TM 11-4000

EPARTMENT OF THE ARMY TECHNICAL MANUAL

TROUBLESHOOTING AND REPAIR OF RADIO EQUIPMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY
APRIL 1958

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WARNING!

EXTREMELY DANGEROUS VOLTAGES
EXIST IN RECEIVERS AND TRANSMITTERS.

DON'T TAKE CHANCES!

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TECHNICAL MANUAL
No. 11–4000

HEADQUARTERS,
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WASHINGTON 25, D. C., *2 April 1958*

TROUBLESHOOTING AND REPAIR OF RADIO EQUIPMENT

2. CAUTIONS

CHAPTER 3. TEST EQUIPMENT

CHAPTER 4. GENERAL TROUBLESHOOTING

6. TROUBLESHOOTING RECEIVERS

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* This manual supersedes TM 11–4000, 20 April 1945.

CHAPTER 1

INTRODUCTION

1. Purpose and Scope

a. This manual is a practical reference guide to the troubleshooting and repair of military radio receivers and transmitters. Figure 1 shows the troubleshooting of a receiver-transmitter. The methods and procedures in this manual are *broadly* general, and are based upon successful experience. Theory is used for purposes of clarification only.

b. This manual is not a substitute for the technical manuals issued for particular radio equipments. Instructions for troubleshooting and repairing a specific receiver or transmitter are given in the technical manual for that equipment, and those instructions are to be followed carefully. This manual takes an overall view of the subject of radio equipment troubleshooting and repair in general. Therefore, it supplements the equipment technical manuals. It supplies a background of general information which the equipment technical manuals assume and take for granted.

c. This manual is designed as a refresher for the experienced Army technician. It may also be of use to others, well-grounded in radio theory, as an introduction to troubleshooting and repair methods.

d. This manual assumes that the reader is familiar with ordinary tools. It describes, therefore, only those special tools that are occasionally required but are not normally used in radio repair work.

2. Role of Repairman

a. World War I was the first war in which radio equipment was used. The limited amount of equipment and the uses to which it was applied required very few repairmen to keep it in working order.

b. Radio uses in the Army today have reached a point where there is scarcely a vehicle, including tanks and many types of trucks, that does not have a radio set as part of its original equipment.

c. The many applications of radio equipment and the number of sets now in use mean that a greater number of repairmen are needed. The complexity of the equipment calls for highly trained skilled technicians to maintain it.

d. The success or failure of a mission depends on the effectiveness of the communications. It is possible for a military unit in combat to become lost or completely separately from other units because of the failure of radio communications equipment.

e. The radio repairman is as important as the man who fires a gun. The Army wins battles because all parts of it work together as a team. The radio repairman is a very important part of that team.

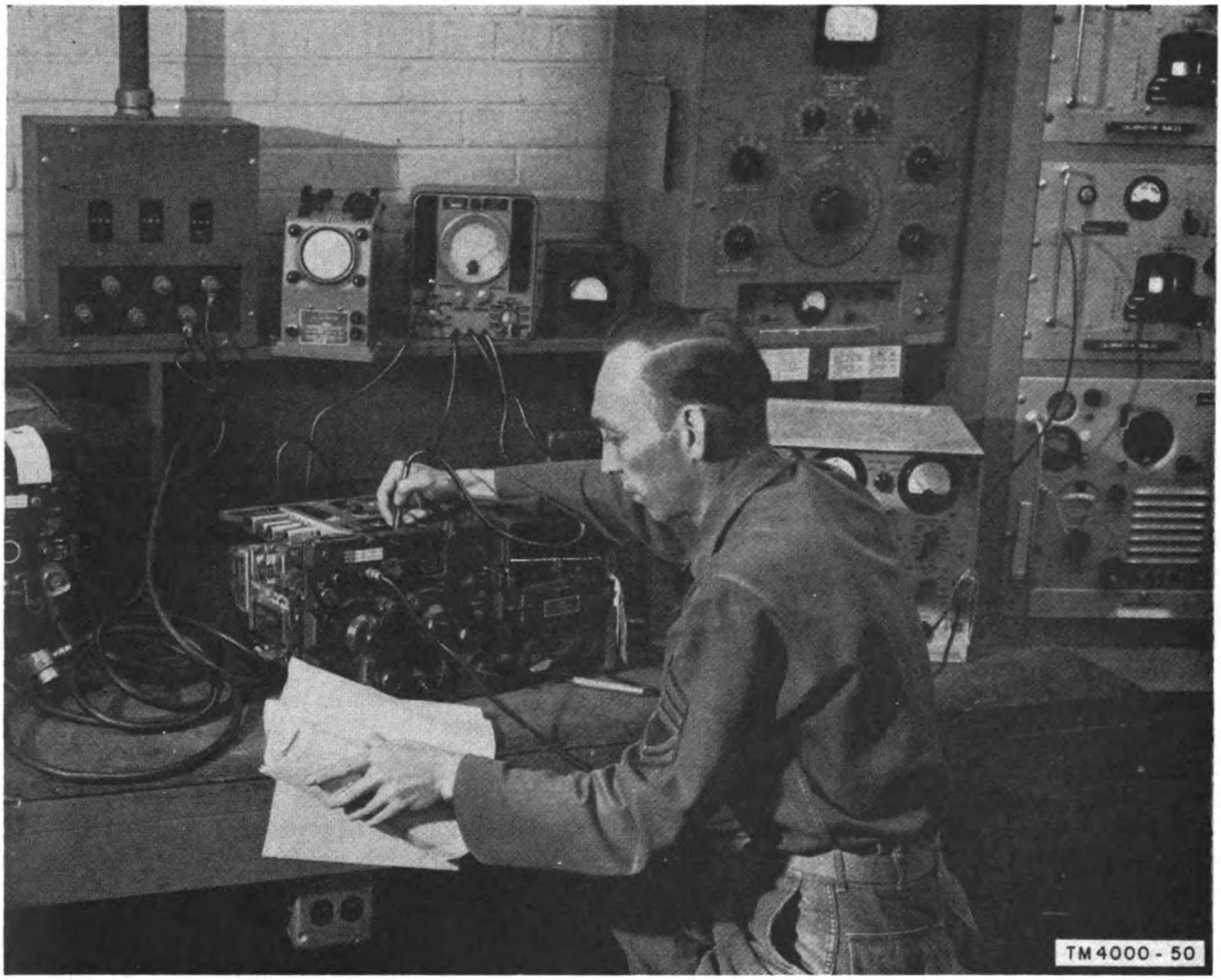


Figure 1. Troubleshooting an Army receiver-transmitter.

CHAPTER 2
CAUTIONS

Section I. GENERAL

3. The Safe Way

The electronic technician must learn and follow safety rules. The first rule of safety is—*Be careful! Never* touch a point in a circuit unless you *know* that it is not *alive.* Refer to the schematic diagram to find out how much voltage may be present, then connect a voltmeter into the circuit and measure the voltage. If you do not know whether a certain equipment is dangerous, do not find out the hard way—use your test equipment first. Have an assistant when working on high-powered equipment.

4. Safety Procedures

a. Safety procedures must be developed by habit so that when the technician is rushed with repair work, he automatically takes precautions. For example, the technician who uses only one hand when working on high-voltage equipment may get only a jolt if he accidentally contacts a high-voltage point, but if he carelessly puts the sweaty fingers of one hand into the equipment and casually rests the other hand on the metal cabinet, he may suffer a severe or fatal injury.

b. Bleeder resistors may open and thus fail to discharge capacitors after the equipment has been turned off. To be sure that the capacitors are discharged, short circuit them with a shorting stick (par. 8).

Section II. HIGH-VOLTAGE HAZARDS

5. High-Voltage Power Supply Dangers

a. Special safety precautions must be observed when troubleshooting and adjusting equipment in which voltages higher than 100 appear. Troubleshooting in transmitters and power supplies is especially hazardous because these equipments contain circuits capable of delivering large amounts of current at high voltages. High-voltage equipment that operates from a 60-cycle power line and contains 60- or 120-cycle rectifiers is especially dangerous. The filter capacitors in such equipment are relatively large and can store a heavy charge that can remain for long periods after the equipment has been turned off. Contact with a charged 4-microfarad capacitor of the type used in transmitter power supplies can be just as deadly as touching a live circuit.

b. The most dangerous circuits, high-voltage or low-voltage, are those that can deliver high currents. The danger is even greater when dampness is present or when the hands are perspiring. Under such conditions, the body resistance is low and a high value of current can pass through the body if accidental contact is made with a live circuit. A current of only 80 milliamperes (ma) through the body can cause death. Even less current can be fatal if the victim is fatigued or if his general health is poor. Because of such dangers, it is good practice to keep one hand in your pocket and to stand on material that is a good insulator.

c. In addition to shock and burns, other injuries also can be caused by working on high-voltage equipment. It is common for the body muscles to contract violently when the body comes in contact with high voltage. This violent contraction of the muscles can hurl the victim into near-by objects with enough force to cause severe cuts, bruises, or even broken bones.

d. Sometimes, contact with high voltage causes the muscles to contract so tightly that the victim freezes to the equipment. If this happens, *do not touch the victim* until the power has been turned off.

6. High-Voltage Danger Points

The technician must know what and where the danger points are in high-voltage circuits, so that he can avoid them when working on equipment with the power turned on. The identity of danger points is indicated below.

a. In a transmitter (fig. 2), the power supply chassis has terminals that are at a very high potential.

b. The secondary terminals of the plate transformer and the plate caps of the rectifier tubes are at high ac potentials.

c. Beneath the chassis, filament terminals on the transformer, the filament terminals of the rectifier tubes, and the components of the power supply, which includes the bleeder resistor, filter choke, and filter capacitors, are at a high dc potential. A high-voltage power supply with the filter capacitor terminals exposed is shown in figure 3.

d. The modulator section also has high dc voltage points exposed; the danger points are shown in figure 2.

e. In figure 4, a different transmitter is shown with radio frequency (RF) as well as the dc danger points. Both dc and RF voltages normally appear at the power amplifier tube plate caps and the tuning coil and tuning capacitor.

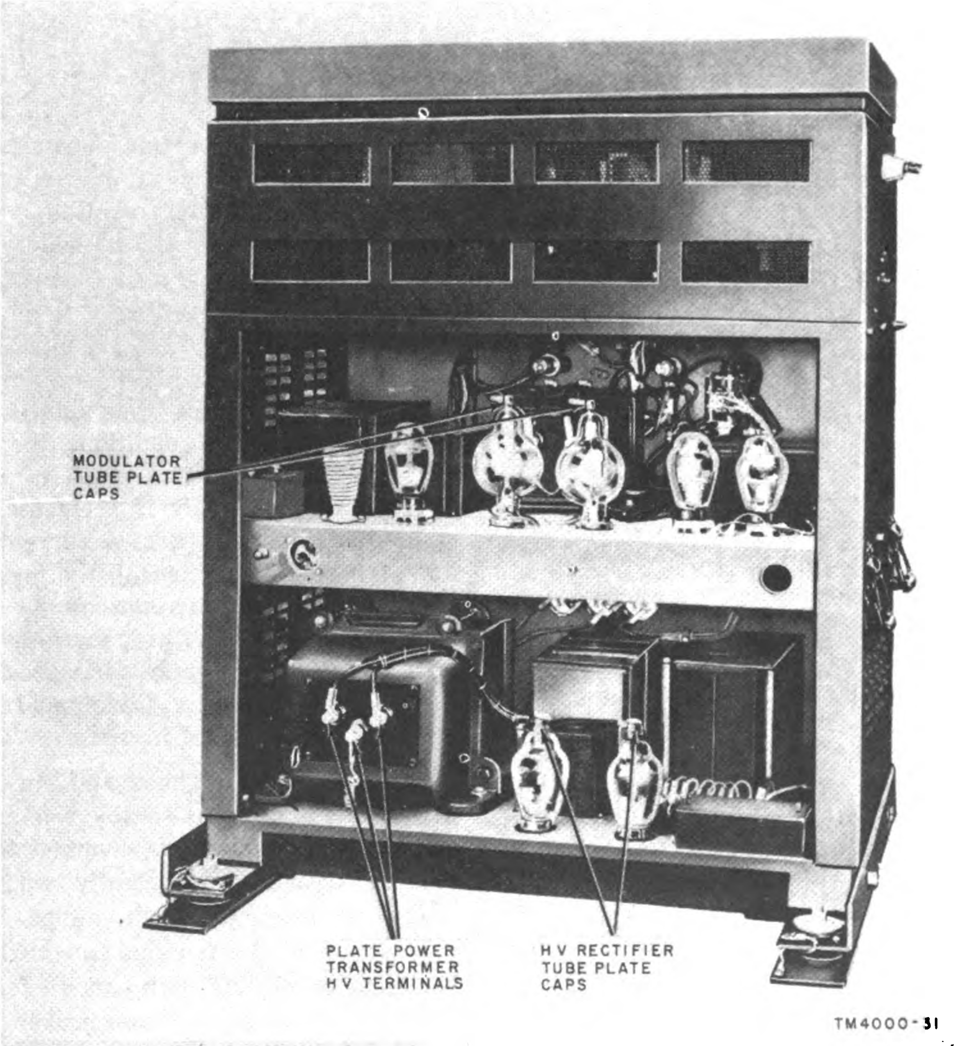


Figure 2. Transmitter, showing high-voltage danger points.

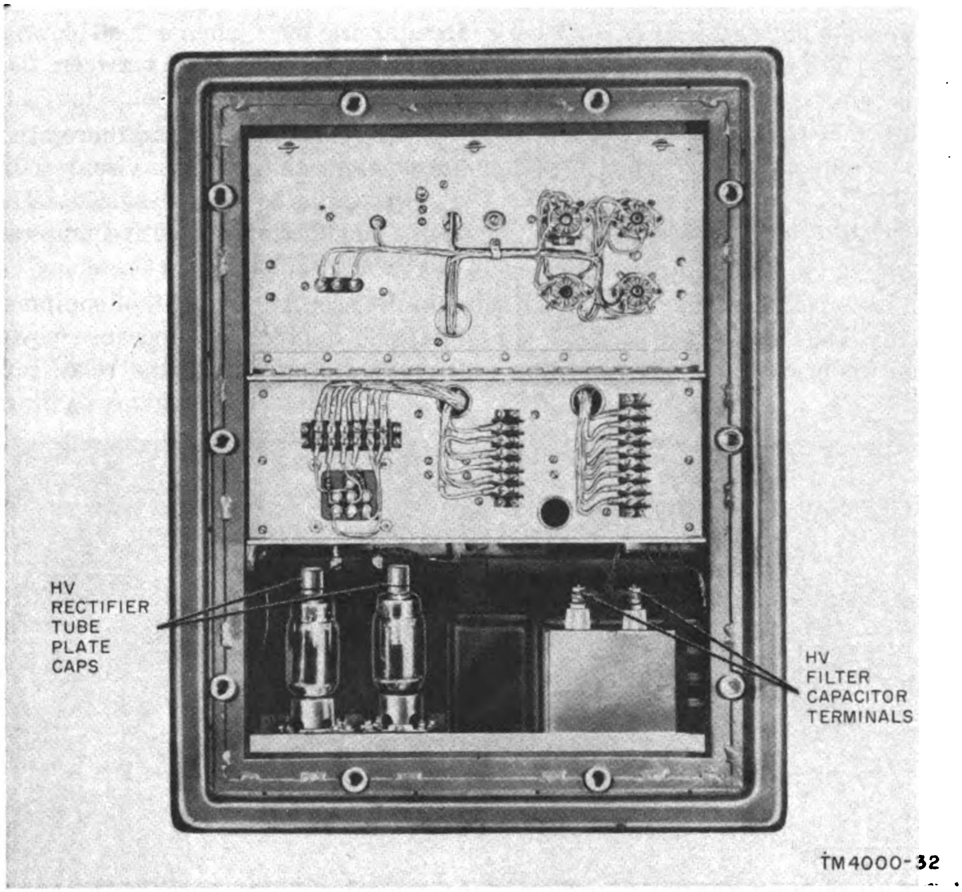


Figure 3. Transmitter power supply, showing high-voltage danger points.

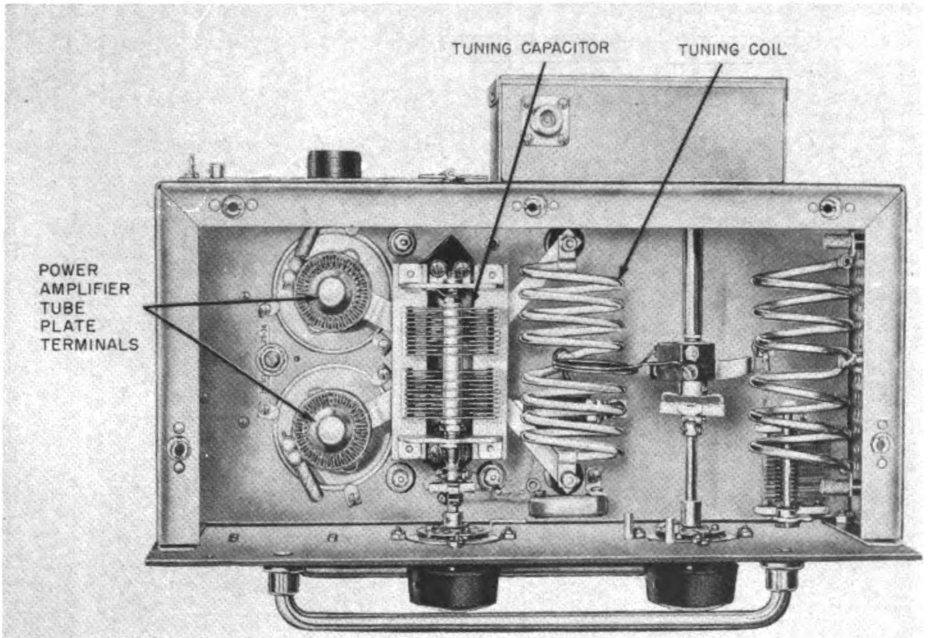


Figure 4. Transmitter RF section, showing high-voltage danger points.

High voltage is present at the terminals of the transmitter meters. The zero adjusting screw of any indicating meter may also be at a high dc potential. Sometimes meters with high voltages present are mounted behind a glass or plastic recessed panel. Be sure the equipment is turned off when adjusting the meter pointer to zero.

f. Another danger point is the fuse panel. Note in figure 5 that the high-voltage fuses are several inches long to prevent the high voltage from arcing over when a fuse blows. There may also be a high voltage between the fuses and equipment panel or cabinet.

g. In many equipments, there are glow lamps and meters that give a visual indication that various circuits are energized. These components may become defective and cannot be relied upon completely.

h. Be especially careful of equipment that uses relays to apply power because power will continue to be applied if the relay contacts stick,

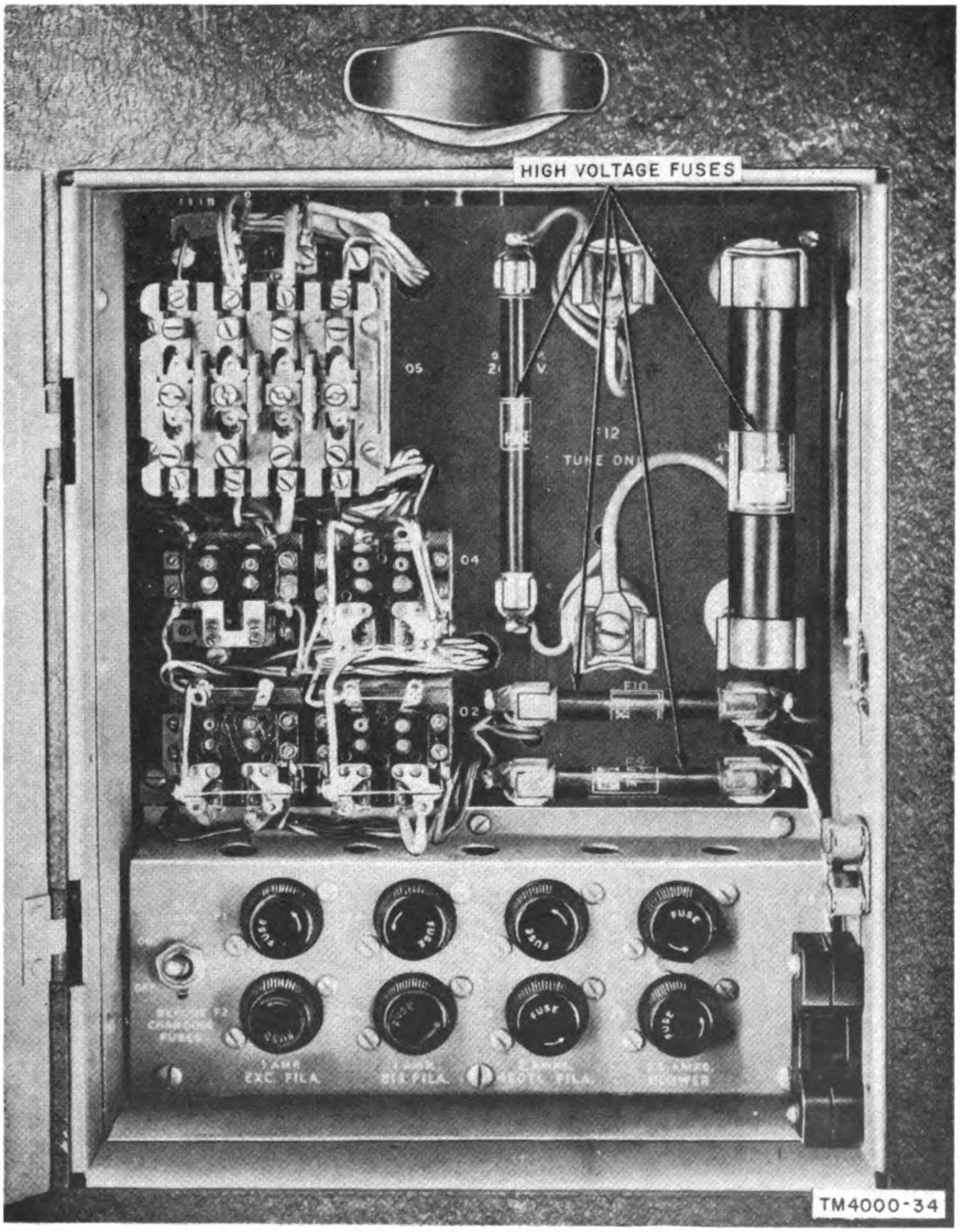


Figure 5. Transmitter fuse panel, showing high-voltage fuses.

even though the relay coil is not energized. As a result, even with the relay coil circuit de-energized and all warning lights out, the contacts can still apply power to the equipment.

i. Do not depend on the sound of a relay releasing as a positive indication that the power is off. Sometimes the armature of a relay can be heard releasing while the contacts remain fused together, in which case the equipment is still energized.

7. Interlock Switches

a. High-voltage equipment usually includes a system of interlock switches for the protection of personnel from accidental contact with live circuits. In some transmitters, an interlock switch is located at every removable panel and access door. Usually, all the switches are wired in series to automatically shut off the power to the equipment whenever a door or panel is opened. Interlock switches are safety devices and must not be tampered with. If it becomes necessary to disable the interlock switch so that power can be applied to the equipment for troubleshooting purposes, be *sure* to restore the switch to its original position before the repaired equipment is returned to service.

b. There are several commonly used interlocks. One type (fig. 6) is an ordinary push switch that has a relatively low current-carrying capacity. This type usually is connected to a relay coil which controls the power to the equipment. If an interlock switch becomes short circuited internally, and if a relay controlled by an interlock is defective, the power will remain on even though there is no visible indication.

c. Another type of interlock (fig. 7) does not control the current flow through a relay but is wired directly into the power circuit. When a panel door is opened, the disk of the interlock comes out of the receptacle and the power is interrupted. Always turn off all power switches and discharge all filter capacitors with a shorting stick before working on the equipment.

8. Shorting Stick

a. One of the simplest and most important aids in troubleshooting high-voltage equipment safely is the shorting stick. It is used to discharge all high-voltage capacitors so that they will cease to be a source of danger during tests.

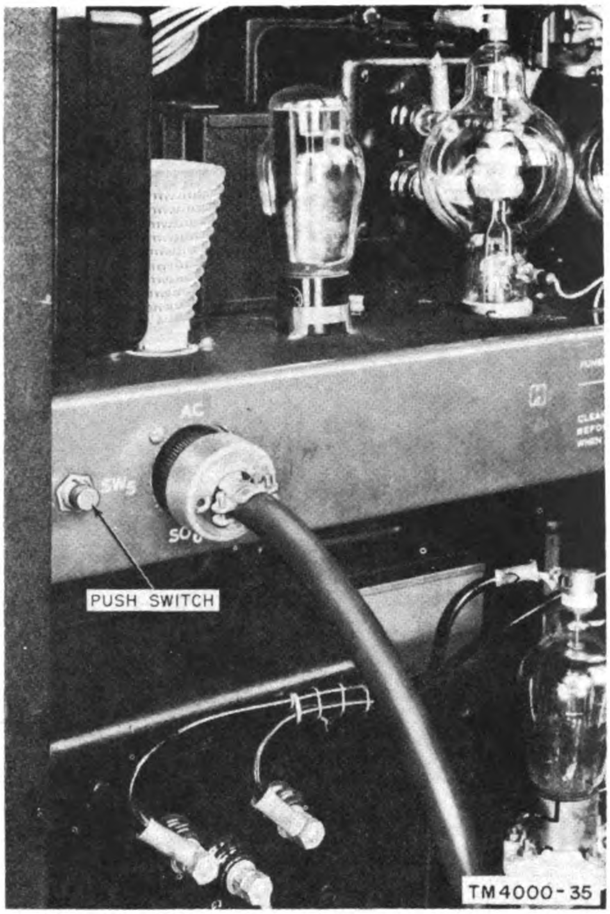


Figure 6. Example of a push-switch interlock.

b. A good shorting stick can be made as suggested in figure 8. Be sure that the wood is thoroughly dry. For the ground lead, use about 2 feet of heavy bare flexible wire with a piece of plastic tubing slipped over it. Bare wire and clear tubing are used so that a break can be seen and repaired. An unseen break can lead to injury or death, because a shorting stick with a defective ground lead will fail to discharge the capacitors. In addition, charged capacitors will appear to be discharged because of the lack of sparking when they are grounded. Use a heavy solder lug and be sure the joint where the wire connects to the lug is a good solder joint. When the stick is used, first connect the clip to the chassis; then touch the hook to the high-voltage point to be discharged. The stick indicated in figure 8 is for large transmitters; use the dimensions as a guide for constructing smaller sticks.

