. Furthermore, the rectifier tube will be required to pass excessively high plate current, bombarding the plates and making them red hot. This high plate current may draw gases out from the plate and produce a glow discharge inside the tube, giving even greater plate current due to gas ionization. The excessive drain on the power transformer and the d.c. voltage drop in the rectifier tube will lower the d.c. output voltages for the signal circuit tubes, and this may cause distortion. The defective filter condenser and the greater load on the transformer will together increase the amount of a.c. ripple in the filter system, giving excessive hum.

► A thorough knowledge of circuit actions thus makes it possible at times to analyze a number of observed symptoms and reason out the exact location of the defect. It is unnecessary to memorize long lists of symptoms and possible defects when you are able to figure things out for yourself like this.

► In general, when there is only a single symptom, it is good practice to check first the more common causes of that particular trouble. For example, if the symptom is hum, it would be wise to check the rectifier tube, test the power pack filter condensers, and check cathode-heater leakage in those signal circuit tubes in which the cathode is not tied to ground.

► If the only complaint is distortion, and you are convinced that it is not due to a loudspeaker defect, check for leakage in a grid-plate coupling condenser in an audio stage before proceeding to the isolation technique, because a leaky coupling condenser produces a positive bias on an audio amplifier stage having R-C coupling, thereby causing distortion.

4. Inspect for Surface Defects. As there may be some surface trouble like a tube out of the socket or dead, plug out of the wall socket, grid cap off of a tube, etc., an inspection for surface defects should be made before going into the chassis.

This inspection may precede effect-to-cause reasoning, become a part of this step or follow it, depending on the complaint. It may even become a part of the second step, as you may confirm the complaint by seeing if the tubes light or get warm, sniff for odors indicating overloaded parts, and listen for noises as you rotate controls while trying the set.

The nature of the trouble, together with effect-to-cause reasoning, will suggest possible surface troubles to look for. If the set plays but is noisy, tubes are not dead; there is probably a loose connection or intermittent short somewhere, and thus this step may be a part of the effect-to-cause reasoning process.

Finally, if effect-to-cause reasoning does not suggest anything, it is still desirable to spend a minute or two looking over the surface of the set. However, don't waste time; learn to go over the surface of the set with a quick glance. If you don't see anything wrong, go on to the isolating steps immediately.

5. Isolate the Defective Section. A single test, oftentimes without instruments, will in many cases enable you to localize the trouble to a defective section.

Thus, if the receiver is dead but all tubes heat up, the logical next step is an isolating technique to determine which section of the receiver (power pack, a.f. amplifier, r.f. amplifier, i.f. amplifier, or local oscillator) is defective. In later lessons, you'll learn exactly how to do this.

6. Isolate the Defective Stage. By using appropriate techniques given later, you localize the trouble to the defective stage which is in the defective section.

7. Isolate the Defective Circuit. Once the defective stage is isolated, you can usually make a few simple circuit continuity tests or d.c. electrode voltage measurements to localize the trouble to a particular tube circuit in the defective stage (to the grid circuit, plate circuit, screen grid circuit or suppressor grid circuit). This eliminates quite a few parts from your list of suspects for the next step.

8. Isolate the Defective Part. Using either an ohmmeter or d.c. voltmeter as you prefer, you test the suspected defective circuit (or the suspected stage if circuit-isolating techniques cannot be applied) until you have tracked down the offending part. This should not be a haphazard task, however, for a rational step-by-step procedure will save time.

A logical general procedure for locating the defective part in the defective stage or circuit involves checking the tube first of all, if it has not already been checked. Next comes a check of the tube electrode supply circuits, either with a d.c. voltmeter or with an ohmmeter used with all power turned off.

► Electrode voltages are checked with respect to the cathode or chassis, after making sure that the main plate supply voltage to the stage is correct. If normal d.c. voltage is absent at some electrode, one probe is anchored to the cathode or chassis of that tube and the other is moved back along the supply circuit, part by part, until a point is reached at which normal d.c. voltage is obtained. By proper interpretation of the voltage readings, shorts or grounds can be detected. By watching the meter pointer, noisy connections and noisy parts can be localized.

► It is not always possible to locate a defect by means of d.c. voltage measurements. For instance, a defect in a signal circuit which is not carrying direct current would not be revealed by a d.c. voltage measurement. Coil defects, tuning condenser defects and certain grid circuit defects are examples. Grid bias voltages in high-resistance grid circuits can be measured accurately only with extremely high-resistance voltmeters, and these are not always available. For these reasons, some technicians prefer to use continuity tests for locating the defect in a stage. Continuity tests with an ohmmeter can be used to supplement d.c. voltmeter tests or can be used exclusively. It is a matter of personal preference in some cases, and a necessity forced by instrument limitations in others.