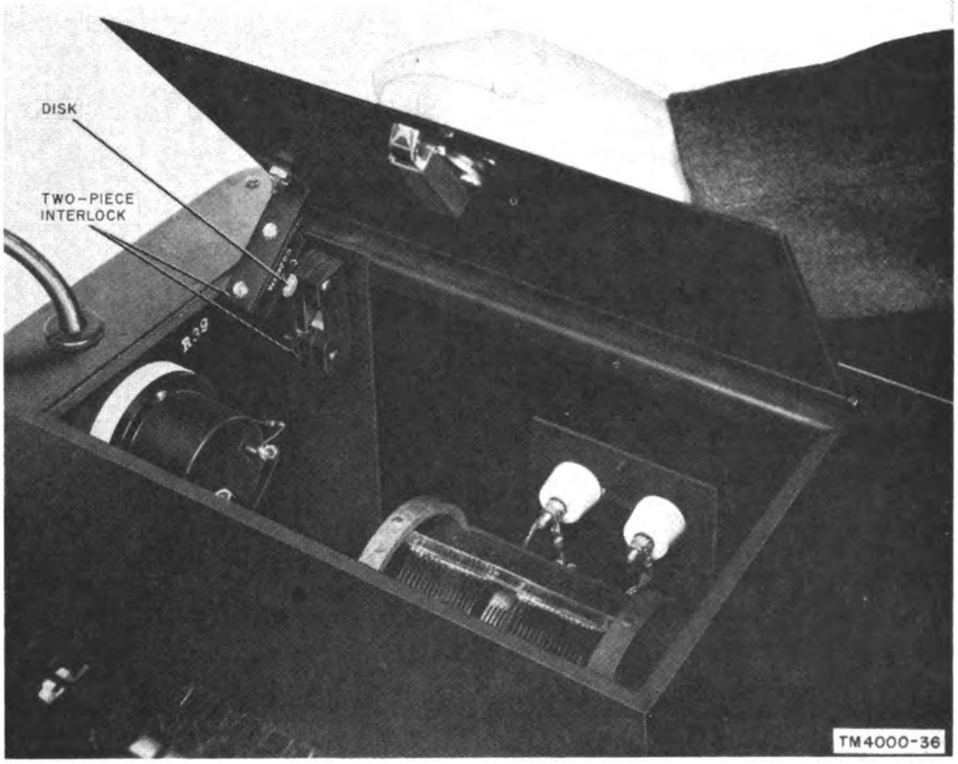


Figure 7. Equipment access cover, showing two-piece interlock switch.

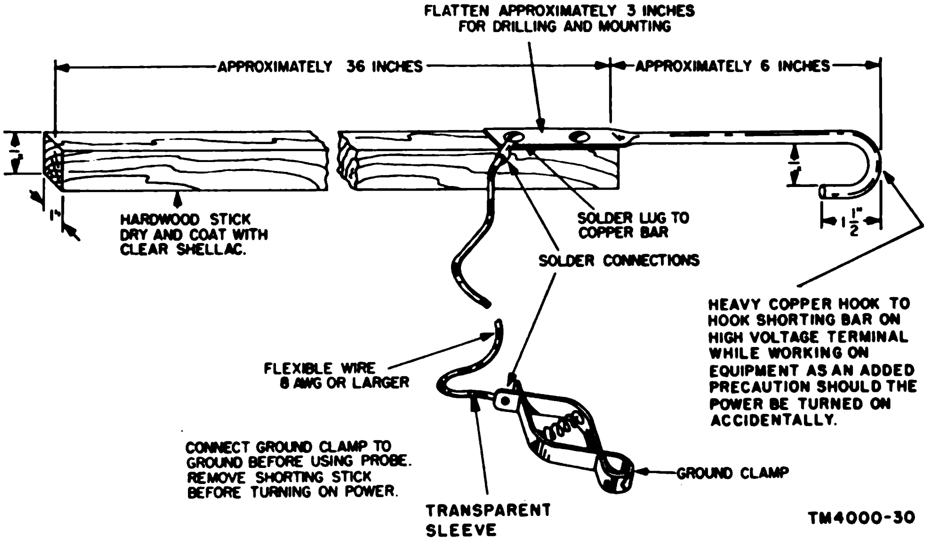


Figure 8. Construction of a shorting stick.

c. Before using the shorting stick, be sure that the handle is clean and dry; this prevents leaks from developing and from allowing high voltage to cause arcs to jump across the stick to ground. Shut off the power and clip the ground clamp of the stick to the chassis of the equipment. Hold the stick near its end and as far from the hook as possible. Touch the hook to the terminal, as shown in figure 9. Make contact for several seconds to make sure each capacitor is discharged.

d. A charged capacitor may become ungrounded. As a safety precaution, short the two terminals of that capacitor together as shown in figure 10. Leave the shorting stick hooked to one of the high-voltage terminals on the capacitor while working on the equipment; if the power is turned on, a fuse will blow and cut off the power. Be sure to remove the shorting stick before turning on the power and as soon as work on the equipment is completed.

9. Precautions Before Making Resistance Checks

a. A basic law of safety is to turn off the power before making resistance checks. This warning is many times repeated and is too many times forgotten.

b. Be sure that the power is off, not only to avoid damage to the ohmmeter, but for your safety and the safety of others. If the equipment has a main switch, *turn it off, and remove the fuses.* Keep the fuses in your pocket. If circuit breakers are used in the equipment, *turn them to the off positions* and lock the panel door. Keep the key in your pocket while working.

c. Post a large sign such as CAUTION! MEN

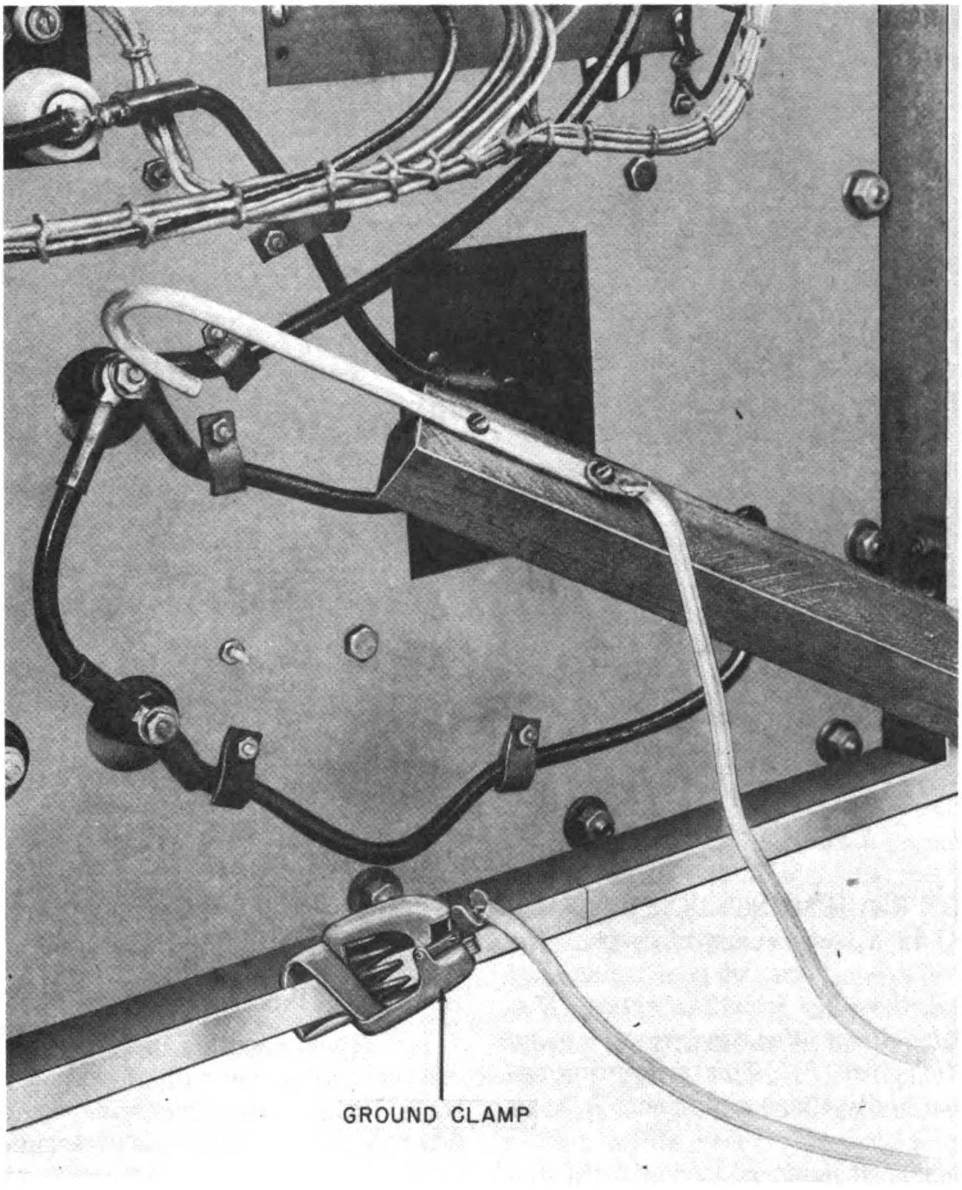


Figure 9. Using shorting stick to discharge capacitor to ground.

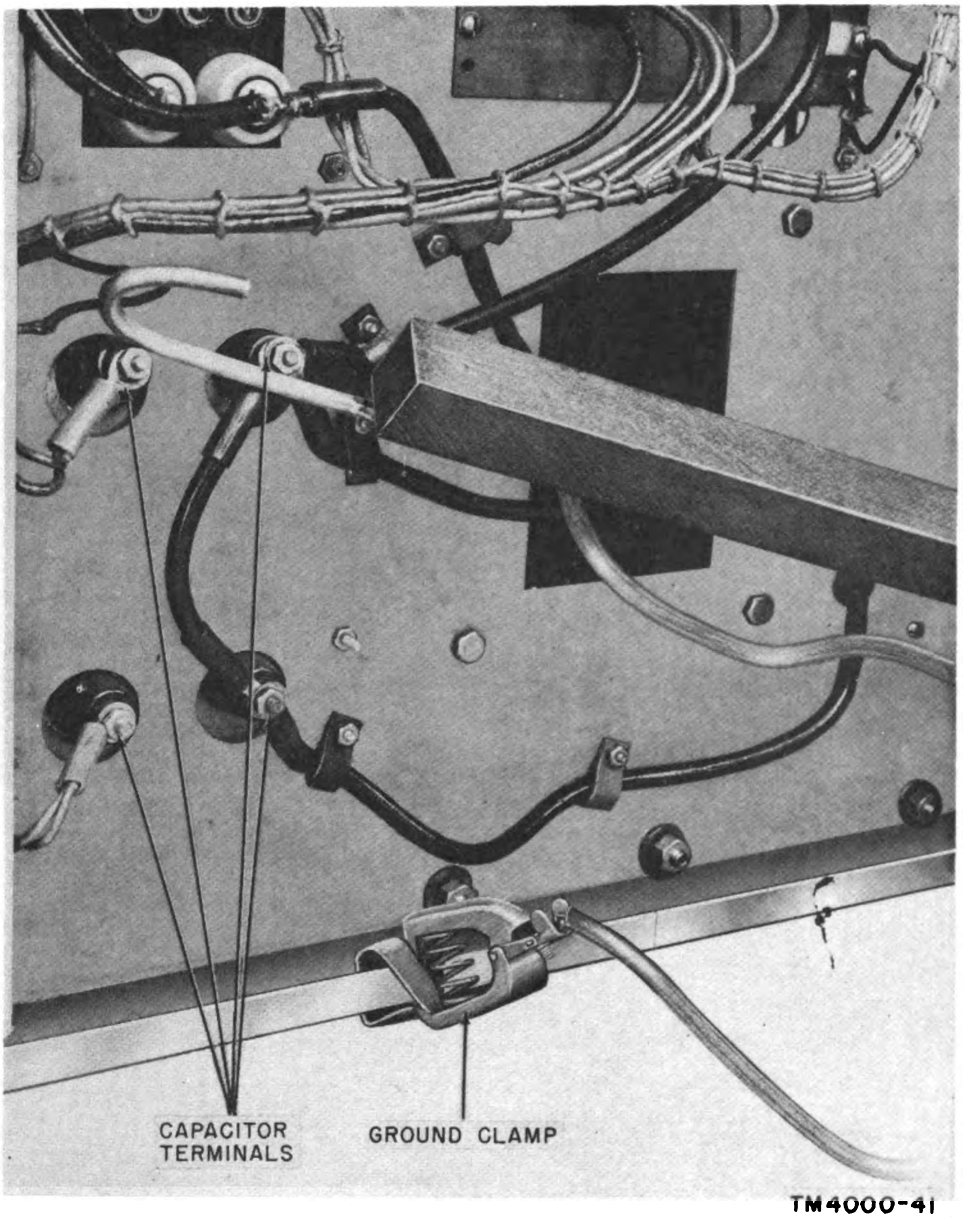


Figure 10. Using shorting stick to discharge capacitor terminals directly.

WORKING ON EQUIPMENT; DO NOT TURN ON POWER! in a conspicuous place near the main power switch. If the set uses a line cord and plug, *pull the plug from the outlet. Discharge all high-voltage filter capacitors by using a shorting stick* (par. 8). This precaution applies whenever high-voltage equipment is being worked on.

d. An ohmmeter is damaged as readily by discharging a capacitor through it as by connecting the ohmmeter to a live circuit. Always discharge the filter capacitors with a shorting stick before making resistance measurements.

10. Troubleshooting High-Voltage Circuits

a. Troubleshooting defective equipment by measuring voltages in high-voltage circuits with an external voltmeter (some equipments have built-in voltmeters) is *not* recommended unless all other methods have been tried and have failed. Always troubleshoot high-voltage circuits first by resistance and continuity measurements after analyzing the symptoms. Sometimes it is necessary to troubleshoot or adjust high-voltage equipment with the power turned on. If the voltage is 100 volts or more, all special safety precautions must be observed.

b. Make sure the test leads and prods are properly insulated before making high-voltage measurements. *Do not work alone.* Make sure the floor is absolutely dry. Working on a wet or damp floor is inviting trouble. Most equipment is grounded to earth and accidental contact by the body with a high-voltage point can cause current to pass from a grounded point through the feet to the heart or brain. Use a good rubber mat on the floor. Beware of black mats; they may contain conductive carbon compounds. If no mat is available, use some dry boards, or several layers of corrugated cardboard. Take these precautions even if you think the floor is dry. *Do not take chances!*

c. The safest method for making voltage measurements in high-voltage circuits is to make all meter connections with the power turned off.

d. If the high-voltage equipment is being tested with no one standing by, and the interlock is jumpered out, be sure to hang a caution sign nearby. The sign would caution anyone from accidentally touching exposed parts in the equipment and receiving a dangerous shock. A better way to prevent such accidents is to avoid leaving exposed circuits unattended.

11. Low-Voltage Dangers

a. Death can be caused just as quickly by low voltage as it can by high voltage. The same safety precautions that apply to high-voltage circuits are to be observed when working with low-voltage circuits. If a low voltage can cause a current of 80 ma to flow through the body, that low voltage will be fatal.

b. High-voltage sets often are clearly marked to indicate the potential dangers present, but low-voltage sets may or may not be marked. High-voltage equipment usually contains interlock switches. Low-voltage equipment may not have interlock switches. This is dangerous for two reasons: First, there is no protection to prevent accidental contact with a B-plus point if a panel is removed which leaves such points exposed. Second, it gives the technician the false impression that the equipment is harmless, or it would have interlock switches. Low-voltage equipment is therefore treated too casually, with the result that the technician tends to become careless.

Section III. OTHER HAZARDS

12. RF Burns

a. RF voltages behave somewhat differently from dc or low-frequency ac voltages. Accidental contact with circuits which contain relatively high RF voltages can produce a painful burn. These burns penetrate the skin deeply, sometimes reaching the bone. At times there may be an odor of burning flesh. An RF burn can be very painful not only at the moment of contact but afterwards, especially if an infection sets in. The danger of accidental contacts resulting in RF burns is present in, and around, transmitting equipment, especially in the final amplifier tank circuit.

b. High-frequency burns are not confined to equipment that operates in the RF range. A burn may be experienced from equipment that operates in the upper audio range and supersonic frequencies. For example, speech equipment may develop a parasitic oscillation in the supersonic range. Accidental contact with a terminal of a RF power output tube could easily result in a RF burn. Some television receivers use a flyback-type high-voltage power supply operating at about 16 kilocycles (kc), which can inflict a painful RF burn. A circuit component that has RF present may also have a high dc voltage at its terminals, so that contact with it can result in double danger.

c. RF and other voltages tend to reach out in search of a short path similar to the action of a corona (blue arc) discharge. Any high-voltage circuit component or solder joint that has sharp points is a potential danger spot. This is especially true in the output section of a transmitter. Sharp points or edges produce a corona that can burn component parts as well personnel.

d. All high voltages which are not confined properly can cause damage to equipment. Equipment operated in damp surroundings may be subject to corona discharges. In daylight, corona may not be seen but at times can be heard as a hissing sound. Darkening the surrounding area may help locate the point of corona discharge; locating this point quickly will lessen the time needed to correct the fault and the time the components are subject to damage.

13. Heat Burns

a. Almost all technicians have suffered from a heat burn either while learning electronics in school or while working on defective equipment afterwards. Heat burns are painful and can be serious if not given proper medical care. Working with hot solder, soldering irons, and equipment with hot tubes requires a little extra care on the part of the technician.

b. The technician is surrounded with many possible sources of heat burns. Large tubes and resistors in high-powered equipment are components that normally run hot. There are many parts, such as power transformers, chokes, and resistors, that run hot when an overload occurs.

c. Soldering is a daily operation for the technician. Usually, a soldering iron, kept hot during the entire work day, is available. Keep the soldering iron in a place where personnel cannot be burned accidentally, and where the danger of fire to benches, furniture, and the building is at a minimum.

d. Severe burns can result from touching hot tubes, even after the power is turned off, because some tubes stay hot for long periods of time. Remove receiving or other small hot tubes with a tube puller. By using a tube puller, the technician is not only protected from possible burns, but it is a convenient method for extracting tubes without bending the pins. If a tube puller is not available, grasp the tube by the base—this is usually the coolest part of the tube.

14. Handling Cathode-Ray Tubes

a. Many technicians do not realize the potential danger that exists when handling cathode-ray tubes. To help prevent injury, wear a pair of protective goggles and heavy gloves. Work slowly and carefully.

b. The tube contains a high vacuum and, depending on its size, will have a force of hundreds of pounds, or even tons, of pressure acting on its outside surface. If the tube is broken, an implosion will result, and glass will fly in all directions with tremendous force.

c. Some cathode-ray tubes have an inner and outer conductive coating that acts as a capacitor, with the glass between them serving as the dielectric. This capacitor can store the full power supply voltage which may be thousands of volts.

d. Do not touch the high-voltage terminal on the side of the tube; contact with this point and the outer grounded coating can result in a terrific shock. The shock may not cause any physical harm, but it can cause the technician to drop the tube. If the tube is resting on a bench, or is in the equipment, a shock will cause the technician to draw his hands away very rapidly, and probably touch another source of high voltage, or cause bodily injury to a fellow worker.

e. The fact that the tube has not been used for some time does not mean that it is safe to handle. A charge has been known to remain between the conductive coatings for weeks after the tube was removed from the equipment. Before handling any cathode-ray tube, discharge it, by shorting the high-voltage terminal to the outer coating or ground. Even then it is not always safe, because a residual charge may be present. For this reason, it is good practice to regard all cathode-ray tubes as dangerous.

f. Do not pick up a cathode-ray tube by the neck, or let it fall, even a distance of 1 or 2 inches. When carrying the tube, use two hands at all times. Grasp the widest part of the bell with both hands, and rest it lightly against the body. Be very careful not to bump into anything or anyone.

g. Do not leave a cathode-ray tube in the open when not in use. Keep it in a carton, face down. If the tube is removed from the equipment temporarily, and no carton is available, place the tube face down on a cloth to prevent the face from being scratched. Surround the tube with boxes or equipment so it will not be accidentally bumped or be in the way of working personnel.

15. Selenium Rectifier Dangers

a. Equipment using selenium rectifiers presents a hazard in the form of poisonous fumes and deposits. These poisonous gases are produced whenever a selenium rectifier burns out or arcs over.

b. A burnout may result from a short circuit which causes excess current to flow through the rectifier. An arc-over may occur because the voltage applied to the rectifier is too high, or because the rectifier is failing intermittently. Either type of failure will cause the poisons to be released.

c. When this type of rectifier fails, ventilate the immediate area at once. Do not handle the damaged rectifier until it has cooled, and then avoid direct skin contact with it. Use pliers to handle the part while it is being replaced.

CHAPTER 3
TEST EQUIPMENT

Section I. IMPORTANCE OF TEST EQUIPMENT

16. General

a. This chapter contains information on the many different types of test equipment which are available for the technician's use and points out the kind of job each is intended to do. Although the test sets mentioned here may be suitable for use with specific equipment, the ones listed in the technical manual should be used so that the readings obtained can be compared directly with the values listed in the manuals. It is not intended that the test equipment mentioned in this chapter replace test equipment authorized for use with specific radio sets. Reference is made to specific test equipment merely to aid in the selection of suitable equipment when none is specified.

b. Also included are special instructions which deal with the use of some types of test equipment. Such items include the effects of circuit loading, isolating requirements, interpretation of Lissajous figures, and other necessary information.

17. Troubleshooting Without Test Equipment

a. It is possible for a good technician to diagnose many types of troubles in electronic equipment without using any test equipment. A good automobile mechanic often can detect the fault in an engine by merely listening to the sounds it makes. In both cases, the senses and a knowledge of the equipment are used in the diagnosis.

b. A stage can be alined roughly without a signal generator by tuning in a weak signal and adjusting trimmers for maximum output. This method, however, is very crude and inaccurate. It is possible that the stage is being peaked at a frequency that is not of the proper value; therefore, the output of the stage is not as great as is would be if it were alined at the correct frequency by using a signal generator.

c. The technician is assumed to have a basic knowledge of the test sets he normally uses. Therefore, the theory of test equipment will not be dealt with here. Mention is made, however, of the use, the precautions to be observed, and the advantages and limitations of each type of test equipment.

18. General Types of Test Equipment

a. The test equipment available to the electronics technician is varied, and it is important that the technician know the use for which each type is intended, so that troubleshooting can be kept to a minimum.

b. Because of the different conditions under which troubleshooting may be performed, the type of test equipment selected for a job may vary. Test sets used for work in the field must of necessity be more rugged and more compact than those used in depots and other fixed installations. Generally, field equipment is less accurate than depot equipment. It is lighter in weight, because certain parts that are not necessary for making field measurements are omitted.

19. Troubleshooting With Test Equipment

a. A technician will at times be called on to place new equipment into operation, perform routine preventive maintenance, or repair complex equipment. In most cases, the job cannot be performed without test equipment; in all cases, the job can be done more quickly, accurately, and efficiently if the test equipment is used properly.

b. The technician will find a large variety of uses for tube testers, multimeters, electronic multimeters, signal tracers, oscilloscopes, and other devices which will be of great help to him.

c. Many circuits require potentials to be of a certain value within close tolerances. To insure this without test equipment is impossible. Other circuits will have an output in which the wave form must be of a certain shape. Here the voltage and resistance measurements may be very close to that required, yet the circuit may not function properly. An oscilloscope or similar device is the only instrument that can be used to display a visual indication of voltage wave forms. Another instance is in determining the field strength of a transmitter at a specified point. If the proper field strength pattern is to be obtained, a field strength meter must be used.

Section II. MULTIMETERS

20. General

a. Probably the most important single piece of test equipment the technician has at his disposal is the multimeter. It is the basic and most useful item used in troubleshooting. Most multimeters are useful for making ac and dc measurements and resistance checks. Voltage and continuity tests, the most useful functions, are used in the simplest troubleshooting assignments.

b. Multimeters are available in a variety of types, some of which are very accurate, delicate, and large in size. Others are small, rugged, and not so accurate. Each type has its advantages and disadvantages.

21. Pocket-Type Multimeter
(fig. 11)

a. The pocket-type multimeter is used mostly for relatively simple troubleshooting where accuracy is secondary. The sensitivity is usually 1,000 ohms per volt, which in itself prevents the indications from being accurate under certain conditions. It is used especially for making continuity and point-to-point resistance measurements. Because of its small size and portability, it is very convenient for checking equipment in the field. It can also be used for relative output meter readings.

b. The ranges on most small meters are limited to those needed for doing simple jobs. The pocket-type multimeter is suitable for checking fuses, battery voltages, measuring the output of dynamotors or vibrator power supplies, and checking cables for open and short circuits. It is not suitable for making measurements in high-resistance circuits because the low meter resistance will load the circuits and give false readings. Circuit loading is explained in paragraphs 29 through 35. The pocket-type voltmeter, properly used, can give very informative voltage measurements.

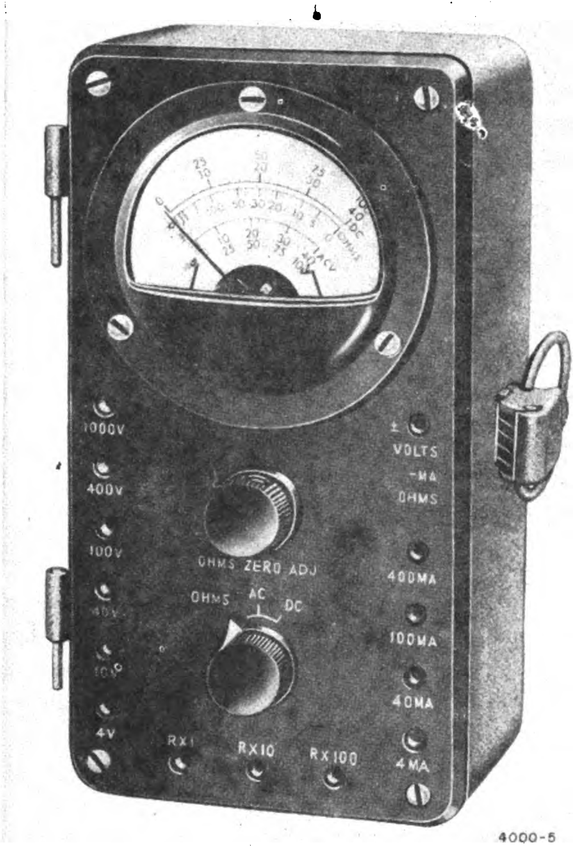


Figure 11. Pocket-type multimeter.

22. Portable Multimeter

a. A portable multimeter may be more accurate than the pocket-type. It is larger and is probably the most useful one for all general troubleshooting.

b. The portable multimeter differs from the pocket type in that it has a wider range of measurements. Some multimeters include decibel (db) scales; others give the technician a choice of two sensitivities for dc measurements—20,000 ohms per volt and 1,000 ohms per volt. By using the proper meter, it is possible to compare accurately the voltages present and those that should be present. Usually, the ac ranges have a sensitivity of 1,000 ohms per volt as this is adequate for ac (not RF) measurements. A portable multimeter with a sensitivity of 20,000 ohms per volt is accurate enough for most voltage measurements that are normally required in electronic troubleshooting.

c. The only serious limitation is that sometimes a 20,000 ohms-per-volt portable meter is not sensitive enough to indicate accurately the voltages in high-impedance circuits. For these special applications, a vacuum-tube voltmeter (vtvm) is required. A portable multimeter with 20,000 ohms-per-volt dc sensitivity and 1,000 ohms-per-volt ac sensitivity is shown in figure 12.

23. Electronic Multimeter
(fig. 13)

a. The most sensitive type of multimeter available uses a vacuum-tube circuit to increase the sensitivity. The indicating meter usually indicates plate current that varies in proportion to the voltage under test. This instrument is the electronic multimeter; it is capable of measuring ac and dc voltages and resistance. The electronic multimeter is useful in troubleshooting high-impedance circuits where loading effects caused by nonelectronic types could give erroneous indications or, in some cases, render the circuit inoperative. The input impedance is about 11 megohms. This type of meter often is referred to as a vacuum-tube voltmeter, or vtvm.

b. A well-designed probe is useful for measuring RF voltages with frequencies up to 1,000 megacycles (mc). RF voltages are measured by using a diode as a rectifier, then applying the rectified dc to the multimeter. The diode may be in the meter case proper, but usually is located in the end of a probe to reduce the capacitive loading on the circuit under test. This is because of the short lead between the test point and the diode. Almost the entire length from the test point to the meter is at a dc potential, rather than RF. It can be seen that RF losses are also reduced.

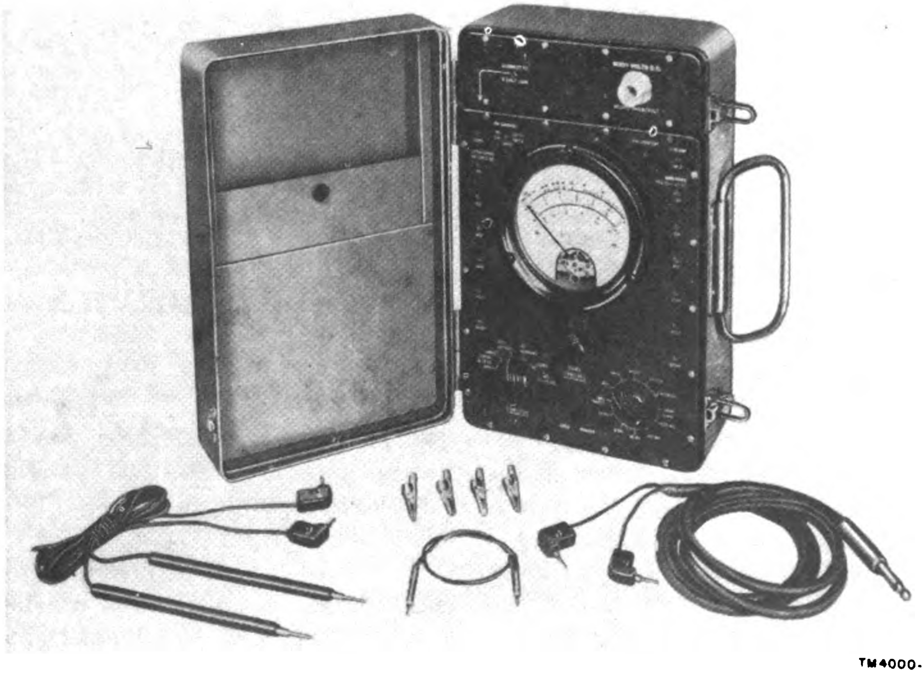
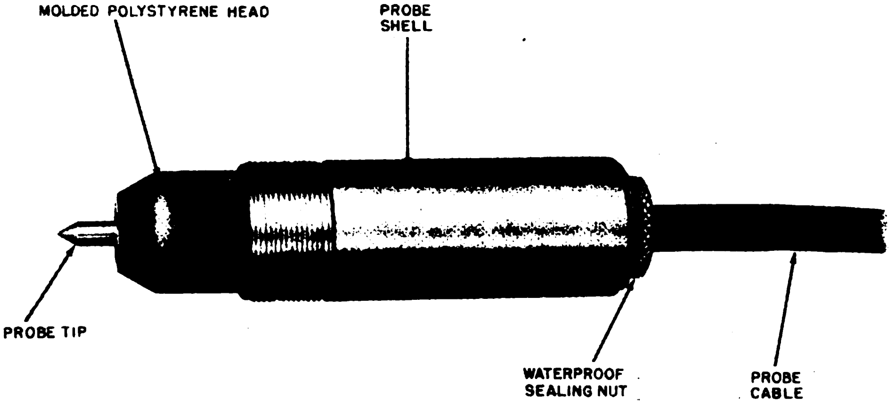


Figure 12. Portable multimeter.


TM4000-7

Figure 13. Electronic multimeter.



TM 4000-9

Figure 14. RF probe.

Section III. USING MULTIMETER

24. Precautions

a. Certain precautions must be observed when using a multimeter to prevent damage from mishandling, jarring, or dropping. Carelessness in making resistance measurements also may result in damage to the meter.

b. Be careful when measuring voltages to set the voltage selector switch to the highest range before connecting the meter into the circuit. If the meter is connected to a voltage source that is too high for the selected range, the meter probably will be ruined.

c. If the multimeter is set to read current or resistance and a voltage is applied across the test prods, damage will result. Therefore, it is important that all switches on the meter be set at the proper positions before making any measurements.

25. Measuring Dc and Ac Voltages

a. With the aid of a schematic diagram, determine whether the voltage to be measured is ac or dc, and set the meter switch accordingly. If the meter switch is set for dc voltage measurements and is connected to a source of ac, the meter needle will not be deflected and damage to the meter may result. For measuring voltages that are positive with respect to the chassis, the negative test lead (black) usually is connected to the chassis or other reference point, and the positive lead to the point to be measured. If the opposite polarity is to be measured, the red and black leads can be reversed.

b. Sometimes a 60-cycle ac line voltage will cause the needle to quiver on dc settings of the meter. This can be destructive because the violent motion of the needle could shake the meter movement out of balance.

c. Unless the multimeter being used is specifically designed to read peak voltages, only sine-wave voltages will give accurate indications. The ac scales on the conventional meter are calibrated to read .707 times the peak value of the sine-wave voltage. The meter indication multiplied by 1.41 is the peak voltage. If necessary, peak voltages can be measured with an oscilloscope. This will be covered in another chapter.

26. Measuring RF Voltages

a. Occasionally, it is necessary to measure RF voltages. This is usually done with an electronic multimeter and an RF probe. Certain precautions must be observed to prevent false readings. To minimize the effects of stray fields near the point in the circuit being tested, the probe tip must be left as it is; it should *not* be extended with a piece of wire for convenience. Such an extension could result in erroneous readings at higher frequencies, because the extension will pick up stray radiated RF energy. It is also good practice not to grasp the probe too firmly or to bring the hand too close to the probe tip. Body capacity effects may introduce additional errors.

b. Another cause of erroneous readings when using a probe is a faulty ground connection or ground leads that are too long. A sign of a poor ground connection to the probe is the inability to repeat a voltage reading when the ground connection is shifted to another point.

27. Measuring Current

Current readings are seldom made because the circuit must be opened to connect the meter into the circuit. If the meter in use has current ranges, it should be used with special care, because if it is set to a low current scale and is connected into a circuit of higher current, the meter will be ruined. The important thing to remember is that for current measurements the meter must be connected in series with the circuit. The current range selected must also be sufficient to pass the current present in the circuit.

28. Measuring Resistance

a. One of the most important tasks of troubleshooting is the measuring of resistance. Under ordinary circumstances, there is no possibility of damaging a meter that is being used to measure resistance. However, when making resistance measurements on a piece of equipment that has been in use just prior to troubleshooting, caution is necessary.

b. Circuits which include high values of capacitance can be a source of trouble. The capacitors should be discharged before anything else is done. If this is not done, the voltage remaining in the capacitors may be sufficient to throw the meter needle against the stop pin. This will ruin the meter or make the readings become inaccurate.

c. When measuring resistance with a multimeter, it is important that the technician keep his fingers off the test prods. This is because the readings may be affected by his body resistance, which will be in parallel with the part being measured.

d. When a multimeter is stored for future use, the selector switch should be set to the off position or to the highest voltage range. This will protect the meter from possible damage if a technician uses it in a high-voltage circuit without first checking the setting. The battery should also be removed from the multimeter.

e. The resistance of individual parts and circuits is often difficult to check because of the shunting effect of other components in the equipment. It will then be necessary to disconnect one terminal of the part in question from the rest of the circuit to obtain accurate readings.

29. Definition of Circuit Loading

a. When a voltmeter is connected between two points in a circuit, the resistance of the meter is added to the circuit. This may change the circuit voltages. Such a change would be due to circuit loading by the meter.

b. The amount of circuit loading produced by a voltmeter depends on the resistance of the meter. Circuit loading results in a meter reading that is lower than the actual circuit voltage without the meter. The technician must be aware of this and must learn to make allowance for it.

c. The ideal voltmeter should measure the voltage in a circuit without upsetting the circuit conditions. However, every meter draws some power from the circuit under test. If the meter is of the low-sensitivity type and is connected across a high-resistance circuit, the meter in parallel with the circuit under test forms a low-resistance circuit. The total current increases; this increased current flows through other resistors in the circuit and produces an increase in the voltage drops across them. The result is that there is less voltage available to operate the meter and a lower reading is indicated.

30. Example of Circuit Loading

a. To understand the effects of circuit loading, refer to the circuit shown in A, figure 15. This is a simple series circuit consisting of two identical resistors and a battery. For the values shown, the voltage between point P and ground should be half the battery voltage; that is, 6 volts. Suppose the technician uses a 1,000 ohms-per-volt meter to measure this voltage. The voltage that is expected to be indicated is 6 volts; therefore, the meter scale would probably be set to the 10-volt scale. This means that the meter resistance is now 10,000 ohms. When the meter is connected from point P to ground, the circuit is no longer like that in A, but is like that shown in B. Notice that R_M, the 10,000 ohms in the meter, is in parallel with R_2, which is also 10,000 ohms. The resultant resistance is 5,000 ohms; this is the effective resistance that is in series with R_1. The voltage from point P to ground is no longer half the battery voltage, but is now only 4 volts.

b. For the example used, the difference is quite large. Since the meter indicates only 4 volts instead of the true value, which is 6 volts, the difference is 33⅓ percent. Notice that the loading error far outweighs the 5 percent tolerance of the meter.

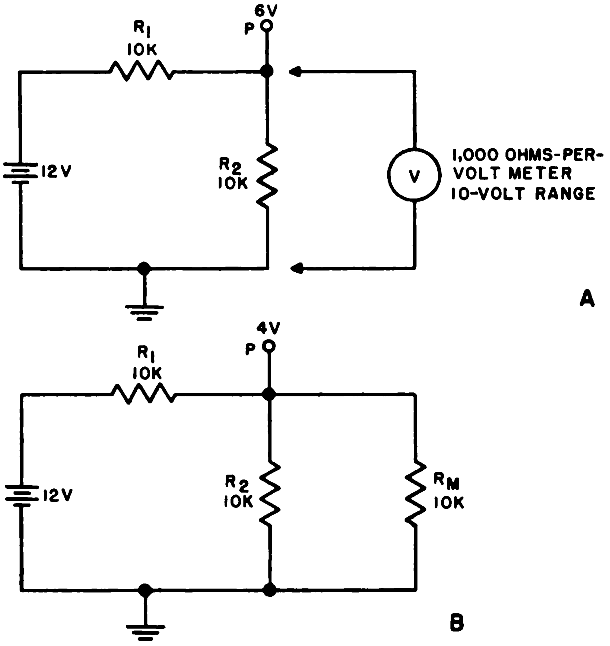
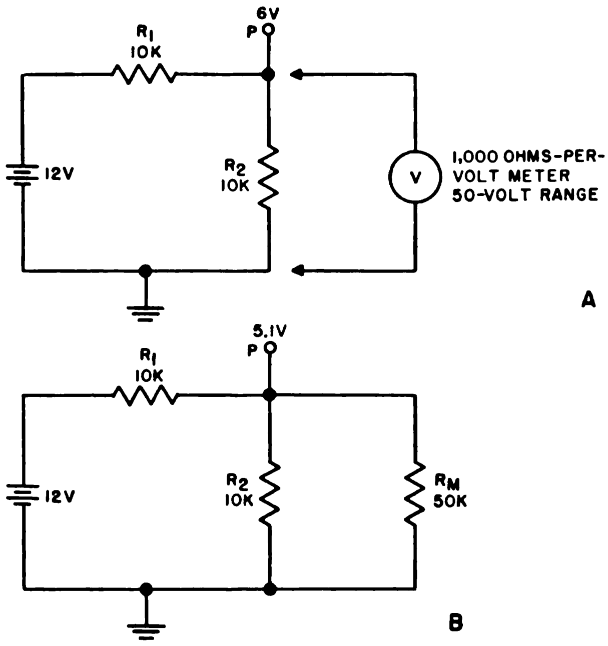


Figure 15. How a low-sensitivity voltmeter loads a circuit.

31. Reducing Effects of Circuit Loading

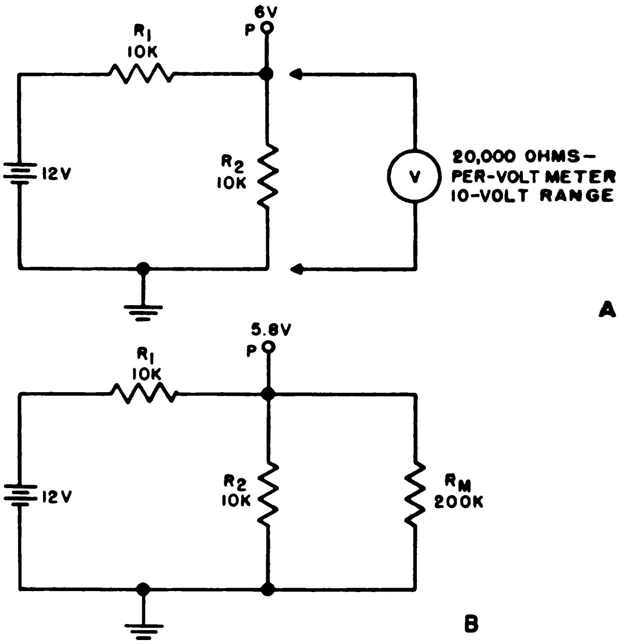
a. When it is necessary to measure voltages in a high-resistance circuit with a low-sensitivity meter, the effects of circuit loading can be reduced by using a higher range than that actually required. This makes it more difficult to read the meter accurately, because the needle is deflected only a small amount. However, the higher range increases the meter resistance and reduces the loading effect.

b. In A, figure 16, the voltage is measured between point P and ground with a 1,000 ohms-per-volt meter, but the 50-volt scale is used. As shown in B, figure 16, the meter resistance, R_M, is now 50,000 ohms. This value combined with R_1 results in an effective resistance of 8,333 ohms. The voltage read on the meter is 5.1 volts, which means that the difference caused by the



TM4000-2

Figure 16. Reducing circuit loading by using higher voltage range.



TM4000-3

Figure 17. How a sensitive voltmeter minimizes the effects of circuit loading.

meter is now only 15.7 percent. While this difference is still too high, it shows that switching to a higher range can reduce the effect of circuit loading. The result should be compared with that obtained in figure 15.

32. Using More Sensitive Voltmeter

a. Because the error is the result of the relatively low resistance of the voltmeter, a higher resistance voltmeter should be used to keep this difference as low as possible. A more sensitive meter requires less current for its operation and therefore uses a higher value of multiplier resistance for the same voltage range. Thus, the more sensitive the meter, the higher is the ohms-per-volt rating and the lower is the loading effect on the circuit under test.

b. An example of using a more sensitive meter is shown in figure 17. The voltage is measured between point P and ground with a 20,000 ohms-per-volt meter. In B, figure 17, R_M is shown to be 200,000 ohms. This resistance in parallel with R_2, which is 10,000 ohms, results in an effective resistance of 9,524 ohms, and the current is about .6 ma.

c. The meter indicates only slightly less than half the applied voltage, 5.8 volts. The difference is now only 5 percent, which is acceptable for most work. Thus, by using a more sensitive meter, the accuracy of voltage readings obtained in high-resistance circuits is improved.

33. Advantage of Electronic Voltmeter

a. The advantage of using an electronic voltmeter is that its input resistance is about 10 megohms on any of the meter ranges. This means that there will be practically no circuit loading.

b. The electronic multimeter is connected from point P to ground (fig. 16). The resistance between these two points becomes 9,990 ohms. The current is .6 ma and the voltage is 5.99 volts. The difference is only .17 percent.

34. Practical Example of Circuit Loading

a. Figure 18 shows a practical example of how circuit loading can give a voltage reading that is far removed from the true value. The socket voltages of this audio amplifier stage are measured with a voltmeter that has a sensitivity of 20,000 ohms per volt. This sensitivity usually is adequate for most measurements. In A, figure 18, the cathode voltage is developed across R_K, a relatively low resistance. If the voltmeter is set to the 10-volt range, the total meter resistance, R_M, is 200,000 ohms. With this value of resistance shunted across R_K, the change in resistance across R_K is negligible and the meter indicates the true value of 8 volts.

b. Suppose the technician desires to read the bias voltage from grid to cathode. If the same meter is now connected from grid to cathode, the 500K grid resistor is in series with one meter lead and the voltage source. The voltage source in this case is the drop across the cathode bias resistor.

c. The circuit in B, figure 18, is a simplified version of that at A. The battery represents the 8-volt drop across R_K. This voltage is applied in series with the 500K resistor. A voltage divider is formed by R_G and the meter resistance, R_M. The result is that instead of 8 volts the meter indicates only 2 volts. Most of the voltage drop is across R_G. If a meter with a lower sensitivity were used, the voltage reading would be even less. The voltage as read on any nonelectronic multimeter, even a very sensitive one, must be carefully interpreted before any decision is made as to whether there is a defect in the circuit.

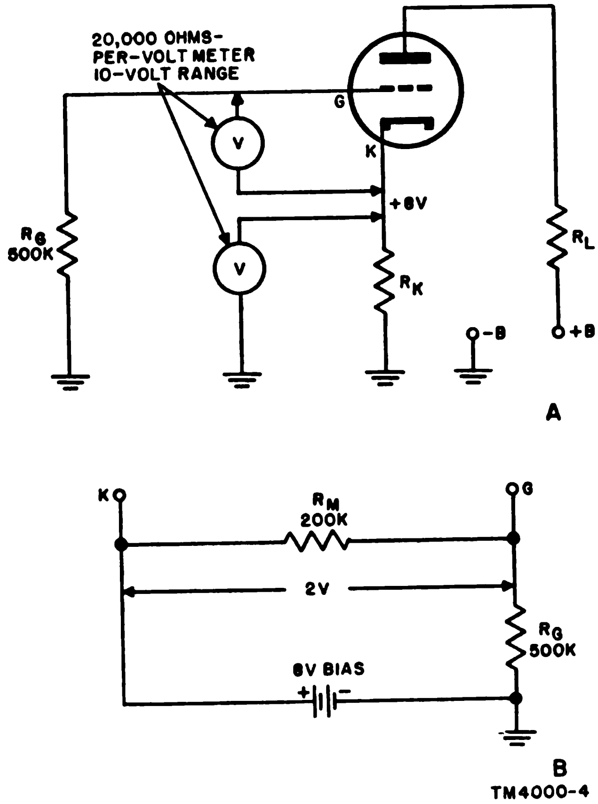


Figure 18. Measuring bias voltage in an audio amplifier stage.

35. Summary of Circuit Loading

a. Circuit loading is a problem in ac circuits as well as in dc circuits. In either case, the meter resistance or impedance should be many times the resistance or impedance between the meter and the point being measured. When the circuit has little or no series resistance, as in a power supply or battery, circuit loading is no problem. Here the shunting resistance, a bleeder for example, may be very high, or even left out. However, the meter drain is so small compared to the available current that loading is unimportant.

b. To minimize the effects of circuit loading, the following points should be kept in mind and followed:

(1) Use a high-resistance voltmeter.

(2) For negligible loading when making voltage readings, the meter resistance should be at least 20 times greater than the resistance of the circuit being measured.

(3) Use the highest voltage range practicable which still allows an accurate reading to be obtained. The higher the range used, the higher the meter resistance and the less the circuit loading.

(4) Use an electronic voltmeter if possible.

(5) To determine whether the meter is loading the circuit, measure the voltage on two or more ranges. If the same voltage is not read on all ranges, the meter is loading the circuit.

c. The chart below shows the relative circuit loading effect of a nonelectronic voltmeter as compared with that of one type of electronic voltmeter. Note that on the highest range on the nonelectric meter, the input resistance is greater than that of the electronic voltmeter.

Range (volts)	Input resistance (meg)		Circuit loading effect
	Vtvm	Nonelectronic*	
5	10	.1	Nonelectronic voltmeter 100 times that of vtvm.
10	10	.2	Nonelectronic voltmeter 50 times that of vtvm.
50	10	1	Nonelectronic voltmeter 10 times that of vtvm.
100	10	2	Nonelectronic voltmeter 5 times that of vtvm.
500	10	10	Nonelectronic voltmeter same as vtvm.
1,000	10	20	Nonelectronic voltmeter half that of vtvm.

* Nonelectronic voltmeter (20,000 ohms per volt).

Section V. ISOLATING MULTIMETER FROM CIRCUIT

36. General

a. Another type of loading which is similar in effect to meter loading occurs when certain types of test equipment are used. This is capacitive loading of a circuit and it is caused by the test leads of the instrument being used to measure dc voltage when RF is present. An example of this type of loading occurs when the technician attempts to measure grid bias voltage in the local oscillator of a superheterodyne receiver. Circuit loading is noticeable mostly when the test leads are effectively connected across a tuned circuit. The capacitance between the meter test leads can be large enough to cause detuning of the circuit, resulting in the oscillator operating at the wrong frequency.

b. To minimize this type of loading, isolate the circuit from the test equipment as much as possible. This is accomplished most conveniently in the vtvm by including a large series resistor directly in the probe, thus effectively separating the test lead capacity from the circuit. The series resistor in the probe combines with the test lead capacitance to form a low-pass filter which confines the RF to the circuit under test, yet allows the dc voltage to be measured. Although the dc voltage impressed on the meter is reduced, this is of no consequence because the vtvm has been designed and calibrated with the resistance in place.

37. Using External Isolation Resistor

By the use of a low-sensitivity multimeter which is not suitable for making measurements of grid bias in low-powered RF circuits, it is possible through adding a high-value resistor (usually 10,000 to 100,000 ohms) to obtain a usable indication that the circuit is functioning (fig. 19). The resistor may be clipped temporarily to the test point or it may be wrapped around the test prod. Although the voltage indicated on the meter will be influenced by the divider action of the isolation resistor and the meter resistance, the presence of bias voltage at the grid of a low-powered oscillator is sufficient evidence that the circuit is oscillating. Another indication of oscillation is that the meter needle will show a quick *kick* as the test prod is touched to the grid; then it will return to zero.