Continuity tests with a multi-range ohmmeter are made with the receiver turned off and with the power plug pulled out of the wall outlet. Continuity is checked first from each tube electrode (at the tube socket ter-

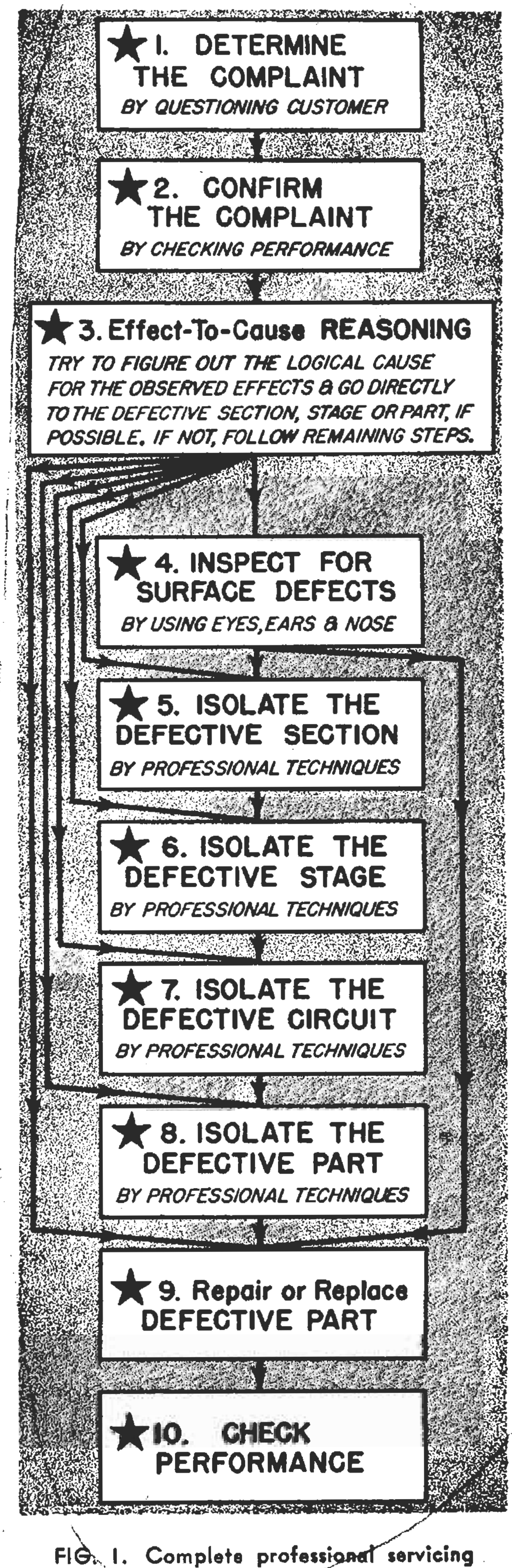


FIG. 1. Complete professional servicing procedure for radio receivers.

minals) to some reference point, such as the rectifier cathode or the rectifier plate, to establish existence of continuity in complete supply circuits.

If an infinitely high ohmmeter reading is obtained for any particular step, this indicates there is an open circuit. To find which part in the circuit is actually open, you can move the ohmmeter probes along and check each part, or you can check small groups of the parts, or you can leave one ohmmeter probe at one end of the circuit and move the other one back along the circuit, including fewer and fewer parts between the probes until the open is located.

This procedure will also detect shorts when the change in resistance due to the short is appreciable, in relation to the total resistance being measured. If you have a 20-ohm coil in series with a 100,000-ohm resistor, and check across both together, you could not tell whether the coil is shorted or not, as the reading would be so little different from 100,000 ohms that you would be unable to detect the presence of the coil. Values of low resistance parts must be checked directly across the part itself, to determine shorts.

Of course, we are just giving the barest description of the methods used —we'll go into them in detail later.

9. Repair or Replace the Defective Part. If the defect is traced to a poor connection, the repair is a simple mechanical procedure. If the trouble is traced to alignment, the correction of the trouble is likewise a mechanical procedure, but one requiring considerable technical knowledge and involving the use of test instruments.

When the trouble is traced to a defective part, it would appear that the simplest procedure would be to secure an exact duplicate replacement from the manufacturer of the receiver or one of his distributors. But remember that more than 10,000 different receivers and amplifiers have been built by hundreds of different manufacturers, many of whom are no longer in business, and that each of these sets contains a minimum of perhaps 50 different parts. If you insisted on making exact duplicate replacements and wanted to keep on hand a stock of all parts which you might need, your stock would be tremendous. On the other hand, if you carried no parts at all in your own stock, you would be ordering parts every day for service work.

Fortunately, radio parts are standardized to a great extent, thus making exact duplicate replacements unnecessary in the majority of cases. Thus, such parts as tubes, pilot lamps, single fixed resistors, fixed condensers of all types and batteries are replaceable with products of any make, provided size and electrical characteristics are suitable. When space permits even size can be ignored. Furthermore, electrical ratings can be overlooked in many cases. For example, an r.f. by-pass condenser originally specified as .01 mfd. can be replaced with a .1-mfd. condenser without a noticeable change in performance. Also, if the original condenser is rated at 400 volts, you can use a condenser having a higher voltage rating, such as 600 volts.

By stocking only basic parts and by making wise substitutions instead of exact replacements, the Radiotrician can conduct his business with a minimum of overhead expense and a minimum of wasted time. It is a matter of good business to keep the stock of parts on hand as small as possible, because parts require a capital investment and there is always the risk that purchased parts may never be used.

The ability to determine whether or not an exact duplicate replacement is required for a particular part can be acquired by experience, or can be figured out from your knowledge of how the part works in its circuit. A combination of experience and knowledge is the ideal situation and is the one you will soon possess.

Only in a few cases will it be necessary to order an exact duplicate replacement, and in these few cases the replacement part will usually be available from your local radio parts distributor or from a mail order radio supply house.

With such items as variable tuning condensers, tuning dial mechanisms, r.f., i.f. and oscillator coils, and loudspeaker parts, the need for exact duplicate replacements becomes considerably more important. In some cases the mechanical construction and styling make it impossible to use universal replacement parts. In the case of air-core coils, the entire receiver design is usually based upon these coils, and few receivers have identical circuit design. When replacing loudspeaker cones, it is again necessary to have an exact duplicate new assembly of voice coil, spider and outer rings, so as to duplicate the original response of the loudspeaker. With the loudspeaker field coil a similar proposition exists; the physical construction, number of ampere-turns, resistance and current-handling ability must all correspond to original specifications.

When exact duplicate replacement parts are not available from distributors, parts which will work equally as well as the original designs can generally be obtained from local or mail order radio distributors. This is particularly true of loudspeaker assemblies, loudspeaker field coils and air-core coils. Some firms will even rewind defective coils or make a suitable cone assembly to order if the exact duplicate part is not carried in stock.

► There will be a few conditions in which it is impossible to secure an exact duplicate replacement part. An alert and ingenious serviceman can still "carry on," by making a repair himself or having a repair made by a competent machinist or mechanic.

Thus, any broken mechanical part can be duplicated by a machine shop. A missing or broken knob of an unobtainable type presents a problem which is solved by replacing all of the knobs with a new design. If a replacement field coil for a loudspeaker is not obtainable, replace the entire loudspeaker. Power transformers, iron-core choke coils and audio transformers can be replaced with universal types having necessary adjustments to fit in most receivers.

If necessary, r.f. coils can be replaced with standard types; the only coil which may give real trouble is the oscillator coil, for it controls the receiver dial readings. Naturally, greater care and more thought is necessary when selecting equivalent replacement parts; thorough mastery of radio fundamentals is invaluable when situations requiring this arise.

Exact duplicate replacement vibrators are available for practically any auto radio set.

10. Check Performance. Try the receiver out, to make sure that all of the customer's complaints have been cleared up. It is often a good idea to let the set run for several hours (volume can be turned down for this) before making this final check-up, to see if any new troubles develop after the set is thoroughly warmed up. This is particularly desirable for sets which have not been in operation for a month or more, or when dealing with a customer who may be unreasonable regarding future troubles which are not your fault.

Discussion. In a sense, locating trouble in radio receivers is similar to expert detective work. The technique to use in each case depends upon the nature of the job, your analysis of it, and the test equipment you have at hand. Each complaint calls for its own careful selection of service steps.

Noise, for instance, is a complaint for which only a limited use of effect-to-cause reasoning is justified. It is usually best to start right away on the isolating techniques which reveal in turn the section, stage and circuit containing the defect.