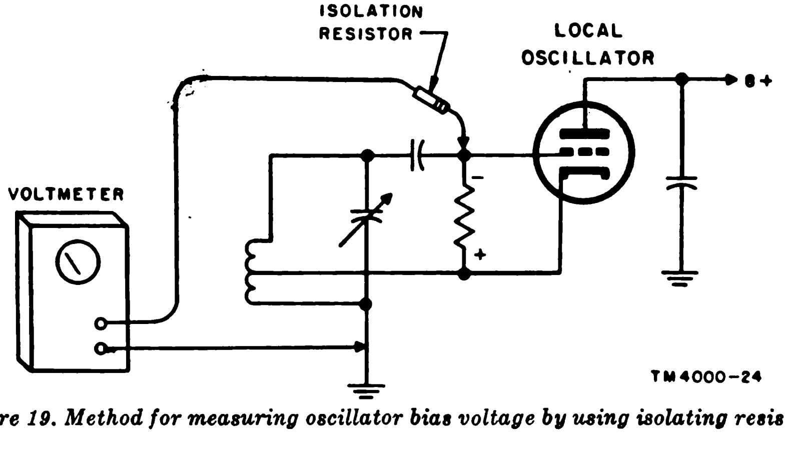


Figure 19. Method for measuring oscillator bias voltage by using isolating resistor.

Section VI. EXTENDING RANGE OF VOLTMETER

38. General

Sometimes a voltage to be measured is beyond the range of the multimeter available. Some multimeters have a high-voltage probe especially designed to extend the range of the instrument. If a high-voltage probe is not a part of the equipment, two methods can be used to measure the voltage. One requires the addition of several series-connected resistors across the voltage source to form a voltage divider so that a measurement can be made across one of them and the total voltage computed. The other method requires the addition of an extra multiplier resistor in series with the meter lead to increase the range.

39. Voltage-Divider Method

a. The simplest method is to connect 10 equal resistors in series across the voltage source. To avoid loading the circuit, these resistors should be quite large, but small compared with the meter resistance. Then the voltage measured across one resistor is multiplied by 10 to give the total voltage present.

b. As an example, the technician knows that the total voltage should be about 10,000 volts. The highest scale on the 1,000-ohms-per-volt meter available is 1,000 volts. Therefore, the resistance of the meter is 1 megohm on the scale used. Each of the 10 equal (approx. 250,000 ohms) resistors in series has 1,000 volts across it.

c. As a safety precaution, the measurement should be made from the ground side of the circuit to the first resistor in the voltage divider so that the lowest potential is applied to the meter. As an additional precaution, the connections should be made only when the power is turned off. After the connections have been made, apply power and read the meter.

40. Added Multiplier Method

a. When using this method, it is necessary to know the meter sensitivity for nonelectronic types, or the input resistance of an electronic type. For example, to check a 7,500-volt circuit with a meter having a sensitivity of 5,000 ohms-per-volt and a top range of 1,000 volts, it is convenient to increase the range 10 times, and since the meter will now indicate 10,000 volts full scale, all readings must be multiplied by 10 to find the voltage present.

b. The first step is to determine the total resistance required for measuring 10,000 volts full-scale reading. This total resistance is found by multiplying the sensitivity by the full-scale voltage reading; that is, 5,000 ohms-per-volt multiplied by 10,000 volts, or 50 megohms. However, the 1,000-volt range already includes a 5-megohm multiplier resistor. Therefore, an additional 45 megohms in resistance is required in series with the meter lead to cause the meter to indicate 10,000 volts full-scale deflection.

c. In a vtvm which has an input resistance of 20 megohms and a maximum voltage range of 1,000 volts, it is necessary to add sufficient series resistance to form a 10 to 1 voltage multiplier. In this case, the added resistor must be 9 times as great as the meter resistance, or 180 megohms. In practice, a resistor of 180 megohms may not be available. It can be formed by connecting several lower value resistors in series.

Section VII. OUTPUT AND DB METERS

41. Use of Multimeter as Output Meter

a. The power output of a receiver or audio amplifier must often be measured to determine whether the equipment is operating properly and has the required sensitivity. One procedure for making power measurements involves the use of an output meter. This kind of ac voltmeter usually has a selection of standard resistance loads which can be connected to the equipment to be tested. Output meters are usually calibrated in decibels.

b. An ac voltmeter and a resistive load can be used in place of an output meter. The normal load for the equipment may be a headset or loudspeaker, but these are not suitable for accurate power measurements because they do not have constant impedance to all frequencies. More uniform results can be obtained by using a resistive load. The resistive load must have the

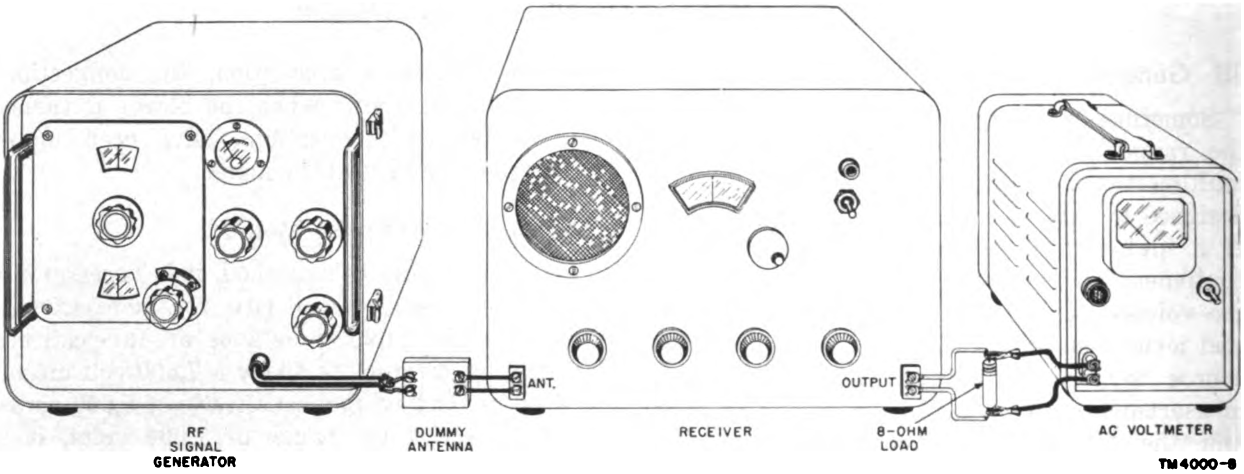


Figure 20. Checking receiver sensitivity by measuring output power.

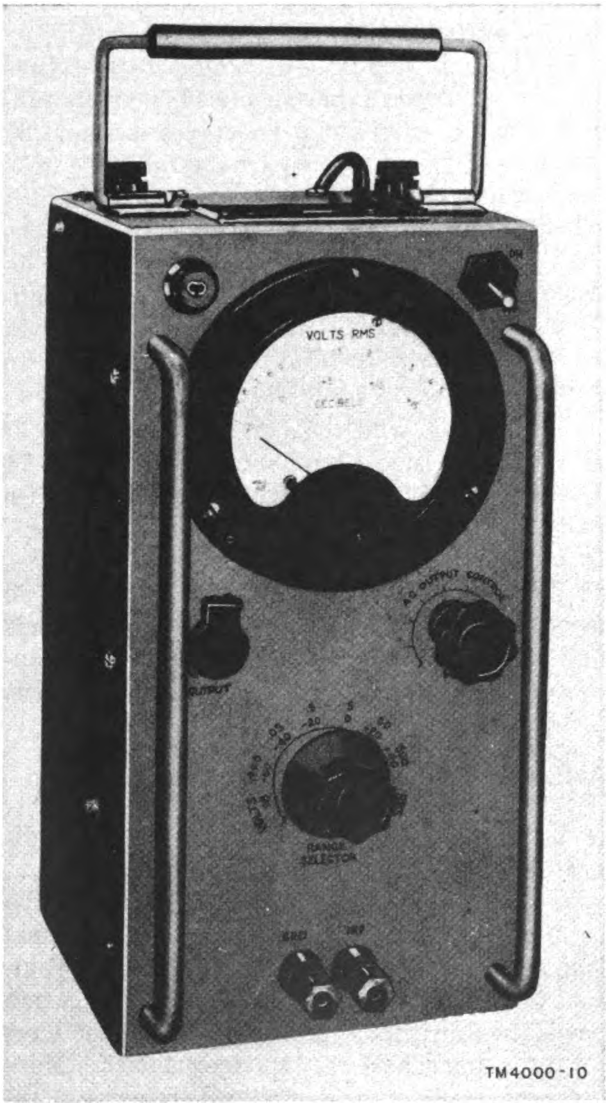


Figure 21. Ac electronic multimeter.

same value as the impedance of the receiver output and must have a wattage rating at least as great as the power expected from the equipment under test.

c. Since the meter can indicate only the ac voltage across the resistive load, the technician must do some simple computations to find the power. However, the technician should know how to do it himself. Figure 20 shows a typical setup for checking the sensitivity of a receiver with an ac voltmeter used as an output meter. This test requires that the audio frequency (AF) output power be at least of a certain value when a standard modulated RF signal is applied to the antenna terminals. If the load resistance is 8 ohms and the minimum power output required is 100 milliwatts, the voltmeter must indicate .89 volt ac or more. This value can be found by using the formula $E = \sqrt{PR}$.

d. Another formula that can be used is $P = \frac{E^2}{R}$.

Note. In both formulas, P is in watts, and 100 milliwatts is written as .1 watt.

42. Db Meters

a. Ac voltmeters intended primarily for use

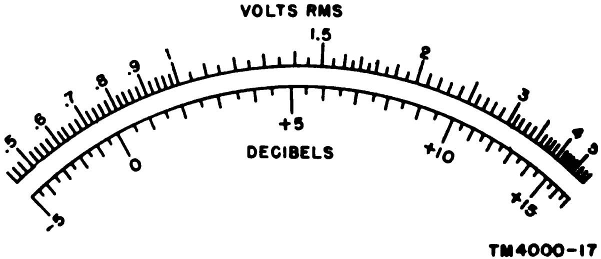


Figure 22. Meter face, showing nonlinear db scale.

with audio frequencies usually have a db scale in addition to the voltage scales. This makes it convenient to make power output measurements when the power level is given in db. An ac voltmeter having a db scale is shown in figure 21. The scales are shown more clearly in figure 22. The voltmeter uses a nonlinear scale for voltage measurements and a nonlinear scale for db measurements. The range of the meter can be changed in 20-db steps by using the selector switch on the panel.

b. The meter shown in figure 21 is calibrated to read directly in db when the meter switch is set to the 0-db range and is connected across a load resistance of 600 ohms. A common reference for db measurements is 1 milliwatt (mw) across a load resistance of 600 ohms, and is taken as 0 db. This corresponds to a value of .775 volt. When using the db ranges, a correction factor must be added to or subtracted from the reading to obtain the true db level (assuming that the load resistance is 600 ohms). The correction factor is marked on the meter panel opposite the setting of the selector switch on each range. A reading on the db scale of +5 db with the selector switch on the —20-db range indicates a level of —15 db. Note that these figures are added algebraically. If the db meter is calibrated for 1 mw across 600 ohms, and is used to make measurements across a load that is not 600 ohms, the db readings require interpretation or correction. A correction factor to be added to or subtracted from the meter reading can be calculated from the formula below, where *Z* is the impedance of the circuit under test.

$$\text{db to be added} = 10_{\log} \frac{600}{Z}$$

Section VIII. SIGNAL GENERATORS

43. General

A signal generator is a piece of test equipment that generates an ac signal. An RF signal generator is, in effect, a small radio transmitter. The generated signal may be modulated or unmodulated, and can be used for alinement of tuned circuits, dynamic troubleshooting (signal tracing), sensitivity measurements, field-intensity and stage-gain measurements, and signal substitution.

44. RF Signal Generators
(fig. 23)

a. The RF signal generator is used for locating troubles that are difficult or impossible to find by making voltage and resistance measurements. Trouble may be localized to a specific stage by injecting a signal from a signal generator into the suspected stage or section and observing the results.

b. RF signal generators are constructed for different frequency ranges and accuracy. The output of an RF signal generator may be modulated, unmodulated, or audio. Any one of the three types of output may be selected and used by the repairman for troubleshooting receiving equipment.

c. Some generators have both am and fm outputs. Portable units are of necessity smaller and lighter and are limited in their accuracy. It may be necessary to check the frequency calibration with an accurate frequency meter. Some types have a meter for accurately measuring the RF output level.

d. RF signal generators used in depots usually have accurate frequency calibration and the modulation percentage can be adjusted. In addition, the RF output level is metered for accurate control of the output. This makes these generators very suitable for work where extremely low signal levels of high accuracy are required. This is important for certain alinements and for measuring signal-to-noise ratio and signal-plus-noise to noise. Generators that are not accurately calibrated to very low levels in output voltage can give misleading results.

45. Sweep Generators

a. A sweep generator is an fm signal generator that sweeps across a range of frequencies and repeats the sweeping at a fixed rate. An example is a signal sweeping between 28 and 32 mc at a rate of 60 cycles. A sweep generator is especially useful for certain types of alinement where a special shape of response curve is required.

b. A sweep generator may have a marker gen-

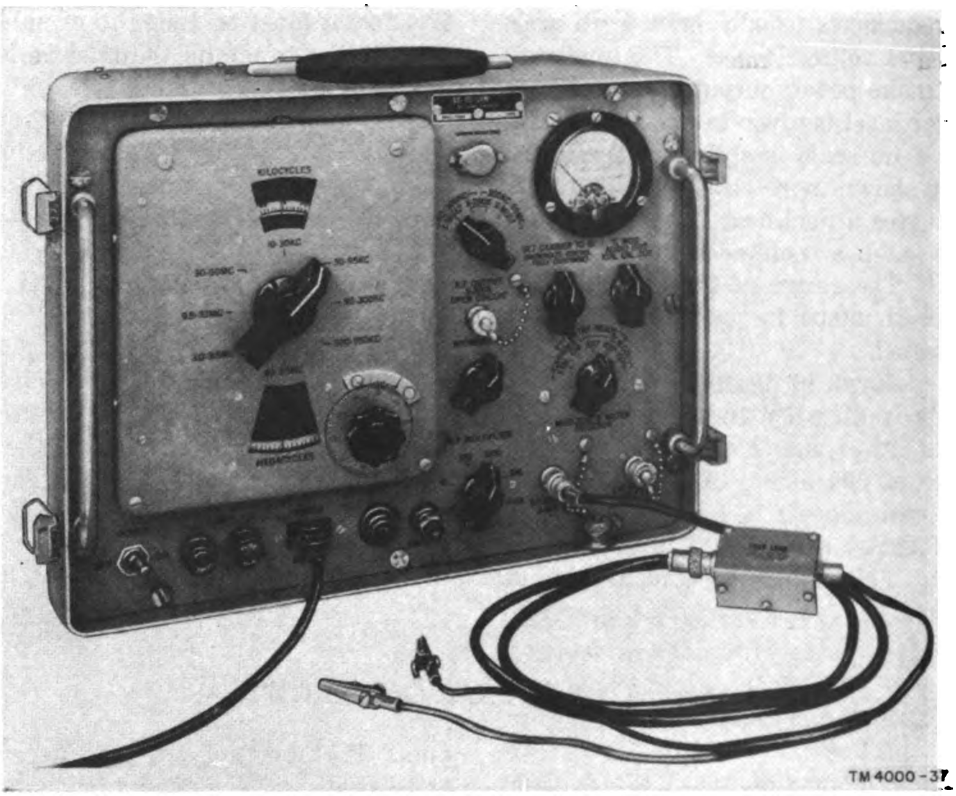


Figure 23. Amplitude modulation signal generator.

erator built into it. A marker generator is a signal generator that is capable of producing an accurately calibrated signal. Its purpose is to indicate the frequency at various points on the response curve by superimposing a marker signal on the curve. The curve must be viewed on an oscilloscope. If a marker generator is not built into the sweep generator, a separate marker generator can be used in parallel with it.

46. Audio Frequency Signal Generators (fig. 24)

a. An audio frequency signal generator, sometimes called an audio oscillator, is capable of producing signals of frequencies ranging from 20 to 20,000 cycles. It is used mainly in troubleshooting audio frequency amplifiers, but is also useful in helping the technician determine the harmonic content of signals in audio circuits. Refer to paragraphs 121 and 156.

b. When the generator is used for simple signal substitution, a signal of any audible frequency can be used. When an audio amplifier is to be checked for harmonic content, the shape of the wave is very important. In this case, an AF square-wave generator can be used, so that variations in the output wave shape can be determined and compared.

47. Matching Impedances

a. The output impedance of the signal generator should be matched to the input impedance of the circuit under test. This is important, especially when alining a receiver and when measuring the sensitivity of a receiver after alinement. The signal generator usually can be terminated properly by using one of the resistive pads supplied as part of the test equipment. Proper termination eliminates the possibility of standing waves on the test cable.

b. If a signal generator with an output impedance of 50 ohms is used, and is terminated with a 50-ohm load, the correct RF voltage at the receiver input terminals can be measured. If the proper load were not used, inaccurate readings would result. With a 50-ohm load connected to the cable and the cable connected to a receiver with an impedance of 300 ohms, there

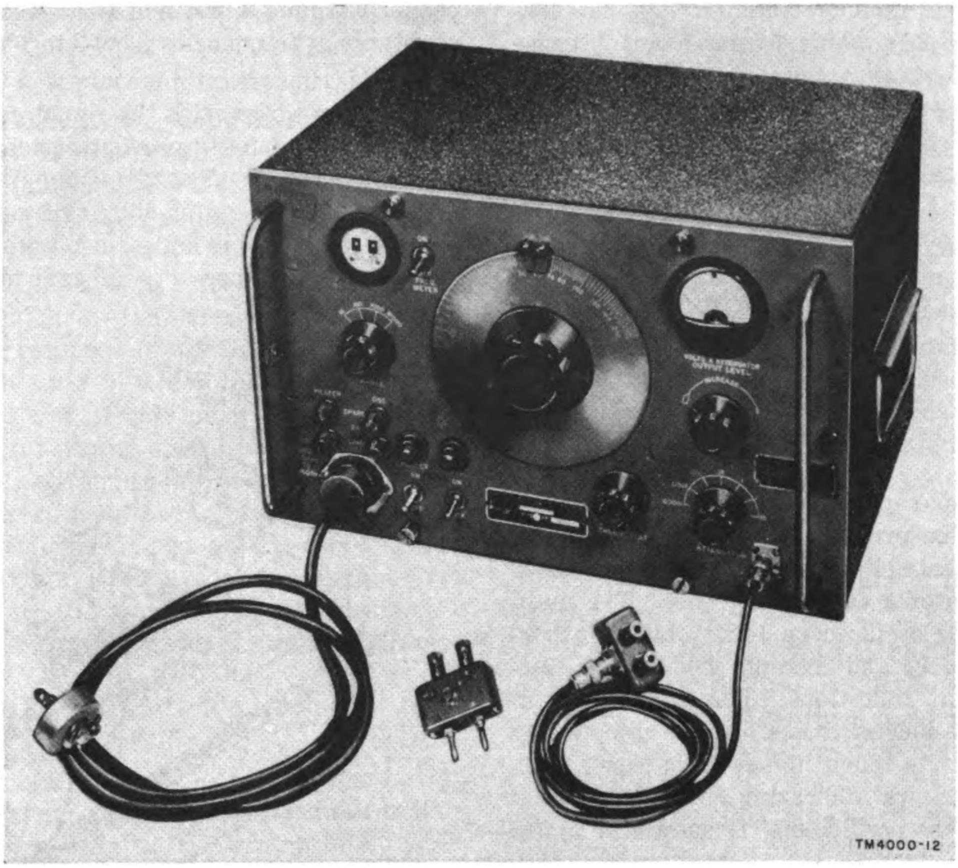


Figure 24. Audio oscillator.

would be an impedance mismatch which would cause inaccurate readings.

c. An impedance-matching network can be used to match the signal generator to the receiver input. An example is shown in figure 25. The coaxial cable *sees* the 50 ohms in the 50-ohm resistor, and the receiver input *sees* the total resistance of the three resistors in series. The total resistance is 290 ohms, which is a very close match for 300 ohms.

48. Using Signal Generator

a. Some general rules to keep in mind when using RF signal generators are given below. For best results, read and follow the instructions given in the manual for the equipment. Although most generators have control markings which are self-explanatory, special instructions must often be followed to avoid erroneous results.

b. Whenever possible, the signal generator specified for the equipment in the technical manual or Repaired Equipment Standard should be used, otherwise inaccurate results may occur because of incorrect impedance matching. When alining a receiver, best results are obtained if a dummy antenna is used. If no dummy antenna

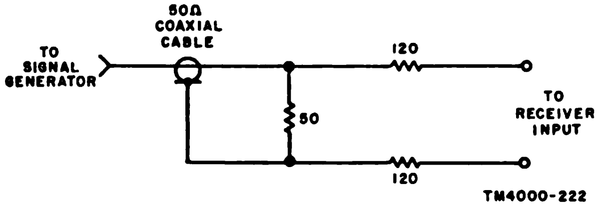


Figure 25. Impedance-matching network.

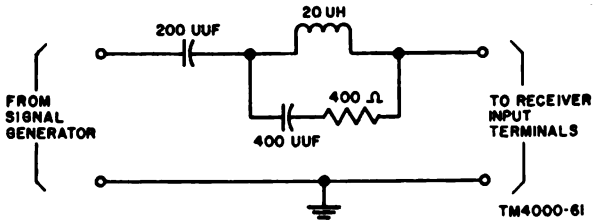


Figure 26. Dummy antenna, schematic diagram.

is specified, a dummy antenna can be constructed (fig. 26). This is important because the correct dummy antenna simulates the impedance that would be present when the antenna is connected. The unit should be inclosed in a grounded metal container and used with a signal generator that has an output impedance not exceeding 50 ohms.

c. This dummy antenna *looks* like a 200-μf capacitance at low frequencies, is a complex impedance around 1 mc, and *looks* like a 400-ohm resistance at frequencies from 2 to 30 mc.

d. It is important to connect a dc blocking capacitor in series with the signal generator hot lead. This is done to prevent accidental contact with high-voltage dc from damaging the generator. In some equipments, this capacitor is a part of the unit, but unless a blocking capacitor is known to be present, an external capacitor should be used.

Section IX. CATHODE-RAY OSCILLOSCOPES

49. General

The cathode-ray oscilloscope is an electronic instrument that provides a visual representation of one electrical voltage as a function of another on the screen of a cathode-ray tube. The main feature of the oscilloscope is its ability to portray graphically and instantaneously the fluctuating circuit conditions. The electron beam has negligible inertia; therefore, the cathode-ray tube responds to much higher frequencies than any other electrical indicating device. A typical general-purpose oscilloscope is shown in figure 27.

50. Advantages of Oscilloscope

a. The oscilloscope is useful for certain types of troubleshooting where multimeters and signal generators are not suitable. Ordinarily, the multimeter is the ideal instrument for indicating common troubles such as incorrect or no voltage, short or open circuits, changes in value of resistors, and defective capacitors. However, when troubles occur which do not show up as incorrect voltage or resistance readings, using the oscilloscope is often the only sure way to locate the trouble. For example, such troubles as hum or distorted signals in the output of a receiver or amplifier can be more quickly isolated if an oscilloscope is connected to various points in the circuit. In the same manner, an open bypass capacitor can be located by noting whether the signal voltage appears where there should be none. An example of this is at the screen grid of an amplifier tube; here the capacitor bypasses the applied signal to cathode or ground. If the oscilloscope indicates a signal voltage present at the screen grid, it means there is no bypass action at the signal frequency and the bypass capacitor is therefore open.

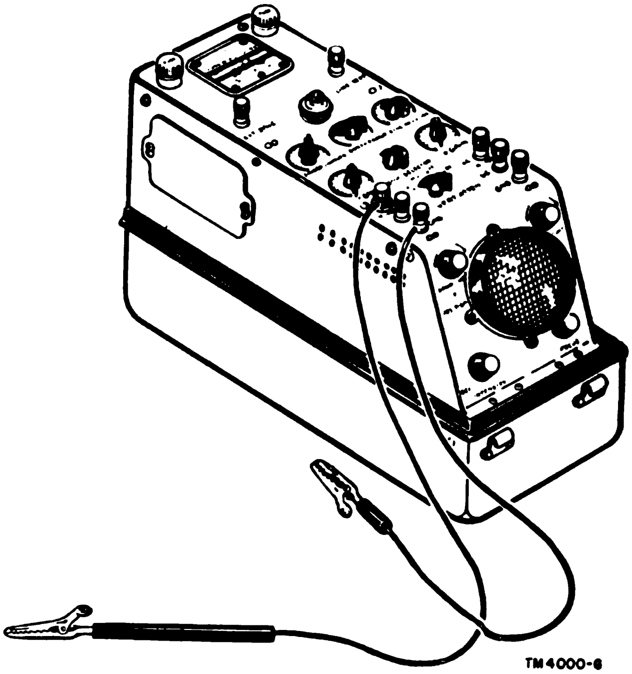


Figure 27. General-purpose oscilloscope.

b. Other examples of troubles where the visible wave form is helpful are: when checking the power supply filter for open capacitors and to see that the ripple is reduced to a negligible amount; checking the gain of a stage by noting the increase in signal amplitude from the grid to the plate circuit; checking vibrator power supplies to see that the output wave form is correct, and checking circuits where nonsine-wave voltages are involved, such as in multivibrators and similar circuits.

c. In addition, the oscilloscope is useful for determining frequency ratios by means of Lissajous figures, or checking frequency response or phase shift in audio amplifiers, and checking the percentage of modulation in transmitters.

d. The oscilloscope is also useful for certain types of alinement which requires that the response curve have a special shape. Examples of this are: adjusting the IF response on receivers which use stagger tuning for a broad pass band where a flat top characteristic is required; alinement of the discriminator in fm receivers which use automatic frequency control, or the response of the IF amplifiers in a television receiver in which the response is not symmetrical but which must have a special wave shape for proper operation of the receiver. In order to use the oscilloscope to examine the response curves mentioned above, a sweep generator output is required at the input to the receiver. This requires special techniques for synchronizing the sweep generator with the oscilloscope so that the proper stationery image is produced.