You can isolate a noisy stage without any test equipment, simply by silencing each stage in turn while working from the loudspeaker towards the antenna. You can silence a stage by removing its tube; if the noise stops when this is done, you know that the defect is either in that tube or in the stages ahead of the tube (towards the antenna). If the noise continues with the tube removed, you know that the trouble is between that tube stage and the loudspeaker, or is in the power pack.

Of course, a simple isolation procedure such as this has its limitations, and requires further tests for final verification. If you have an expensive signal-tracing instrument, you can listen to the signal at each stage while working from the antenna to the loudspeaker; the first stage at which noise is heard is the one which is likely to contain the defect.

In this Course you will learn still other methods of isolating the defect when the complaint is noise; some will be better for shop work where full equipment is available, while others will be more suited for work which has to be done in the customer's home with minimum equipment.

SUGGESTIONS FOR MASTERING PROFESSIONAL SERVICING TECHNIQUES

Servicing does not follow an absolutely fixed pattern. You cannot say that hum is only caused by an open filter condenser or that distortion is only caused by a leaky coupling condenser. These are common causes for the particular complaint, and may even be the usual cause in some particular receiver. However, there are always exceptions to the general rule. To be a successful radio serviceman you must have a general approach which will localize the trouble regardless of the cause and must then fill in by effect-to-cause reasoning and from practical experience, for those special cases where short cuts are possible. You should never have to resort to the guess and try procedure of the inefficient, untrained serviceman. Unlike many other skilled occupations, that of a radio serviceman is a one-man job. Once a serviceman starts a job, he is in the best position for completing the work. No one sitting on the sidelines can give definite advice unless the serviceman can state clearly the exact trouble, all the symptoms, and all the results of his measurements. Even then, an adviser can only suggest more likely sources of trouble, and suggest more efficient isolating techniques.

In order to become an expert professional Radiotrician, you must know the various professional servicing techniques, you must acquire experience, and you must be able to figure out technical problems. As you proceed to master the various techniques, as given in the following lessons, you will appreciate more and more the importance of knowing the fundamentals of radio circuits.

Value of Reviewing Early Lessons. A review of previous lessons on radio fundamentals at the rate of two or three lessons a month will prove highly beneficial during your study of these advanced lessons. Early lessons will have an entirely new meaning, and fundamentals of circuits will seem far more practical now that you really recognize their value in radio servicing work.

Following the N.R.I. Plan. Elsewhere in the Course, a plan for acquiring practical radio servicing experience in your own home is given. We strongly recommend that you give this phase of your training immediate attention, if you want to get the most out of these advanced lesssons on radio servicing. Obtain a suitable radio receiver chassis as soon as you can, and begin to carry out on it the N.R.I. plan for securing the experience so necessary for efficient radio servicing.

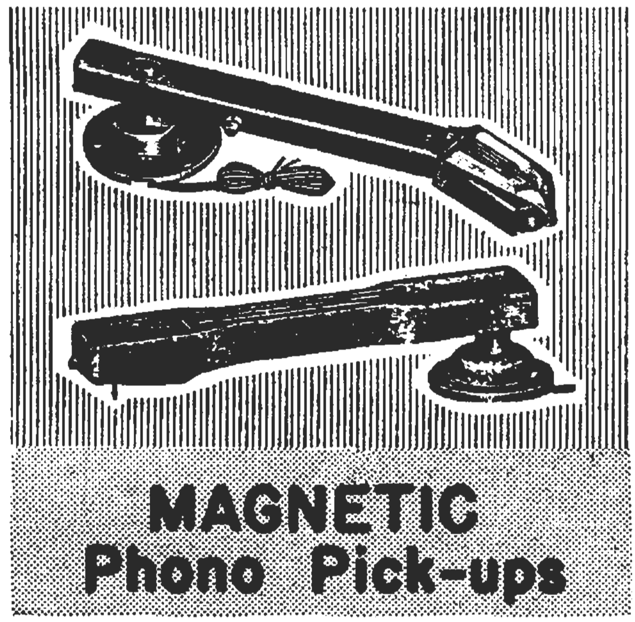
You can also use this chassis in connection with your advanced servicing lessons; whenever you study a particular professional technique or learn about locating a particular defect, try it out on the chassis and demonstrate for yourself the relative effectiveness of the recommended procedures. Your studies will take on a new meaning when you do this, and you will have little trouble in remembering what you studied. You may not be able to test everything which you study, but those tests which you do carry out will definitely prove worth while.

PRACTICAL ADVICE ON REMODELING RADIO EQUIPMENT

Radio servicemen eventually learn by sad experience that it is by far the better policy to stick to their own work, and avoid remodeling sets. Any attempts at remodeling always involves changes in the design, which is a far more intricate problem than might be imagined.