51. Care of Oscilloscope

a. Since the oscilloscope is comparatively complex, the technician should become familiar with it before using it. He will not only use it safety but will learn to use it properly. The best way to do this is to read the technical manual procured with the oscilloscope.

b. When using the oscilloscope, observe these precautions to avoid damaging it.

(1) Never leave the brightness turned up when there is no sweep voltage present; that is, a single spot of light should never be left on the screen. If a spot of light is allowed to remain on the screen, a hole will be burned in the screen material and ruin the tube. Usually, the oscilloscope is used with the internal horizontal sweep in operation; therefore there is less danger of damage.

(2) Some tests require that the sweep be turned off and external voltages applied to both horizontal and vertical inputs. To be safe, turn down the brightness level until the signal voltages have been applied, then turn up the brightness, just far enough to see the pattern clearly.

(3) Avoid placing the oscilloscope where light will fall directly on the cathode-ray tube. This would require turning the brightness up higher. The higher the brightness the shorter the life of the tube. If necessary, use a shield to block out the surrounding light.

(4) Locate the oscilloscope away from strong magnetic fields. Such fields can distort the image on the cathode-ray tube and also magnetize the oscilloscope case or the deflecting plates. If this happens, the oscilloscope may become permanently inaccurate, even after the source of magnetism is removed.

52. Helpful Hints for Using Oscilloscope

The following hints will aid in the use of the oscilloscope.

a. It is good practice to set the horizontal frequency control on the oscilloscope so that at least two cycles of the wave form appear on the screen. Figure 28 shows two cycles of a sine wave. Oscilloscopes vary in the number of vertical sweep amplifier stages they include, with the result that some oscilloscopes may produce an inverted image because normally each amplifier stage inverts the signal in polarity. Ordinarily, this is no handicap when examining sine waves or other symmetrical wave forms. However, when doing alinement work with a sweep generator the required response curve will appear inverted on the screen of some oscilloscopes.

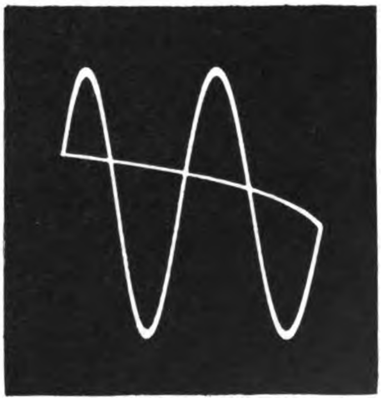


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Figure 28. Oscilloscope pattern showing two cycles of a sine wave.

b. Another characteristic which may vary from one oscilloscope to another is the direction of the slope of the trace for comparison of in-phase and out-of-phase signals. This can be checked easily by applying the same signal to both vertical and horizontal terminals with the internal sweep turned off. The signal source can be the 60-cycle voltage taken from the test terminals usually located on the front panel of the oscilloscope. The trace produced will slope either to the right or to the left. Whichever way it slopes represents the in-phase condition. If in-phase signals produce a trace sloping to the left, then input signals 180° out of phase produce a trace sloping to the right.

c. Refer to figure 29. If the test described in *b* above shows a pattern similar to that of A, that is the in-phase or 0° phase-shift condition. Then when two signals of equal amplitude and frequency are compared, B indicates a 45° phase shift; C indicates a 90° phase shift; D shows a 135° phase shift; and E shows that the two signal voltages are of opposite polarity, or that there is a 180° phase shift between them. If however, the test described in *b* above shows a pattern similar to that at E, that is the in-phase condition. Then D would indicate 45°; C would still be 90°; B would be 135° and A, 180°.

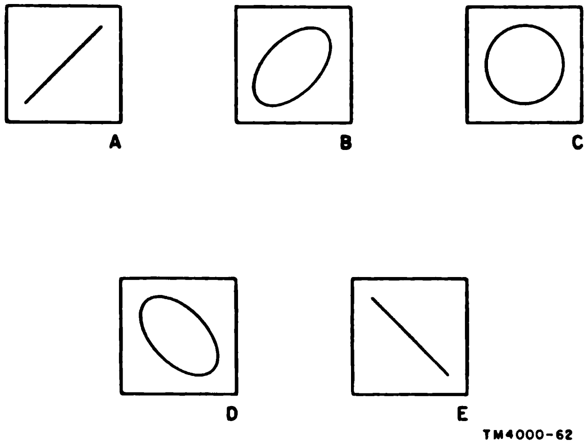

Figure 29. Phase angle patterns.

d. Sometimes misleading information is presented on the cathode-ray tube because of interference from external sources. The oscilloscope should be grounded to a ground point on the equipment under test. Be careful that the stray electric fields do not come close to the cathode-ray tube. Such fields also can be picked up through the technician's body as he handles the test leads. This condition becomes more troublesome when examining low level signals with the gain of the oscilloscope amplifiers near maximum. To minimize the effects of such stray fields, avoid holding the test leads in the hands; instead, clip them into the circuit and then examine the pattern. Avoid using too much gain in the oscilloscope amplifiers and keep the input low, otherwise overloading may occur with the result that the wave forms appear distorted. Examples of overloading are shown in figure 30. Shown at A is the only pattern that is not distorted; the others are flat either at the top or bottom or at both.

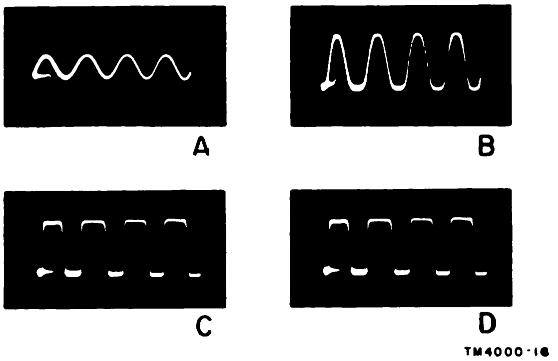

Figure 30. Oscilloscope patterns showing undistorted and distorted wave forms.

e. Sometimes it is necessary to use a voltage-divider probe such as the one shown in figure 31. This probe is useful for high input signal voltages and prevents overloading of the oscilloscope amplifiers. The probe cuts down the signal by a known amount so that a true evaluation of the signal amplitude is possible. The probe also isolates the oscilloscope from the circuit under test so that loading is held to a minimum. As in the case of multimeters, capacitive loading can be reduced by the addition of a resistor in series with the hot test lead, if a probe is not available.

53. Frequency Measurement with Lissajous Figures

a. One of the most important and useful functions of the oscilloscope is the measurement of frequencies. When two sine-wave voltages are fed to the deflection system of a cathode-ray tube, the resultant pattern is known as a Lissa-

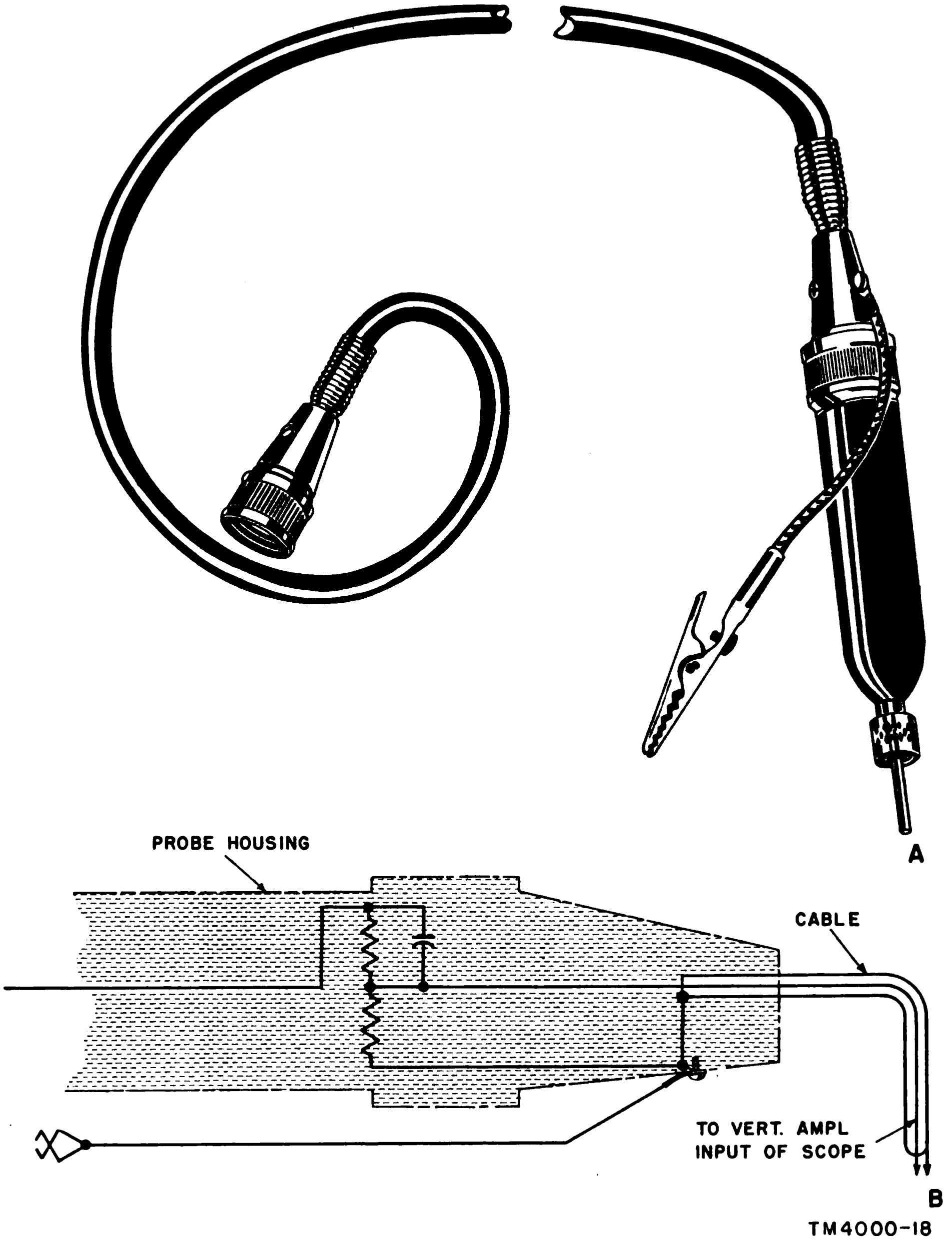

Figure 31. Input probe for oscilloscope.

jous figure. Figure 32 shows three Lissajous patterns for ratios commonly encountered in frequency measurements. The ratio of the two frequencies can be determined by counting the number of loops along the top (or bottom) edge of the pattern and the number of loops along the right (or left) edge and substituting the results in the formula below.

$$\frac{\text{Frequency on horizontal axis}}{\text{Frequency on vertical axis}} = \frac{\text{Number of loops on right edge}}{\text{Number of loops on top edge}}$$

b. The accuracy of measurements by this method is limited by the accuracy of the reference, or known frequency. These patterns sometimes change form because of slight variations in phase and frequency between the reference signal and the signal under test. This constantly changing pattern increases the difficulty encountered in counting the loops. Pattern drift and the consequent difficulty is counting the loops limit this method of frequency measurement to a practical ratio of 10 to 1. However, if extreme care is taken in counting, and if the gain of the oscilloscope is increased, it is possible to count as many as 30 loops.

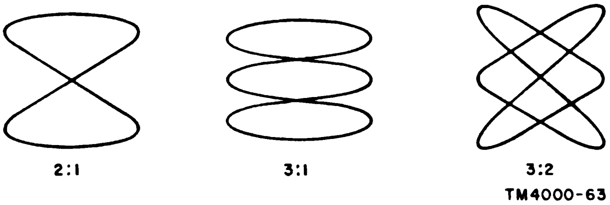

Figure 32. Lissajous figures showing some common frequency ratios.

54. Determining Polarity of Deflection

Some patterns, such as a simple sine wave on the screen may show a distorted upper or lower half. The trouble cannot be definitely traced to its source unless the input polarity of the oscilloscope is known. A method of determining the polarity of deflection is described below.

a. Turn off the horizontal sweep and reduce the intensity (to protect the screen from being burned) to the point where the spot of light can barely be seen. Turn the focus control to a position that causes the spot to be as large as possible. Turn the vertical sweep gain control to its maximum clockwise position.

b. Connect short pieces of insulated wire to the vertical amplifier terminals. Touch the two leads momentarily and at the same time to the terminals of a battery of from 4 to 6 volts. The spot will jump either up or down, then return slowly. It jumps because the battery causes the vertical sweep input blocking capacitor to charge, then slowly discharge.

c. Touch the wires together to discharge the capacitor completely. Reverse the connections to the vertical terminals and connect them to the battery. The spot will now jump in the opposite direction. Note the polarity of the battery that makes the spot jump up. If the negative side of the battery is touched to the hot terminal of the vertical amplifier of the oscilloscope and the positive side of the battery is grounded, the input polarity is negative. If the opposite is true, the oscilloscope has a positive input polarity.

Section X. TUBE TESTERS

55. General

For practical use in the field, a tube tester must provide a simple and quick appraisal of a tube. Tube testing equipments, however, have certain limitations. Although they compare tubes to a predetermined standard, they do not reveal how a tube may operate under a specific set of conditions. The final and most accurate indication of the condition of a tube is its ability to function in a circuit designed for its use. Although tube testers do not test a tube under actual circuit conditions, they are still considered important as an aid to fast troubleshooting.

56. The Emission-Type Tester

a. The emission tester measures the condition of a cathode emitting surface. The end of the useful life of a tube usually is preceded by a reduction in cathode emission.

b. The emission tester has certain limitations and disadvantages. Since the manufacturer does not state a definite 100 percent emission point which could be used for reference, the emission test is not conclusive. High emission does not necessarily indicate a good tube, because this condition might be present in a tube with a faulty grid structure, or gas content. Very high emission has been observed just before a tube fails; therefore, the emission test could indicate that a tube is in perfect condition when it is about to fail.

c. A further disadvantage of the emission test is that gas is liberated within the tube when ac test voltages are applied unless the test is made quickly. In addition, because the tube is not operated at its recommended dc electrode voltages, it is not tested under actual operating conditions. It is possible for a tube to show normal emission and still not operate properly. One reason for this is that the efficiency of the tube depends on the ability of the grid voltage to control the plate current.

57. The Transconductance-Type Tester

a. The transconductance-type tester provides a more accurate evaluation of the condition of a tube than the emission-type tester because it measures the amplification ability of the tube under simulated circuit conditions. The transconductance is measured and compared with ratings supplied by the tube manufacturer.

b. The meter scale of this type of tester is usually calibrated to indicate the transconductance (Gm) either directly in micromhos or in terms of good, weak, or bad. A tube usually is considered defective when its transconductance decreases to 70 percent of the value stated in standard tube tables. From this it can be seen that the true condition of a tube can be determined only by testing it in terms of mutual conductance. A tester for testing the Gm of a tube is shown in figure 33.

58. Use of Tube Tester

Follow the instructions given in the technical manual supplied when using a tube tester. Perform the tests in the order given. Observe the following precautions to avoid damage to the tubes or to the tester.

a. Be sure the controls on the tester are set to the proper positions *before* a tube is inserted for testing.

b. Be especially careful with the filament voltage control. If it is set too high for the tube being tested, the filament will be burned out. As a safety precaution, the filament control should be set to the lowest voltage position when

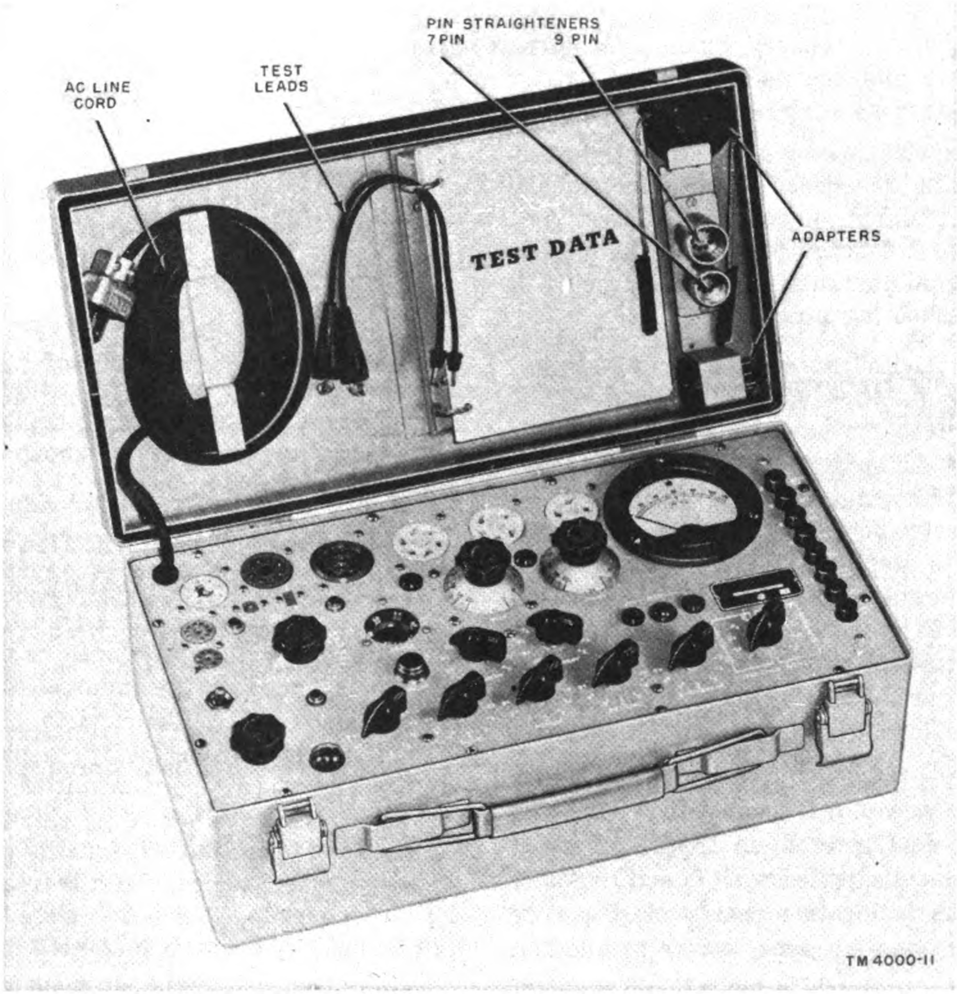

Figure 33. Transconductance-type tube tester.

the tester is not in use. This will prevent the next user from burning out a tube that is inserted before setting the controls.

c. Take special care when inserting miniature tubes in the tester because the pins bend easily.

d. Be sure to connect grid or plate cap leads before beginning any tests.

e. Reset the line voltage control for each type of tube tested. This is necessary to give a true reading on the meter, and also to protect the tubes from excessive voltage. This is especially true after checking high-current tubes such as power output or rectifier tubes. These types require that the line voltage be adavnced when they are tested. Unless the line voltage is reduced, excessive voltage may be applied to the next tube checked.

f. The usual order used in checking a tube is as follows: test for shorts and filament continuity. Then test for leakage, and finally for mutual conductance or emission. If the tube shows a short, make no other tests. They might damage the tube tester.

g. If a tube tests slightly below normal in the Gm tests, try a new tube in the equipment. Unless there is a noticeable increase in performance, the original tube can be returned to the equipment.

h. If a tube is suspected of being intermittent, tap it lightly during all tests. If the tube gives erratic indications when tapped, replace it.

Section XI. FREQUENCY-MEASURING METERS

59. General

a. Basically, a frequency meter is a tuned circuit with a dial that is calibrated directly in kilocycles or megacycles.

b. The frequency meter is an accurate instrument used for frequency measurements and calibration of signal generators and receivers. Some types of frequency meters can be used in place of a signal generator for signal tracing or other troubleshooting procedures.

60. Heterodyne Frequency Meters
(fig. 34)

a. An RF heterodyne frequency meter has excellent stability and accuracy. It usually contains an electron-coupled oscillator which is known for its stability. Another good feature is that it generates strong harmonics. A heterodyne meter of the more elaborate type includes a crystal-controlled oscillator which is used to check the accuracy of the divisions on a calibrated dial. Most heterodyne frequency meters have provisions for connecting a headset.

b. The accuracy of a frequency meter depends on the individual heterodyne frequency meter calibration charts supplied with it and the crystal used. The calibration charts must not be switched from one frequency meter to another. Each chart is calibrated for one particular meter only and cannot be used with others.

c. The heterodyne frequency meter can be used to calibrate both transmitters and receivers. During receiver calibration, a portion of the frequency meter output is radiated and is picked up by the receiver. When the heterodyne frequency meter is used to check the frequency of a transmitter, it acts as a receiver and picks up the signal radiated by the transmitter. Many types of heterodyne frequency meters are available. Although the operating procedure for all frequency meters is similar, a frequency meter should not be used until the technical manual has been read and thoroughly understood. This is important because accurate results cannot be obtained unless the operator knows how to read the dial and set it properly.

61. Proper Use of Heterodyne Frequency Meters

a. To prevent damage to the frequency meter, never connect it directly to a transmitter output circuit. Many transmitters generate enough RF energy to burn out the input circuit of a frequency meter placed too close to a transmitter. Usually, it is only necessary to place the frequency meter near the transmitter, and the signal strength can be varied by changing the distance. If the transmitted signal is weak, a piece of wire may be connected to the frequency meter for better pickup. It may run close to the transmitter but must not be connected directly to it.

b. Before using the frequency meter for frequency-measuring purposes, allow at least 30

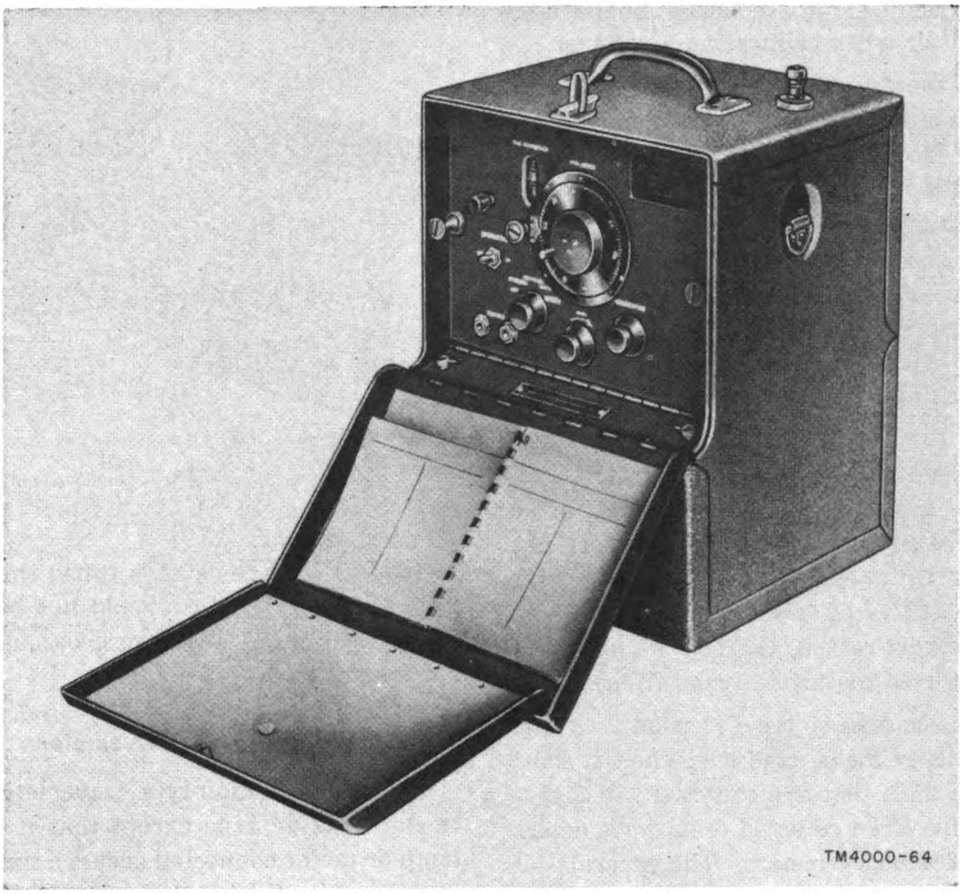

Figure 34. Heterodyne frequency meter.

minutes as a warmup period, because the equipment does not reach a stable operating temperature for some time. After the warmup period, the temperature does not change and the frequency of the frequency meter does not drift.

c. If the unit is battery-operated, remove the batteries before placing it in storage. Batteries have a tendency to corrode, and if corrosion occurs while the batteries are in the unit, the corrosive action will produce a sticky substance that will leak out and ruin component parts.

62. Using Heterodyne Frequency Meter When Tuning Transmitter

a. If the oscillator in a transmitter is crystal-controlled, there is no problem in keeping it on frequency. If the oscillator is not crystal-controlled, the frequency meter may be used to insure its operation on the desired frequency.

b. Set the frequency meter to the frequency at which the oscillator is to operate. Couple the frequency meter output loosely to the oscillator, and tune the oscillator until a beat note is heard in the headset. Continue tuning the oscillator until the beat note finally reaches zero. Zero beat has then been reached and the oscillator is on frequency.

c. The same procedure is used to tune buffer amplifiers, frequency multipliers, and final amplifiers to the desired frequency.

63. Using Heterodyne Frequency When Calibrating Receiver

a. Under normal operating conditions, a receiver should maintain calibration for long periods. There are times, especially after certain tubes have been replaced and after some components have changed physically and electrically, when alinement is necessary.

b. The procedure used for receivers is opposite to the procedure used for transmitters. That is, the frequency meter is used as a receiver when setting a transmitter on frequency, but is used as a transmitter when calibrating a receiver.

c. Couple the frequency meter loosely to the receiver antenna terminal. Set the frequency meter to the frequency required to calibrate the receiver. With the receiver bfo turned on, pick up the frequency meter signal on the receiver and tune it to zero beat. If the receiver dial does not indicate the frequency to which the frequency meter is set, the receiver requires adjustment.

64. Wavemeters

a. One of the simplest and most useful types of frequency-measuring devices is the wavemeter. Some units may be small enough to be held in one hand while being used. There are no operating voltages required; all power for operation is extracted from the circuit being checked. For this reason, the use of the wavemeter is restricted mainly to transmitters.

b. The wavemeter is the forerunner of the modern frequency meter, and even though some of them have dials that are calibrated in megacycles, they are often referred to as wavemeters rather than frequency meters. The accuracy of the wavemeter does not compare with that of the frequency meter; it is therefore used to a great extent in detecting the presence of RF in transmitter circuits and to give an approximate frequency reading. Wavemeters cannot be relied on for an accurate measurement because they tend to detune self-excited oscillators to which they are coupled. Wavemeters consist of a coil shunted by a variable capacitor. Some units have a milliammeter or a small lamp connected across either the inductor or capacitor.

65. Reaction-Type Wavemeter
(fig. 35)

The reaction-type wavemeter absorbs very little power from the circuit to which it is coupled, and is preferred to other types of wavemeters for measuring frequencies in low-power circuits. It has no resonance indicator; an indication of resonance is usually supplied by a milliammeter in the device under test. If the circuit under test includes a current meter, resonance is indicated by a deflection on the meter as the wavemeter is tuned through resonance. The wavemeter should not be placed too close to the circuit under test, because the resonant frequency may change.


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Figure 35. Reaction-type wavemeter.

66. Absorption-Type Wavemeter

a. The absorption-type wavemeter is similar to the reaction type except that it has a small lamp or meter connected across a fixed capacitor in series with the tuning capacitor. This capacitor has a much higher capacitance than the variable capacitor. The high capacitance permits a very large voltage to be built up across it that will light the lamp or operate the meter, but has practically no effect on the circuit because of its low reactance. This wavemeter is more accurate than the reaction meter, but absorbs more power from the circuit under test. Its use is generally restricted to high-power devices because it tends to load the circuit.

b. The brightest indication on the lamp or the highest reading on the meter resonance indicator signifies that resonance has been reached. For greatest accuracy, the wavemeter should be coupled loosely to the tank circuit so that the lamp barely glows. The looser the coupling, the less the loading on the circuit. If the absorption wavemeter contains a sensitive meter, be careful to avoid close coupling to the circuit under test. In addition to loading effects, enough energy may be absorbed by the wavemeter to damage the resonance-indicating meter.

67. Combination Absorption and Reaction Wavemeter
(fig. 36)

This wavemeter uses a set of plug-in coils to cover the tuning range of the unit. It can be used either as a reaction-type or an indicating-type (absorption) wavemeter. A pilot lamp is included and may be screwed into a socket to make the unit an indicating type. With the lamp in use, the wavemeter is slightly less sensitive because of the power consumed by the lamp.

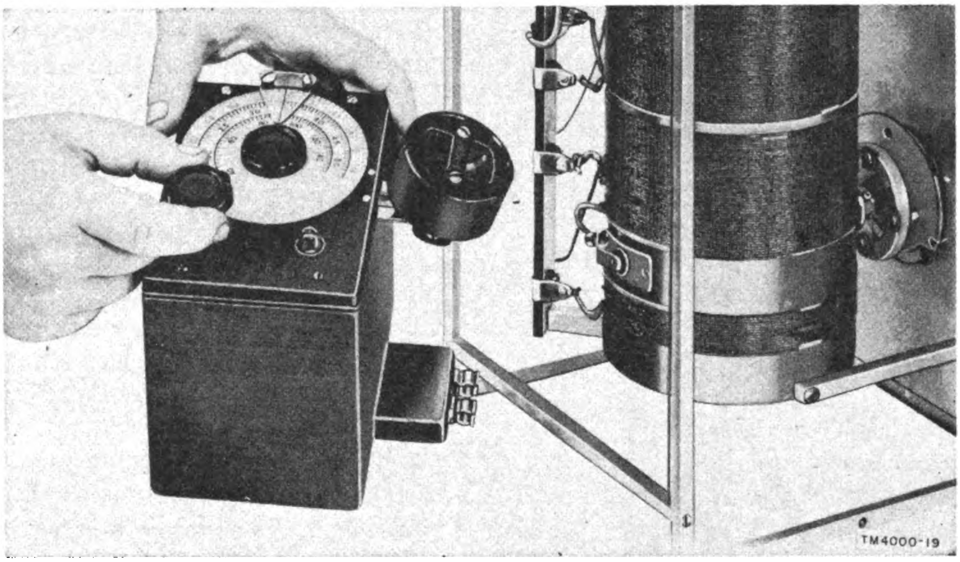


Figure 36. Combination absorption-reaction meter.

Section XII. FIELD-STRENGTH METERS

68. General

a. The field strength of a radio wave is determined by measuring the RF voltage induced in an antenna.

b. The field-strength meter is not generally classified as test equipment because it is used primarily for selecting transmitter and receiver sites. Since the main purpose of a transmitter is to produce optimum radiation at the correct frequency, the field-strength meter actually measures a part of the radiated field, thereby providing a true indication of the amount of energy being radiated.

c. Some types of field-strength meters measure only the relative magnitude of field intensity; other types measure the absolute magnitude of the field intensity in terms of microvolts per meter. The latter type field-strength meter is more widely used.

69. Field-Strength Meter Operation

a. A field-strength meter usually consists of a receiver that picks up the signal and compares it with a reference voltage generated by a self-contained calibrated oscillator.

b. When this equipment is used, locate it away from persons or objects near the radiating source and the test equipment. This precaution is necessary to prevent erratic meter readings.

c. To determine the best site for a transmitter, move the field-strength meter from place to place, and compare the readings at each location. Place the field-strength meter in the desired receiver location and move the transmitter, if portable, to produce the best results. An absolute field-strength meter is shown in figure 37.

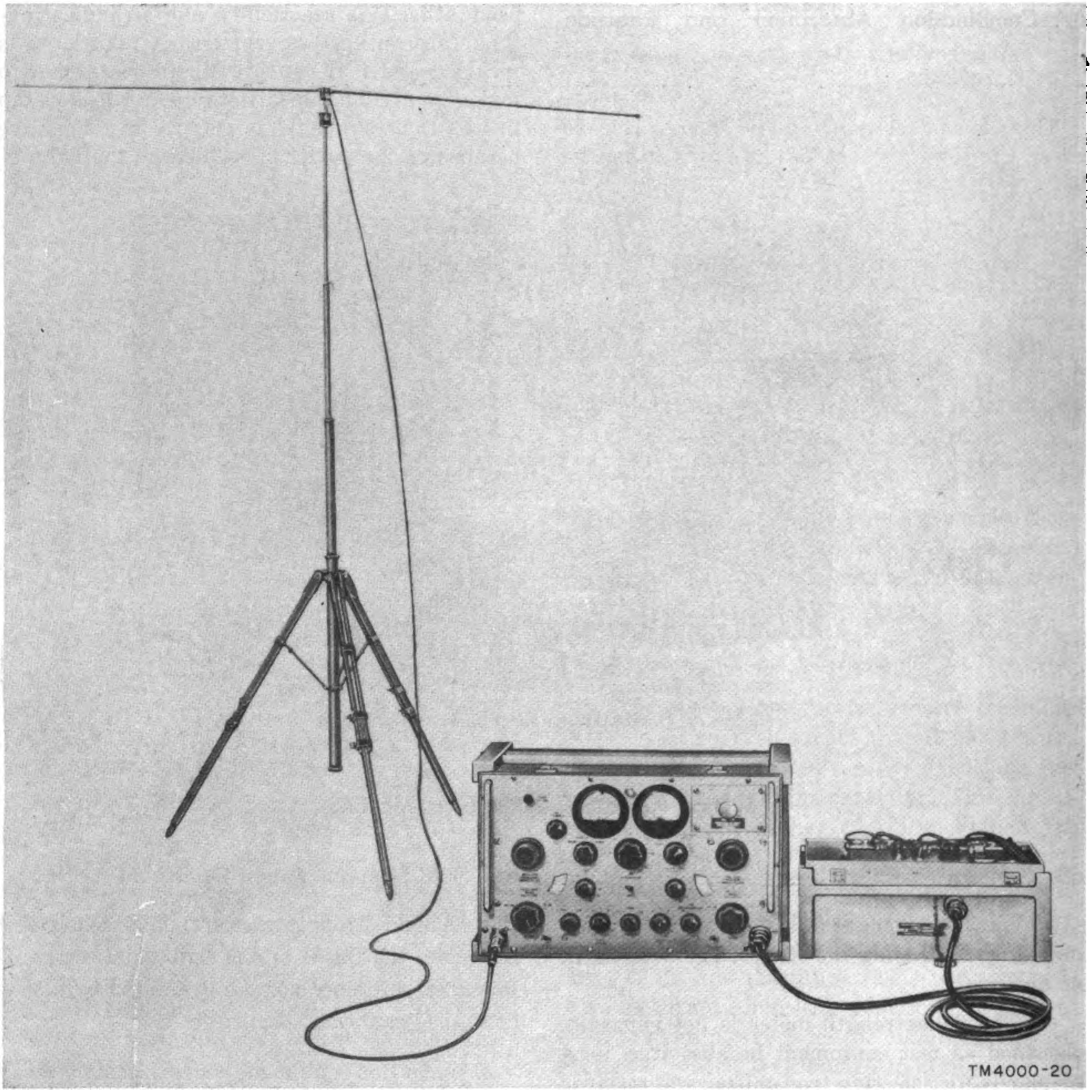


Figure 37. Absolute field-strength meter.

Section XIII. SUBSTITUTION OF TEST EQUIPMENT

70. General

a. Substitution of test equipment can be used at times when the designated test equipment is unavailable or inoperative. The use of substitute test equipment can lead to a false and misleading analysis of a circuit or it can result in misalinement and erroneous sensitivity readings. Substitution of test equipment should not be done haphazardly. It requires careful and intelligent selection.

b. If the technician cannot obtain the test equipment specified in the technical manual for the equipment being tested, he should determine whether other test equipment is suitable as a substitute. For certain types of repair, the substitution of one test equipment for another may be very simple and may cause no difficulty. Other types of repairs require special test equipment for which there is no substitute.

71. Multimeter Substitution

a. If the multimeter specified in the technical manual is not available, another with similar voltage and resistance ranges and the same sensitivity will probably work just as well. If the sensitivity of the substituted multimeter is far less than that of the recommended one, the technician can expect some wide variations in the voltage readings made in high-impedance circuits. If the substitute multimeter has a higher sensitivity than that called for, some of the voltage measurements will be considerably higher than those specified in the voltage chart in the technical manual. If the substitute multimeter has a lower sensitivity than the one specified in the technical manual, lower voltage readings will be obtained in certain circuits.

b. A substitute multimeter can be used for obtaining accurate voltage readings even if it has a higher or lower sensitivity than the one designated in the equipment technical manual. Use the substitute multimeter to measure voltages in a normally operating set similar to that being repaired. Compare results on the two sets and use the readings on the good set as the correct ones.

72. Signal Generator Substitution

a. If the specified signal generator is not available for troubleshooting by the signal substitution method, another type of generator with similar frequency coverage will do as well. An fm generator can be used to apply an unmodulated signal to an am receiver by turning off the sweep.

b. If the receiver is being alined or checked for sensitivity, the signal generator specified for the equipment should be used if at all possible, and the technician should follow the instructions in the technical manual carefully. If the alinement is performed with a substitute signal generator, any or all of the problems listed below may be present.

(1) The substitute generator may not have the necessary frequency range to allow complete alinement on all bands of the equipment. The accuracy of the frequency calibration may not be high enough to produce an alinement job which will guarantee that the receiver will give the required dial calibration accuracy.

(2) Another important factor to be considered is the output impedance of the signal generator. This is important when measuring the sensitivity of an alined receiver. The receiver and signal generator impedances must be matched. If the output impedance of the signal generator is nearly the same as the input impedance of the receiver, the error will not be very great. An example of a matching network is shown in figure 25.

(3) It may be necessary at times to use a harmonic from a signal generator, whose fundamental frequency is not high enough. In this case, the accuracy of the harmonic output is less than the accuracy of the generator.

(4) If the accuracy of the substitute signal generator is not as accurate as it should be, it can be calibrated at various frequencies near the ones to be used. This can be done by comparing the frequency of its output with that of a heterodyne frequency meter or a crystal oscillator.

CHAPTER 4

GENERAL TROUBLESHOOTING

Section I. INTRODUCTION

73. Importance of Logical, Accurate Troubleshooting

a. Logical Thinking. Troubleshooting electronic equipment requires logical thinking. To be effective, troubleshooting must be accurate and swift. Therefore, it calls for clear thinking, combined with ingenuity and common sense and logical working procedures. The technician must think for himself and thereby make the best use of the information gathered, in each particular case, from the equipment technical manual, the operator of the equipment, and from other repairmen who may have worked on it. The technical manual furnishes the technician with detailed information on the equipment, but it does not supply basic maintenance practices. The technician must have this as part of his background.

b. Knowledge and Experience. Troubleshooting electronic equipment is not learned in a short time. The man with experience is limited if he has had no training in theory. Practical experience can be gained only by working with equipment over a period of time. To be a good troubleshooter calls for an effective combination of practical experience and equipment theory.

74. Why Technical Manual Is Needed

a. Specific Troubleshooting Information. No technician knows everything about the various equipments that may be brought to him for repair. He may be familiar with the block diagram of the superheterodyne receiver and the modulated transmitter. This knowledge will help him at the start of troubleshooting, but there are certain circuits requiring additional knowledge on his part if he is to understand their functions. The equipment manual then becomes useful, because it is often the only source of information describing the unit and the exact step-by-step procedures for its operation, disassembly, and alinement. In addition, the repair manual includes the tube socket voltages and resistance charts, and the resistances of transformers and coils. Also, the technical manual shows pictorially the location of each component part, and it may reveal whether a circuit is common to both transmitter and receiver and whether a defect in one can affect the other too. It also includes schematic diagrams, wiring diagrams, and interconnections.

b. Specialized Technical Data.

(1) Communication equipment may often be intended for specialized use. It will be as compact and self-contained as possible, and it may have certain special mechanical and electrical features. For troubleshooting specialized equipment, the repairman must equip himself with correct specialized information.

(2) The repairman must know the method used for interconnecting the components of a radio set and, in particular, for connecting the transmitter and receiver to a power source. A set that operates on either 115 or 230 volts ac, or one that operates on 6, 12, or 24 volts dc can be seriously damaged by the incorrect use of a switch or plug.

Section II. CHECKING TUBES AND COMPONENT PARTS

75. Tube Testing Techniques

a. Before testing the tubes at all, test the cables and external connections. Isolate the trouble to a unit or section of the equipment.

b. Before removing any tubes, turn on the power to see whether they warm up properly.

If the envelopes are of glass, a visual inspection will show whether any is burned out. If the tube envelopes are of metal, *turn off the power* before attempting to feel them with your fingers. (One-volt or other low-current metal tubes, however, will not generate sufficient heat for this purpose.)

c. If a tube tester is available, first turn off the power, and then remove and test the tubes *one at a time.* Substitute new tubes only for those that are shown to be definitely defective. If a tube is suspected of being intermittent, it should be tapped gently while being checked, to bring out the defect if it exists.

d. If a tube tester is not available, troubleshoot by the tube substitution method.

76. Tube Checking by Substitution

a. Replace the suspected tubes with new tubes one at a time. If the equipment begins to operate normally, discard the last tube removed, and return the other original tubes to their sockets. Some circuits, such as oscillator circuits in very high-frequency units, may operate with one good tube and not with another. This is because of the difference in the interelectrode capacitance between the tubes, which plays a large part in determining the resonant frequency. Therefore, if a tube does not operate in an oscillator circuit, do not discard it until it is known to be definitely bad.

Caution: By rocking or rotating a tube, you may bend the pins, you may break the weld wire where the pin enters the glass, or, even if the weld does not break, you may cause a high-resistance joint to develop. Before handling large tubes, allow them sufficient time to cool.

b. In some equipments, it is possible to remove a tube from one section of the equipment without affecting the section being checked. In such a case, it is possible to troubleshoot the defective section by using a tube from another section as a substitute, if sufficient spares are not available.

Note. If a replacement for a bad tube becomes defective immediately, check the component parts in that circuit. In the case of a transmitter, check for proper tuning. An off-resonance condition with its extremely high plate current can easily ruin a tube.

c. If a component has more than one bad tube at the same time, substituting tubes one at a time and reinserting the original tube before substituting for a second tube will not locate the defective tube. The original tube may have been defective, but it was not evident because there is another defective tube that is preventing normal operation. To correct this trouble, install new tubes, and keep putting in new tubes until normal operation is restored. The last tube replaced is defective and should be discarded. To determine whether another original tube is bad, return an original tube to its socket. If there is a noticeable change in operation, discard the last original tube installed. Another method is to install all new tubes, then replace them with the original tubes, one at a time. When failure or change is noticed, discard the last original tube installed. Do not leave a new tube in a socket if the equipment operates satisfactorily with the original tube. If none of the above procedures restores the equipment to normal operation, further troubleshooting is necessary. If the equipment is to be sent to a higher echelon for repairs, return all of the original tubes to their sockets, even if the tubes are suspected of being defective.

d. A tube should never be discarded unless a tube tester or other instrument shows it to be defective, or it can be seen that the tube has a broken glass envelope, an open filament, or a broken base pin. Do not discard a tube merely because it has been in operation for a long time. Satisfactory operation in the equipment is the final proof of tube quality.

77. Checking Series Filaments

a. Tube filaments connected in series present a problem. An open filament in a tube will cause all other filaments in the string to go out. This makes it difficult to detect a burned-out tube quickly.

b. One way to test the tubes for open filaments is to remove them one at a time and check the filaments for continuity with an ohmmeter, but this procedure usually takes too much time. In addition, it can cause burnouts in the 1-volt or other low-current tubes. The ohmmeter should be set on a scale other than the lowest, because usually the current the ohmmeter can pass through the tubes on its lowest scale is often high enough to burn out the filament.

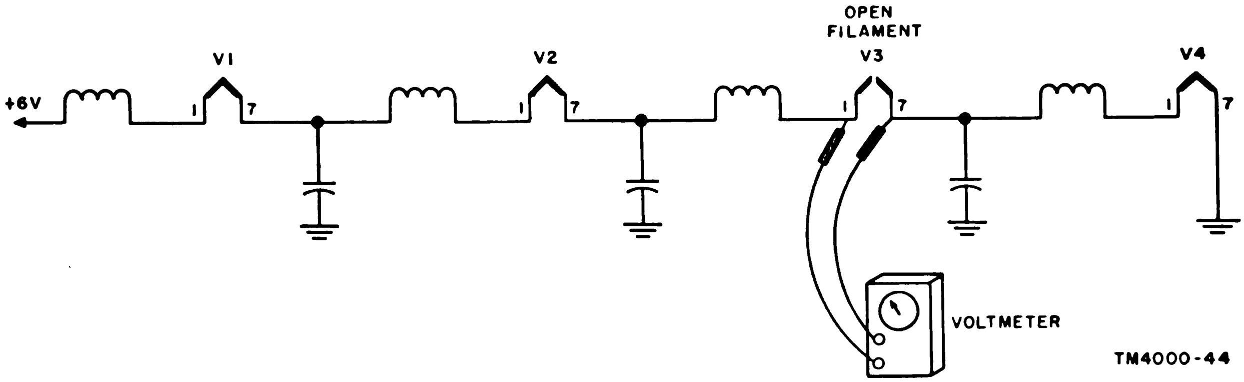


Figure 38. Finding open filament with a voltmeter.

c. If the bottom of the tube sockets is accessible, the tube with the open filament can be found by measuring the voltage across the tube filament terminals with all tubes in their sockets. All good tubes in the string will measure zero voltage across their filaments, but the one that is burned out will have the full voltage that is applied across the string (fig. 38). The open filament will have 6 volts across it. If any one tube has 1½ volts across it, all filaments are good, because the 6 volts will be divided equally among the four tubes.

d. Equipments using series-parallel filament circuits often have shunting resistors across some tube filaments in the series circuit to maintain the correct value of current flow in each tube. In this type of circuit, the voltage measured across a burned-out filament may be nearly the same as the voltage across a good tube. This is because the shunt resistor may be intact. That is why measurements should be made carefully and not too rapidly.

e. In some field equipment, the keying relay must be closed to apply power to the transmitter filament circuits. For example, relay K101 (fig. 39) can be closed manually and the voltages across the various components in the filament circuits measured. If the bottom of the tube sockets is not accessible, filament circuits can be tested through another circuit. The ohmmeter test prod can be connected to the chassis and the microphone input connector (fig. 39) and, if only a single series string existed between these points, the filament circuit could be checked for continuity. These points are shown in the upper left-hand corner of the right-hand diagram.

78. Testing Parts

When the trouble has been narrowed down to a section and then to a stage by using test equipment or simple shortcut methods, the trouble must be pinpointed to the defective part. This means testing the suspected parts—resistors, capacitors, or inductors. In many cases, the testing can be accomplished with a multimeter. This procedure is useful whether the parts are mounted in a unit or have been removed.

79. Checking Resistors

a. Before checking the suspected resistor with an ohmmeter, the circuit should be examined to determine whether it is necessary to disconnect one lead of the resistor. If it is shunted by another part that can form a dc path, the resistance indicated will be lower than the actual resistance of the resistor, because the total resistance of two or more resistances in parallel is less than the resistance of the lowest value in the branch. When the resistor is disconnected it can be checked for continuity and resistance. It is advisable to use the ohmmeter range that will give a midscale reading to insure accuracy.

b. In figure 40, resistor R4 is shunted across the grid winding of transformer T1. If a continuity measurement is made across R4, the low-resistance path through T1 in parallel with R4 will be indicated on the ohmmeter and an erroneous reading will result. It is therefore

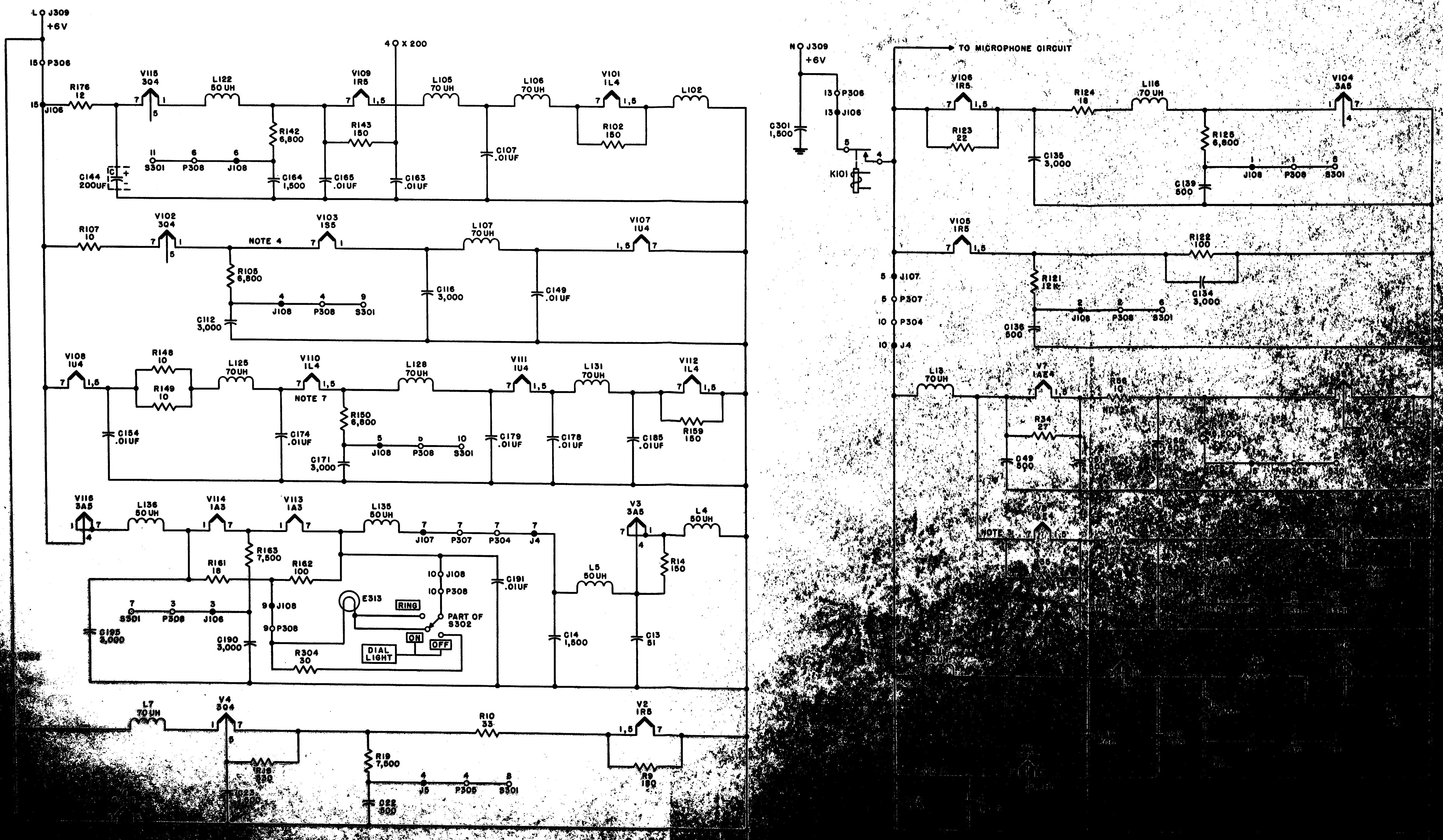


Figure 29. Radio set schematic diagram, showing [illegible]

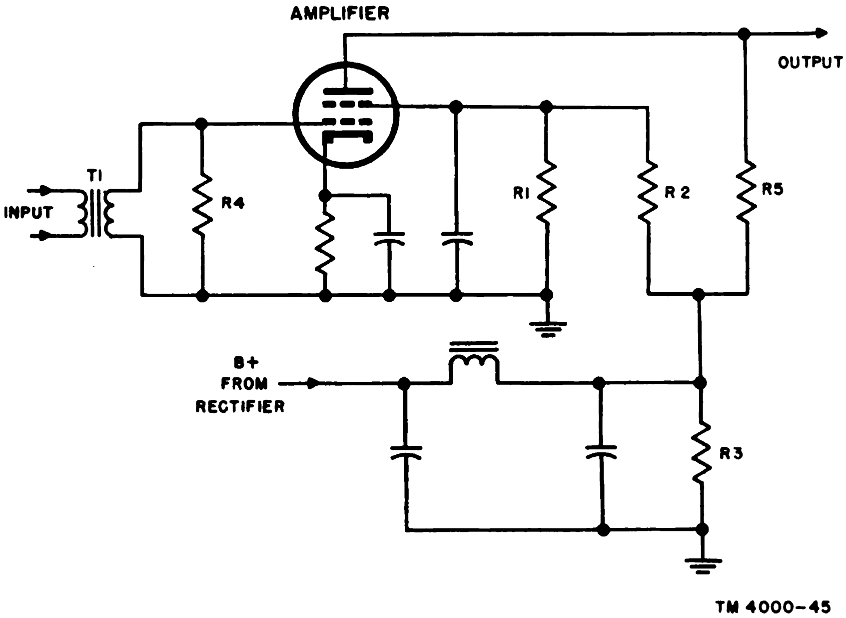


Figure 40. Audio amplifier circuit.

necessary to disconnect R4 at one end before checking it. Plate load resistor R5 has no parts in parallel with it and can be checked while it is in the circuit. The resistance from the screen grid to ground is measured through R1 which is in parallel with R2 and R3 in series. If the resistance and voltages are different from that called for in the TM, any one of the three resistors could have changed in resistance. To check one of these parts, disconnect one end of it from the circuit.