For example, it would seem to be a simple matter just to change sockets, so newer type tubes can be used. Trouble starts, however, when you begin trying to get the same output level, the same selectivity and the same sensitivity from the remodeled unit. The newer tubes may be capable of even better performance than the originals, but the circuits must usually be redesigned to utilize this superior capability.

Similarly, changing from an i.f. value of 175 kc. to 456 kc. will give greater freedom from image interference. However, just swapping transformers introduces problems, for the tuning dial range depends on the i.f. value. You will then be involved in the necessity of changing the oscillator coil and, even if you get the same tuning range, you will still have the problem of getting the same gain and selectivity at the new i.f. value.



These pick-ups generally require such repairs as replacement of rubber parts or replacement of a defective coil.

The customer will quickly recognize any deficiency in performance in a remodeled set because of his familiarity with the performance of the original receiver. Not only will you have a "headache" on your hands in attempting to improve the original performance, but you will also run the serious risk of having a dissatisfied customer in the end.

The cost of the material required, plus a fair rate for the time spent in remodeling, will usually total up to so much that you could not possibly charge the customer for the whole job. You cannot expect to make a ten year old receiver have all the qualities and performance features of a modern unit unless you replace practically all the parts in it, and redesign the unit completely.

This means you take a loss on most remodeling jobs. It is far better to recommend that the customer purchase a new and modern receiver. For comparable performance, the new receiver will be cheaper, and you will win a satisfied customer for future work.

Another thought—even though you do redesign a receiver successfully, you will very likely be expected to keep that receiver operating satisfactorily for the rest of its life. In other words, you become "married" to that receiver and will be blamed for all troubles which develop in it.

As a general policy, a radiotrician should turn down all opportunities to remodel receivers or amplifiers. It is the job of a radiotrician to recognize, isolate and repair defects in radio equipment, align receivers, and do certain other things that are necessary to restore the original performance of the receiver.

Lesson Questions

Be sure to number your Answer Sheet 36RH-1.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. When the customer's complaint is fading on distant stations, with local reception being entirely satisfactory, which of the following procedures should be used: (a) *Look for trouble in the receiver;* (b) *Explain to the customer that fading is due to natural causes over which you have no control;* (c) *Look for some electrical apparatus nearby which is causing the fading.*

2. A customer says that both distant and local stations are very faint. You notice that the tuning indicator operates normally when stations are tuned in. In what section of the receiver would you first look for trouble?

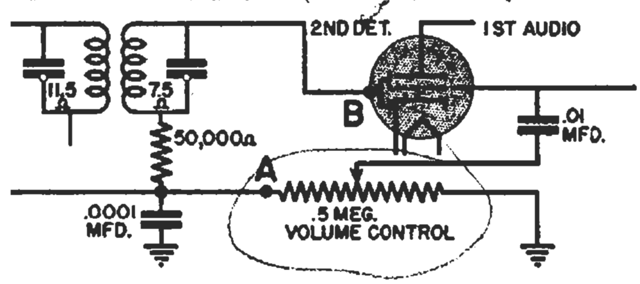
   The audio section

3. When a stock of new condensers is at hand, what is the simplest and best way of finding out whether a particular suspected condenser is open?

   Shunt the suspected condenser with a good one

4. Suppose ohmmeter measurements in the circuit at the right show an open circuit between B and ground. Which part is defective if further tests give readings of:

   B to A: 50,000 ohms.
   A to Ground; OPEN.



5. A raspy, buzzing sound is heard along with distortion of low-frequency sounds in programs, such as men's voices and drum beats, but high-frequency sounds come through clearly. Which part in the receiver would you suspect?

   The loud speaker

6. What complaint is associated with a leaky coupling condenser in an R-C coupled audio stage? Distortion

7. Name, in correct order, the ten steps in the complete professional servicing procedure.

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8. A 410-ohm, 1-watt cathode resistor in the output stage is burned out. You are unable to get a new exact duplicate resistor, nor can you get a 400-ohm resistor of any kind. Would two 800-ohm, 1-watt resistors in parallel work satisfactorily? [illegible] yes

9. Suppose that you trace the trouble to a defective 90,000-ohm carbon resistor having standard 20% tolerance. The distributor does not have this value in stock, but says a 100,000-ohm resistor will work just as well. Is he right? [illegible] yes

10. Would it be practical to modernize a 15-year old t.r.f. receiver so it would pick up foreign short-wave stations and could be tuned just by pressing buttons?

    No