(1) It is important to use the right scale of the ohmmeter when measuring resistance or continuity. If a high range is used, a low-resistance part or a poor connection will show up as a full-scale or a closed-circuit reading. Use the high range only when checking high-resistance circuits. If a low range is used, a fairly high resistance will give the same reading as an open circuit. The resistance value will be known approximately, either by its markings or circuit information; therefore, the range that will give approximate half-scale indications should be used. Another precaution is to be sure that the fingers do not touch the ends of the test prods, because the resistance of the body will cause an inaccurate indication on the ohmmeter.

(2) Sometimes a resistor will have normal resistance when it is cold, but will change value as its temperature rises. Measure the voltage across it as soon as the power is turned on, and also after it warms up. If the voltage changes considerably over a short period of time, the resistor is changing in value and should be replaced.

c. If voltage or resistance tests indicate that a variable or adjustable resistor may be defective, a final test will have to be made, and for this purpose two of the three leads will have to be disconnected, thus effectively isolating the suspected resistor from the rest of the set. To check the resistor then, measure the resistance from one end to the other and from the top to each of the two ends separately. To test for breaks that show up only as the resistance is varied, slide the movable member back and forth while testing it to each end.

d. A resistor measured with an ohmmeter will usually measure a small amount higher or lower than the marking or color code specifies. This is because of the tolerance of the resistor. For example, a 1-megohm unit with a 20 percent tolerance will measure anywhere from 800,000 ohms to 1,200,000 ohms. In addition, the ohmmeter will not be 100 percent accurate, and its deviation from accuracy can cause a further error in measurement. A resistor having a tolerance of 5 percent is marked with a gold band; and one with a tolerance of 10 percent is marked with a silver band. Resistors of greater tolerance are not marked.

80. Testing Coils and Transformers

a. Coils and transformers include RF and audio chokes, power transformers, relay coils, audio transformers, IF transformers and coils, and any component that is wound with wire, except wire-wound resistors. These items should be checked for resistance values and the readings compared with the normal values. If necessary, one lead should be disconnected to prevent errors in readings. If the readings look suspicious, each winding should be checked for shorts or leaks to ground or a leak to another winding within the same component.

b. Refer to figure 41 for an example of a power-transformer-winding schematic diagram. The following chart shows the check points, normal readings, and the points to check for shorts.

Power-transformer resistance chart

Test points	Normal indication (ohms)	Test for short to:
Primary 1–2	5 to 10	Frame (ground) Terminals 3, 4, 5, 6, 7, 8, 9
5-volt filament 3–4	less than one	Frame Terminals 5, 6, 7, 8, 9
High-voltage 5–6	50 to 100	Frame Terminals 8, 9
High-voltage 6–7	50 to 100	Frame Terminals 8, 9
6.3-volt filament 8–9.	less than one	Frame

c. The condition of low-voltage windings is often difficult to determine because usually the resistance is so low that the readings appear as short circuits. However, these windings need never be suspected of short circuits unless there is evidence of a blown fuse or severe overheating of the transformer. These windings rarely open because the wire is so heavy that a fuse will blow before the winding opens. One method of testing a power transformer for shorts is to connect a 115-volt lamp of 50 to 100 watts in series with the primary winding. If the line voltage is 220 volts, a 220-volt lamp must be used. Remove all tubes to take the load off the secondaries.

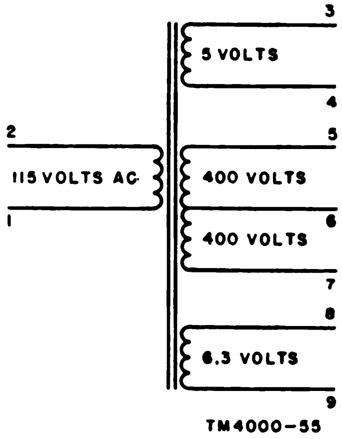


Figure 41. Power-transformer windings.

d. Turn on the power; if the lamp lights brightly, the high-voltage secondary winding is probably shorted. If the condition existed only after the power had been turned on for some time, the test will not show up the trouble immediately. It will then be necessary to run this test for several minutes to an hour; if the short circuit takes time to develop, the lamp will glow when the defect appears. This test does not apply to a defective primary; if the primary were shorted, the line fuse would have blown. The troubles that will cause the lamp to glow will therefore be in the secondary windings. If the lamp lights only when the tubes are in their sockets, the transformer is not at fault.

e. The windings used in RF and IF amplifier stages are subject to some of the defects found in power transformers. The windings can be tested for open circuits with an ohmeter. They rarely develop short circuits, but if they are suspected, resistance checks can be used to detect them. When a coil has a very low normal resistance, the available ohmmeter may not be able to indicate accurately the difference between a normal and shorted coil. The only way to be sure is to install a new part. This information applies also to RF choke coils.

81. Checking Capacitors

a. There are several ways in which a capacitor can fail. It may become shorted, it may develop a leak or an open circuit, or its capacitance may change. In most cases of leaks or shorts these failures can be checked with a multimeter or a vtvm. A capacitor checker or an ac meter must be used to detect a change in capacitance. If the capacitor is suspected of being open, a good method of double checking it, while it is in the circuit, is to bridge it with a capacitor known to be good.

(1) To determine whether a capacitor is leaky or shorted, disconnect it from the circuit and test it with an ohmmeter. There are occasions when a leak will not show up unless the capacitor is subjected to the voltage appearing in the set; therefore the ohmmeter test will not indicate a defect. Disconnect coupling capacitor C1 in figure 42 at the low-voltage side. Connect the voltmeter between the free end of the capacitor and ground and turn the set on. If there is a short or leak in C1, part of the dc voltage applied to the other side of C1 will be indicated on the voltmeter.

(2) A suspected bypass or filter capacitor (C2, fig. 42) should be disconnected at the ground side. Connect the voltmeter between the low side of C2 and ground. With the set turned on, part or all of the screen-grid voltage will be indicated on the meter if C2 is leaky or shorted. Use an ohmmeter to test the capacitor ((1) above), but turn the power off first.

(3) Whenever a capacitor, such as C1 or C2 in figure 42, is suspected of being open, the quickest way to check it is to shunt a good capacitor across it.

(4) Capacitors of comparatively large values, such as electrolytics, can be tested for open circuits with an ohmmeter. Be sure to connect the positive lead of the meter to the positive lead of the capacitor. Connect the ohmmeter terminals across the capacitor terminals and watch the meter needle. If the capacitor is good, the needle will rise rapidly as the capacitor is charging, and will fall slowly as the capacitor becomes charged.

(5) Another way of testing is to connect the capacitor across a source of dc power where the voltage is equal to, or less than, the dc voltage rating of the capacitor. If the capacitor is polarized, be sure to connect the plus side to the plus side of the power source. After a few seconds of contact, remove the capacitor and bring its terminals close together. If a spark results, the capacitor is not completely open.

(6) Capacitors may change in value, thereby producing abnormal results. To check the capacitor accurately, it is

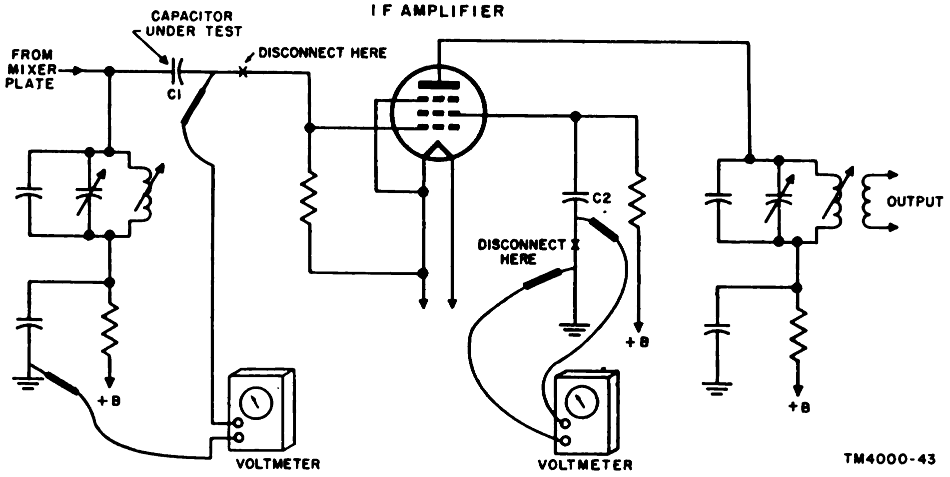


Figure 42. Method for checking capacitors with a voltmeter.

necessary to disconnect one end or remove it entirely and check it with a capacitor checker. Electrolytic capacitors lose capacitance with age because the electrolyte dries out.

b. A variable tuning capacitor or air trimmer can become shorted or leaky. To test for either condition, one end of the capacitor must be disconnected from the circuit to prevent a dc path through a coil or other part. The operation is the same as for other capacitors; that is, the ohmmeter test leads must be connected from one set of plates to the other. Any accidentally bent plates must be straightened and foreign matter removed from between them. While observing the meter needle, move the rotor plates through their complete range. When the abnormal condition has been remedied, the ohmmeter will read infinity.

82. Cable Troubles

a. General. A large number of communication sets used in the military forces are composed of several basic components connected together with multiconductor cables to form an operating unit (fig. 37). These cables conduct signal, power and control voltages between the various units that form the complete installation. Sometimes cable in vehicular installations are difficult to inspect because they are inaccessible, having been built into the vehicle at the time of manufacture. Cable troubles in this type of installation are often difficult to find and spare cables of sufficient length are not always available. A radio set may have a transmitter that is being keyed constantly, but the key is not being operated. The trouble could be caused by a shorted capacitor across the keying conductors, or the conductors could be shorted internally.

b. Types of Cable Troubles. Troubles in cables occur in the same forms as in any electrical circuit; that is, cables may develop short circuits, open circuits, or leaks. In addition to short circuits and leaks between conductors, the same conditions could occur between a conductor and any point along the length of the outer shielding. Often, a visual inspection will reveal cable troubles, especially in vehicular installations, where vibration can cause a cable plug to work loose or cause one or more conductors to break. A defect in a cable may result in a trouble that appears to be in one of the basic components. Although the trouble appears to be in the transmitter, it could be a shorted pair of conductors in the cable. The cabling in vehicular installations is especially likely to cause troubles and should always be checked before removing any of the units for further checking.

83. Testing Cables

a. Testing for Short Circuits. Disconnect the cable at both ends, to eliminate any possibility of trouble in the units showing up as cable troubles. An ohmmeter, on its high range, can be used to check a cable for shorts. If a low range is used, a high series resistance will be indicated as an open circuit. When testing the cable for intermittent short circuits, check between the shielding and each conductor while shaking the cable. Also test for shorts from each conductor to the metal plugs and shields.

b. Testing for Open Circuits. A simple continuity test will reveal an open circuit. Use the low range on the ohmmeter. If the high range is used, a high resistance will be indicated as a closed circuit. The continuity test is made from one end of the conductor to the other. Also, as in *a* above, shake all conductors while they are being checked to reveal any possible intermittent open circuits.

c. Testing for Leaks. As with the short tests, test for leakage between conductors and from conductors to the shields. Where the leak is a high resistance, the voltage supplied by the ohmmeter may not be sufficient to force current through it, and the meter would indicate that there is no leak; it will read infinite resistance and a *megger* must be used. A megger is a form of ohmmeter that uses several hundred volts to operate it; this voltage is usually supplied by a built-in, hand-operated generator. As with the short tests, test each conductor for leakage to the metal shield. The leakage resistance between any two conductors in a cable should be at least 100 megohms. An example of a cabling system in a keying circuit is shown in figure 44.

d. Checking Long Cables. To test a long cable for open circuits, connect one end of the conductor being tested to the shield or chassis. Connect one test prod of the ohmmeter to the other end of the conductor and the other test prod to the shield. Test each suspected conductor in the

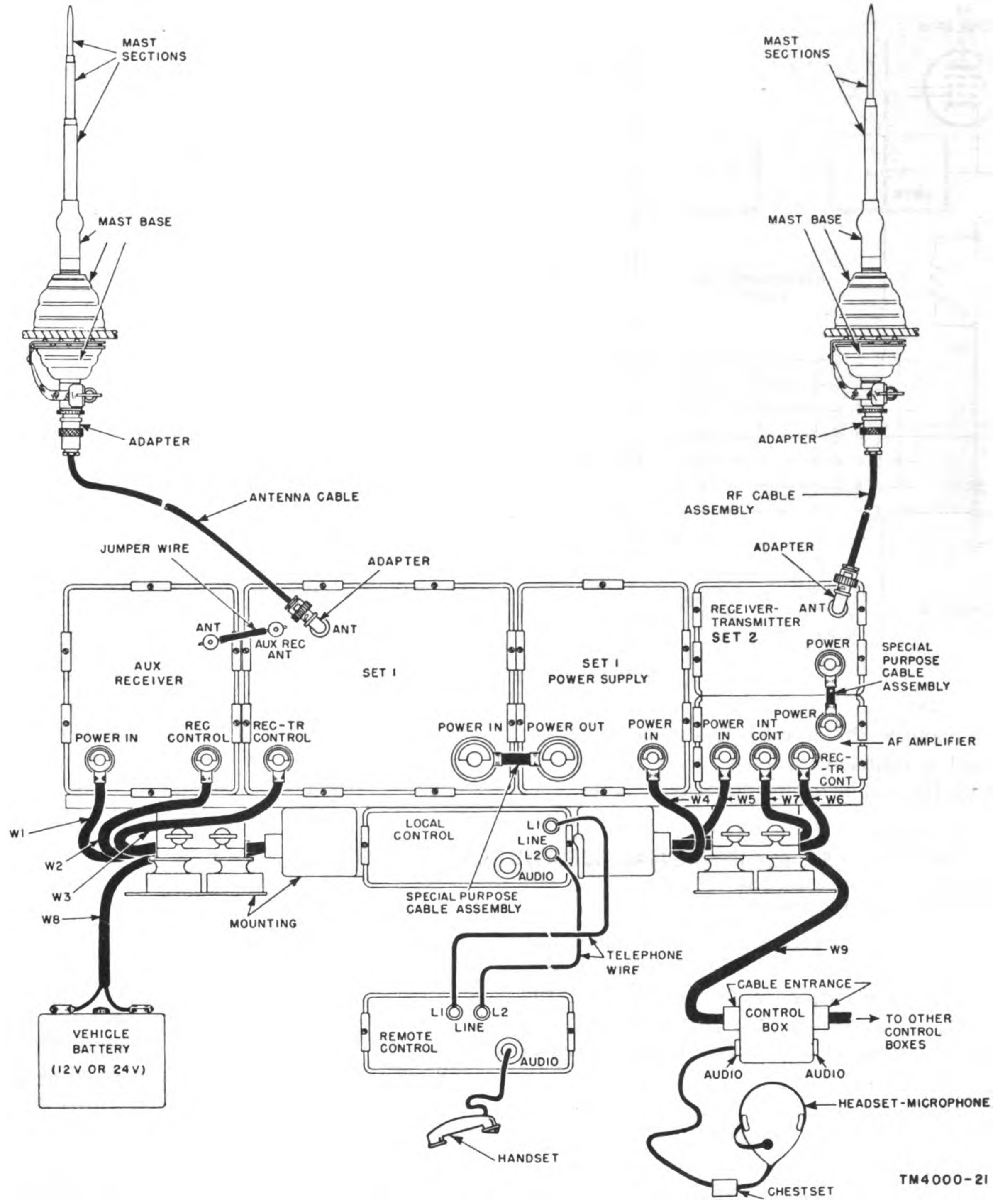


Figure 43. Cabling diagram.

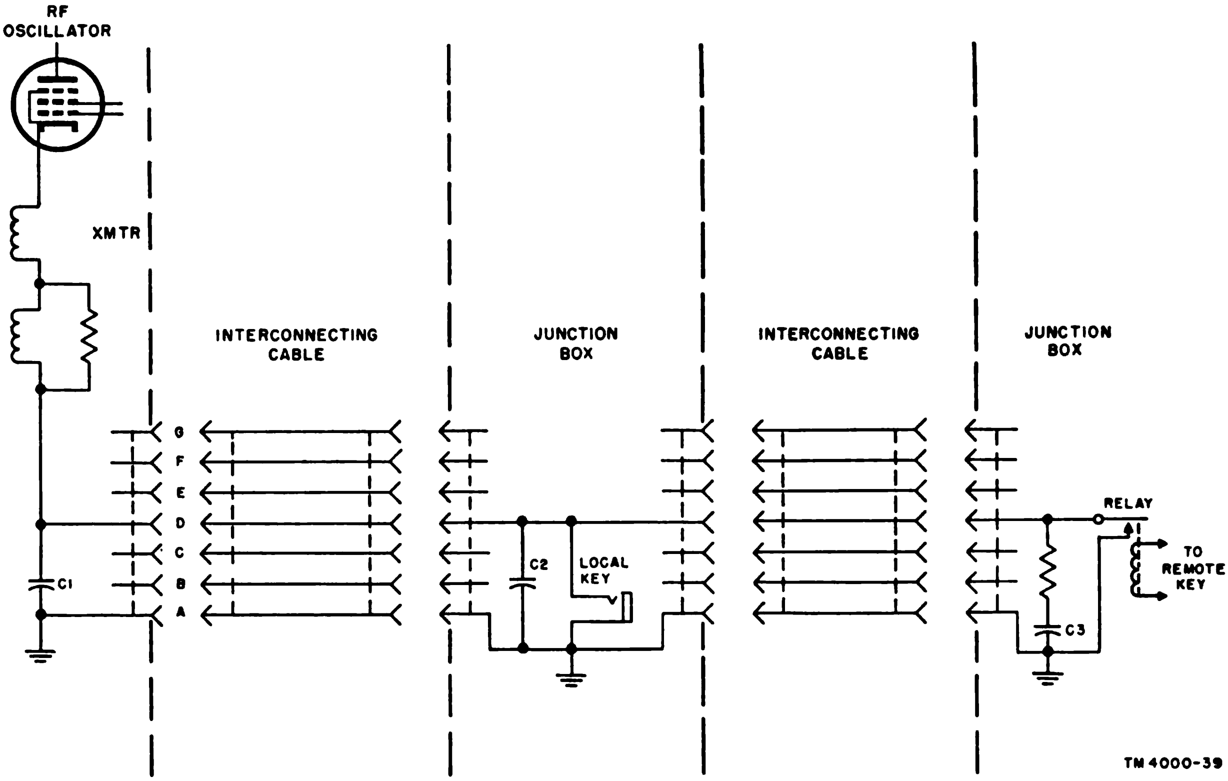


Figure 44. Transmitter keying circuit.

same manner. If the cable has no outer shield, connect a conductor known to be good to one end of the conductor being tested. Having an assistant make the necessary connections at the far end will reduce the length of time for checking long cables.

Section III. SIGNAL SUBSTITUTION AND SIGNAL TRACING

84. Signal Substitution

a. Signal substitution is used to determine the stage or section that is causing the trouble (fig. 45). The output device, in this case the speaker, remains connected to the same point, while the point of signal injection is changed during the tests.

b. Feed a signal from an audio signal generator to the output of the audio stage. If there is no output from the speaker, the trouble is in the speaker. If there is an output from the speaker, the speaker is in operating condition.

c. Feed the signal into point 1, the input to the audio stage. If there is no output from the speaker, the trouble is in the audio stage, or the power supply. If there is an output from the speaker, the trouble is not in the audio stage, or the power supply.

d. Feed a modulated signal into the detector at point 2. If there is no output from the speaker, the detector is defective. If there is an output, the detector is operating normally.

e. Feed a modulated signal into the other stages, working toward the antenna. When a point is reached where there is no output, the defect is in the last stage tested.

85. Signal Tracing

a. Signal tracing is also used to determine where the trouble is, but the method is different (fig. 45). The point of signal injection remains the same, but the output indicator is moved from point to point.

b. Feed a modulated IF signal into the detector at point 4. Connect the ground terminal of an audio signal tracer (fig. 46) to the chassis.

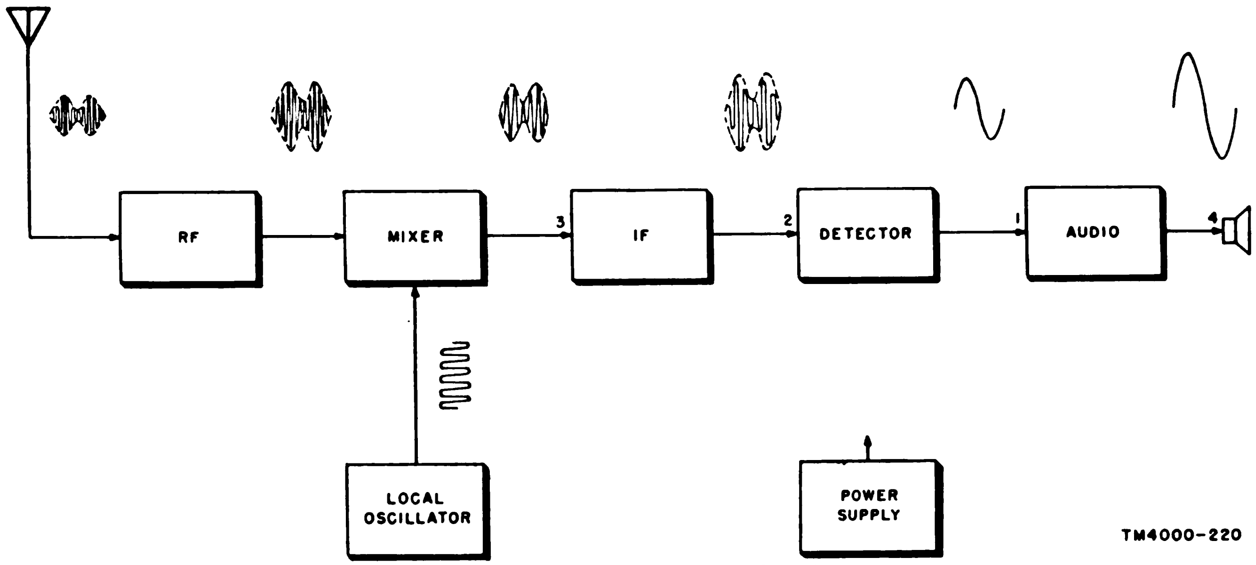


Figure 45. Superheterodyne receiver, block diagram.

Connect the other terminal of the signal tracer to the volume control at point 3. If there is no output indicated in the audio signal tracer, the detector is not operating. If there is an output, the detector is operating.

c. Connect the signal tracer to the input of the audio stage at point 2. If there is no output, the volume control is defective. If there is an output, the volume control is in operating condition.

d. Connect the signal tracer to the output of the audio stage at point 1. If there is no output, the audio stage or the power supply is defective. If there is an output, the audio stage and power supply are operating.

e. Connect the signal tracer to the output of the pa stage. If there is no output, the pa stage is not operating. If there is an output, the pa stage is in operating condition.

f. Thus, the signal tracer can be moved from stage to stage closer to, or away from, the point of signal injection, to locate the defective stage. If a signal tracer is available that can demodulate an RF signal, it can be connected to the IF and RF stages to pick up a signal that is coming in from the antenna.

g. Another method of signal tracing uses a signal generator and an oscilloscope (fig. 45). Feed a modulated signal from a signal generator into the input of the RF stage. Connect the vertical amplifier terminals of the oscilloscope to the output of the various stages, beginning at the RF stage. The wave forms show the type of signal present at the various stages. When a point is reached where there is no indication on the oscilloscope, or the signal is not stronger as it progresses toward the output, there is trouble between that point and the antenna. If the circuits are operating normally, an audio signal similar to that shown above the audio section will appear on the oscilloscope. This is true whether the output is taken from the RF, IF, or audio sections. When the oscilloscope is connected to other than the audio section, a demodulator (detector) probe similar to the one shown in figure 47, must be connected between the oscilloscope and the test point.

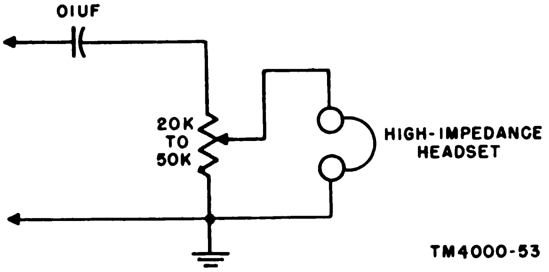


Figure 46. Audio signal tracer.

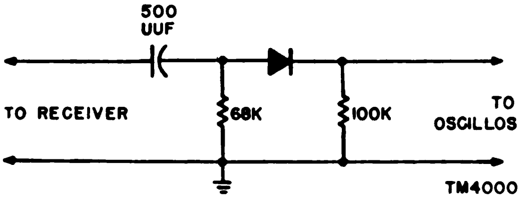


Figure 47. Detector probe, schematic diagram.

Section IV. GENERAL TROUBLESHOOTING PROCEDURES

86. Sequence of Troubleshooting Techniques

a. The quickest and most logical method of troubleshooting is to follow an organized plan of attack. All troubleshooting procedures are based on the observation of symptoms, the combination of which may tell an experienced repairman exactly where the trouble lies. A vital rule of troubleshooting, therefore, is to observe and analyze. The presence of certain symptoms and the absence of others enable the repairmen to eliminate at once the impossible, or at least the improbable, causes of trouble. Thus, if a multiband receiver operates on all bands but one, the repairman discards immediately the possibility of a blown fuse or the possibility of a defective power supply rectifier, because either of these two faults would prevent the receiver's operating on any band at all. With two possibilities out of the way, the repairman concentrates more narrowly upon the probable causes of the trouble.

b. The normal sequence of troubleshooting procedures is as follows:

(1) Obtain the history of the equipment.
(2) Preliminary examination by sight, hearing, and smell.
(3) Sectionalization.
(4) Localization.
(5) Isolation.
(6) Testing after repairs.

87. History of Equipment

Before attempting repairs, the technician must learn as much as possible about the nature of the complaint by questioning the operator as well as by reading the complaint notice attached to the equipment. The more information he can gather, the more accurate his diagnosis will be and the sooner repairs can be made.

88. Preliminary Examination

Preliminary examination by the use of the senses will help in gathering evidence that may lead to the defect. Arranged in proper sequence below are things to look for by sight, smell, and sound.

a. Visual. Improperly connected cables, blown fuses, burned-out tubes, broken cords or plugs, tripped circuit breakers, abnormal meter indications, broken transmission lines or antennas, burned-out resistors, arcing, and smoke. In addition, switches and dials must be inspected to see that they have been set to the proper positions.

b. Smell. The odor of burned insulation, charred resistors, overheated transformers, and overheated dry rectifiers.

c. Hearing. High-voltage arcing between wires and between wires and the chassis, and the *cooking* of overloaded or overheated transformers. The hum, or lack of hum, in vibrators.

89. Sectionalization

Sectionalization means tracing the trouble to a component of a system, or to a component of a radio set.

a. Sectionalization in System.

(1) If receiver 4 (fig. 48) is not producing a signal at its output, receiver 4 operator requests the operator at transmitter 4 to use the order line to ask receiver operator 3 to alert transmitter 2 operator. Transmitter 2 operator will check his transmitter by observing the meter indications. If the transmitter is normal, receiver 4 is probably defective.

(2) At the same time, the technician at receiver 4 begins to troubleshoot the receiver, by following the procedure in *b* below. He can also make some simple tests. For example, if the receiver is completely dead, the receiver is at fault. If there is a noise at the receiver output when the gain control is advanced to maximum, the defect is in the RF, mixer, local oscillator, or antenna system.

(3) In this way, by using the order line for communicating between terminal sets and the relay station, the trouble can be sectionalized to a component in any part of the system.

b. Sectionalization in a Radio Set. Many radio sets have a common antenna and a common power supply (fig. 49).

(1) If the transmitter *and* receiver do not produce any output, the power supply is probably at fault.

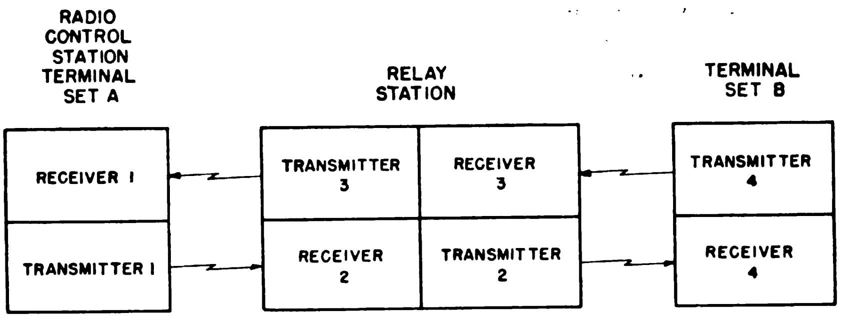


Figure 48. Radio-relay system, block diagram.

(2) If the receiver operates, but the transmitter does not, the transmitter is defective. If the transmitter operates, but the receiver does not, the receiver is defective. The fact that one of the components operates, eliminates the power supply as a possible source of trouble.

(3) If the receiver produces only noise and the transmitter meters indicate that the transmitter is operating normally, but the signal is not being radiated, the antenna is disconnected from both transmitter and receiver.

(4) If the transmitter is operating normally, but the receiver produces only noise, the receiver RF section is at fault, or the antenna is not connected to the receiver.

(5) If the receiver operates normally, and the transmitter meters indicate that it is operating normally but there is no signal being radiated, the antenna is not connected to the transmitter.

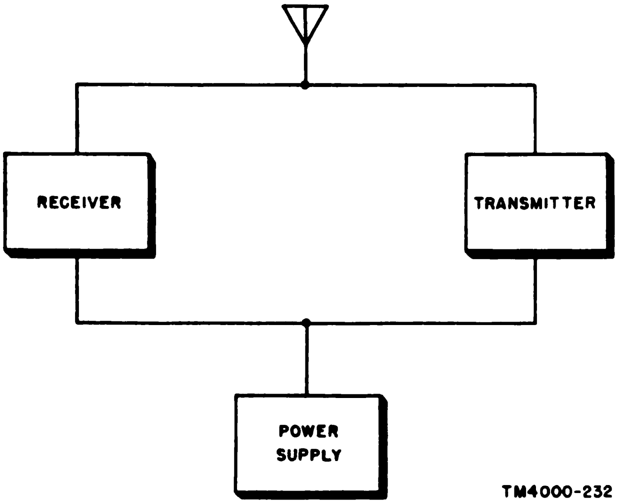


Figure 49. Radio set, block diagram.

90. Localization

Localization means tracing the trouble to a stage of a section. Before removing the chassis from the cabinet, and prior to disconnecting cables, be sure that power is being supplied, the tubes are not at fault, the antenna is intact and connected, and that the defect is not something that can be corrected without disassembling the equipment. For example, if a receiver is completely inoperative, turn the sensitivity and the audio gain controls up to produce maximum output. If only noise is heard, the local oscillator RF stage, or the mixer stage is defective. Check the tubes in these stages. The following tests are used in tracking down trouble:

a. After the chassis has been removed from the cabinet, check the resistance at the point where the dc from the power supply is applied to the stages, to tell whether there is a short circuit in the power supply.

b. Find out which portion of the equipment (RF, IF, or audio) is faulty. Use signal substitution (par. 84).

Note. Localizing the trouble to a subchassis or to a portion of the main chassis is also referred to as sectionalization.

c. Check the suspected tubes with a tube tester or by substitution.

d. Make voltage measurements in the plate, screen-grid, and bias lines and at the tube sockets of the suspected stages.

e. Measure resistances at the points where the voltages are abnormal.

f. If the complaint is a weak receiver and other tests fail to detect the troublesome stage,

stage-gain measurements must be made. This means feeding a signal of a given strength into the suspected stages and measuring the strength of the signal at the output of those stages and comparing it with that of a good set.

91. Isolation

Isolation means tracing the trouble to a part, such as a capacitor, resistor, transformer, or relay. Isolation is usually done by:

a. Using the senses as was instructed in the paragraphs on sectionalization (par. 89) and localization (par. 90), but in this case it may lead the repairman directly to the defective part.

b. Making voltage and resistance measurements at the tube sockets. Examples of this are covered in the next section.

c. Signal substitution and signal tracing as used in localization.

d. If a tube is defective it probably would have been located in paragraph 90 on localization. However, there may be a component part that has short circuited and at the same time has damaged a tube.

e. Stage-gain tests may not be necessary at this point, but if they are, the information in paragraph 90 applies.

f. Bridging the suspected part, such as a capacitor, with one known to be good.

92. Repairs

Although repairs are not a part of troubleshooting and come after troubleshooting, they do come before testing can be made after repairs. For information on how to make repairs, refer to chapter 10.

93. Testing After Repairs

After faulty parts are located and replaced, the equipment may not necessarily be free of faults. For example, a weak tube replaced in a vhf unit can cause operation to cease even though the new tube is in perfect condition. The difference between the interelectrode capacitance of the new tube and that of the old one can detune the circuit so that the circuit is no longer at resonance. Therefore, after parts or tubes are replaced, the equipment should be given an overall test and the results compared with the data specified for a good set. These tests are covered in chapter 11.

Section V. ISOLATION OF TROUBLES IN INDIVIDUAL STAGES

94. General

a. The isolation of troubles in individual stages is basically the same regardless of the type of stage in question. Once the defect is known to be in a certain stage, voltage and resistance measurements must be made. The information gathered by making these measurements will, in most cases, pinpoint the trouble to a particular part.

b. General information on voltage and resistance measurements is given in paragraphs 95 and 96.

c. In the several paragraphs that follow, those on voltage and resistance measurements are examples of isolating defects in various types of stages used in both receivers and transmitters.

95. Voltage Measurements

a. The usual procedure is to make the voltage checks first. This will locate the general area of the trouble. When an abnormal voltage condition has been found, the power must be turned off and resistance checks made to determine a short or an open circuit.

b. In most equipments, voltage measurements are made with the negative lead of the voltmeter connected to chassis ground. The positive terminal is then connected to the points to be measured. In this way, all voltages that are positive with respect to the chassis are measured. If a voltage to be measured is negative with respect to ground, the positive terminal is grounded. If an electronic multimeter is being used, the common terminal is left connected to the chassis and the polarity reversing switch is set to the positive position for measuring positive voltages or the negative position for measuring negative voltages. The meter range switch must be set to its highest range if the approximate voltage present is not known. This prevents possible damage to the meter. Once an indication is observed on the meter, the range switch should be set to obtain a midscale indication.

c. There are certain voltages that are not normally measured with respect to the chassis and it is important to avoid incorrect readings and possible damage to the meter. For example, the ac power input voltage usually is isolated from the chassis. This is a safety feature that prevents grounding of the power line when power line polarity is not observed, and keeps personnel from getting a shock when the chassis is touched. This is especially true if the chassis is grounded to the earth. To measure accurately the voltages present, the test leads must be connected directly across the points where the voltage is present. In another example, the filament of a power supply rectifier tube may be at a high dc voltage with respect to the chassis. If the rectifier filament voltage is measured with respect to ground, the meter will be ruined by the high voltage present. When checking the filament voltage in this case, the meter terminals must be connected to the filament terminals without touching the chassis. One way to prevent meter damage is to remove the rectifier tube, thereby removing any dc voltage present.

d. If the measured voltage is high or low by more than 20 percent, it is possible that the voltage source is the cause, especially if the equipment is operated from batteries. A voltmeter can be inaccurate also, or it can have a lower sensitivity than the one originally used to make the measurements. This must be taken into consideration when making measurements. For the most accurate results, the voltmeter should have the same sensitivity as the one that was used to make the original measurements.

96. Resistance Measurements

Before making resistance checks it is very important that the power be turned off and all filter capacitors be discharged. Resistance measurements can be made between certain points and the chassis, or between any two points that are connected by wiring or parts.

97. Isolating Trouble in Audio Circuit

a. The circuit in figure 50 contains the component parts referred to in this paragraph. Most troubles encountered are due to failure in circuits where dc is present. This means that the trouble can be located by voltage and resistance measurements.

b. Assume that the stage becomes inoperative. There must be certain dc potentials present for the stage to operate. The first step is to measure the voltage from the plate to ground. The voltmeter range switch must be set to the maximum voltage position because the voltage present is unknown. This precaution is necessary to prevent possible damage to the meter. If there is no voltage present, move the hot voltmeter prod to the point marked B+. If a voltage is indicated, there is an open circuit between that point and the plate of the tube. The screen-grid

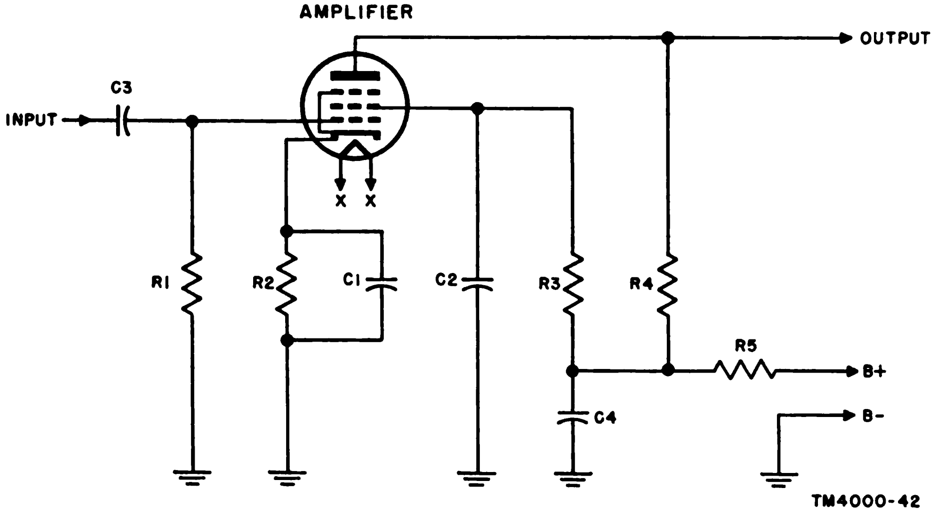


Figure 50. Audio amplifier circuit.

voltage will be below normal because the drop across screen dropping resistor R3 is greater than the normal drop. Figure 50 shows that the plate voltage is applied through resistors R4 and R5. Move the meter hot test prod to the other side of R5. If the reading is zero, R5 is probably open, or C4 is shorted. A resistance check will verify this. If the reading is about normal, move the test prod to the plate again. A voltage reading on one side of R4 and none on the other means that R4 is probably open. A resistance check completes the test. Refer to paragraph 79 for checking resistors.

c. A shorted C4 could cause the removal of plate voltage from the tube even though the B+ voltage is about normal. The screen-grid voltage also will be affected because it is taken from the same source as the plate voltage. A continuity check of C4 will then show either a dead short or a partial short to ground. In addition, R5 will be overheated and may even char and smoke, because if C4 is shorted, R5 will be placed directly across the power supply.

d. Another cause for complete failure of the stage is the lack of screen-grid voltage when the plate voltage is nearly normal. A shorted screen-grid bypass capacitor C2 will reduce the voltage to zero. This can be checked by measuring the voltage from the screen grid to ground, and double checked by making a continuity check between the same two points. Refer to paragraph 81 for checking capacitors. If the power is left on for a considerable length of time under these conditions, R3 and R5 will overheat and may even smoke, because they are connected directly across the power supply. This is a definite indication of a short circuit. Because the screen grid has more control on the plate current than the plate has, the plate current will go down; therefore, the plate voltage will be higher than normal.

e. Another test that can be made is the measurement of the cathode voltage across R2. If the voltage is higher than normal, R2 is probably open. There is neither plate nor screen-grid current flowing; therefore, the plate and screen-grid voltages will be higher than normal. The high-voltage reading is present across R2 because the high resistance of the meter completes the circuit across R2, creating a large voltage drop across the meter. The value of the voltage will depend on the type of voltmeter used. If R2 is shunted by an electrolytic capacitor, the circuit from cathode to ground will be completed by the leakage resistance of the capacitor. The cathode voltage would be only slightly higher than normal, regardless of the type of meter used to measure the voltage.

f. If the output of the amplifier is distorted, it is probably because the bias has decreased from the normal value. If the plate and screen-grid voltages are found to be lower than normal, bias capacitor C1 is probably shorted. This will cause the tube to operate on the nonlinear portion of its Eg-Ip curve and will produce distortion. Measure the bias between the grid and cathode. The voltmeter must be set to indicate a negative voltage. If C1 is shorted, the voltage will be zero. If the meter needle goes below zero, the grid is positive.

g. There is only one way the grid can become positive, in addition to gassy tube troubles, and that is for the coupling capacitor to develop a short circuit or leak, allowing the B+ on its other side to leak through to the grid. If C3 is checked with an ohmmeter, it may show an extremely high resistance, which means that it is not leaky. However, when power is applied to the circuit, including the preceding stage, the B+ appears between the ground and the input side of C3. As a rule, any capacitor having equal, or nearly equal, dc voltage from either side to ground should be suspected as being shorted.

h. If all voltage and resistance measurements are normal but the stage does not operate, coupling capacitor C3 may be open. The simplest, quickest, and easiest method to check it, is to bridge it with a good capacitor of the same capacitance and voltage rating. If C3 is open, bridging it will produce a signal in the output of the stage if a signal is applied to the input.

i. If the output is not as great as it should be (the procedure used to determine it is described in chapter 11) and the voltage and resistance measurements are normal, it is possible that bypass capacitor C1 is open. If it is open, the decrease in output would be caused by degeneration. Signals that would normally be bypassed around the resistor by a good bypass capacitor will cause a signal voltage drop across the resistor. This voltage drop bucks the applied signal and effectively decreases the amplitude of the signal applied to the stage. As a result, the output also decreases. For example, assume that a 3-volt ac signal is applied between grid and ground. During the positive portion of the ac signal, the grid is 3 volts positive with respect to ground. This causes an increase in plate current through R2 and the developed voltage across it makes the grid negative with respect to ground, say 2 volts. Therefore, the grid is only 1 volt positive with respect to cathode. The 3-volt input signal is seen by the input of the tube as a 1-volt signal.

98. Isolating Trouble in IF Amplifier

a. The method of isolating trouble in an IF amplifier is similar to that used for an audio amplifier. There will be shorted or open capacitors, open resistors, and open inductors; they can be detected by making voltage and resistance measurements. An IF stage is shown in figure 51.

b. There is one exception to the above statement and that is that the IF stage operates at a fixed higher frequency. The inductors must be tuned to the proper frequency. Thus, if trimmers C1, C2, C3, and C4 are not set accurately, the output of the stage will be weak. There are some equipments in which the windings of T1 and T2 are tuned by varying the inductance with a powdered-iron slug adjustment.

99. Isolating Trouble in RF Amplifier

a. An RF amplifier is similar to an IF amplifier in practically all respects, except that its tuned circuits can be adjusted to resonate over a wide band of frequencies instead of one fixed frequency. Therefore, the troubleshooting method will also be similar.

b. In the RF amplifier stage (fig. 52), choke RFC is the load. Other circuits may have a transformer winding or a resistor as a load. Regardless of the type of load, defects in them will cause similar symptoms.

c. The combination of the secondary of T1 and C1 and C2 must be tuned accurately to the incoming signal. Capacitor C2 is a trimmer which is set during alinement procedures. If its setting is disturbed, the sensitivity of the stage will be decreased and the signal output will be weak.

100. Isolating Trouble in Mixer Stage

a. The mixer combines the incoming signal and the local oscillator signal, to produce the difference frequency.

b. Troubleshooting a mixer (fig. 53) is similar in most respects to troubleshooting an RF stage. In addition, it is important to check coupling capacitor C2. If it should open, there would be no oscillator signal fed to the mixer grid, and the intermediate frequency would not be produced. As in the RF amplifier, it is necessary to keep the adjustments that tune T1 and T2 set to the proper frequencies, otherwise, the output will be weak or not present. Transformer T1 is tuned to the signal frequency and T2 is tuned to the difference between the incoming signal and the local oscillator frequency. Figure 53 shows a triode mixer; a pentode mixer will include a screen grid and suppressor grid; otherwise, the operation will be the same as the triode mixer.

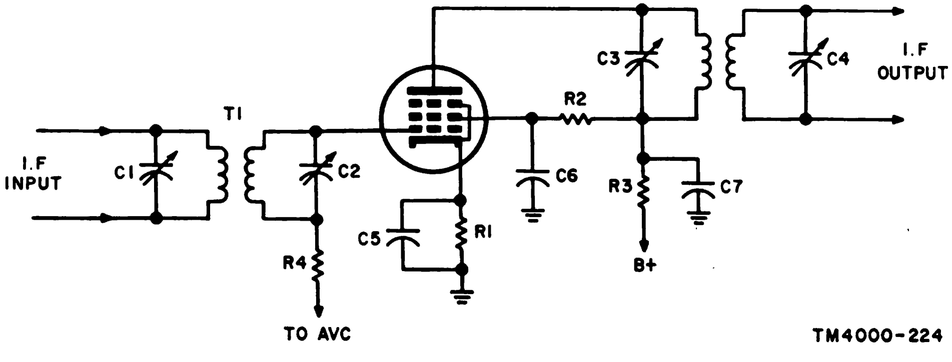


Figure 51. IF amplifier stage.

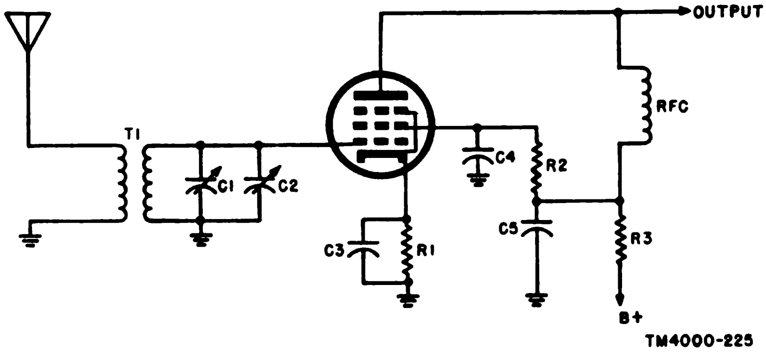


Figure 52. RF amplifier stage.

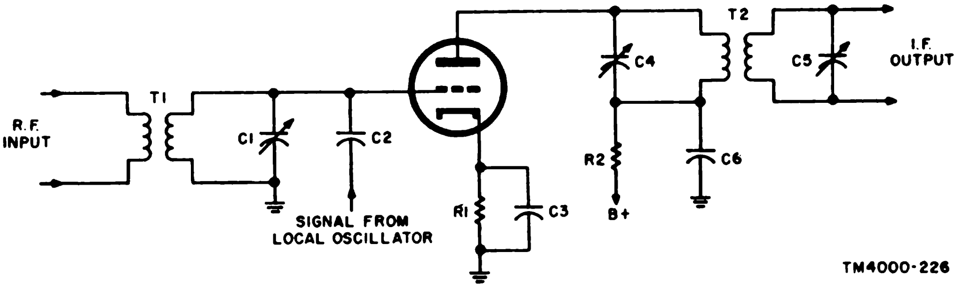


Figure 53. Triode mixer.

101. Isolating Trouble in Converter Stage

a. A converter stage combines the elements of the oscillator and mixer tubes in one envelope. When making voltage and resistance measurements, the socket measurements are made at one socket instead of two.

b. In a pentagrid converter stage (fig. 54), the oscillator anode is also the mixer screen grid. Therefore, if the screen-grid voltage is absent, there is no voltage at the oscillator anode. The signals are mixed in the electron stream of the tube.

c. Anything that causes the oscillator to cease operating will prevent the intermediate frequency from being produced and fed to the primary of T3. The first test to make on the oscillator is to measure the bias. The bias must be measured across R1. If a voltmeter other than one of at least 20,000 ohms-per-volt sensitivity is used, it may load the circuit to the extent that the oscillator will seem to be defective when it is operating normally. If there is very little or no bias present, the oscillator is not operating.

d. If trimmer C5 has been tampered with, the dial calibration on the receiver will be inaccurate and a signal of the wrong frequency will be fed to T3. If trimmer C2 is not set so as to produce maximum output, the output being fed to T3 will be weak.

102. Isolating Trouble in Detector Stage

a. The detector demodulates or removes the intelligence from the carrier wave. Thus, when a signal contains voice modulation, the output from the detector will be speech.

b. Figure 55 shows an example of a diode detector. Because this type of detector is used almost exclusively in am circuits, other types will not be mentioned.

c. Because there is no high voltage present in this circuit, the chance of component breakdown is not very great. The primary and secondary windings of IF transformer T must be tuned to the proper frequency to produce maximum output. If R1 or R2 should open there will be no output. An open circuit in C3 or C5 will reduce the ouput, but a short circuit in one of them would result in grounding the signal and no output.

d. The avc voltage is developed across load resistor R2. If avc filter resistor R3 opens, there will be no avc voltage fed to the grids of

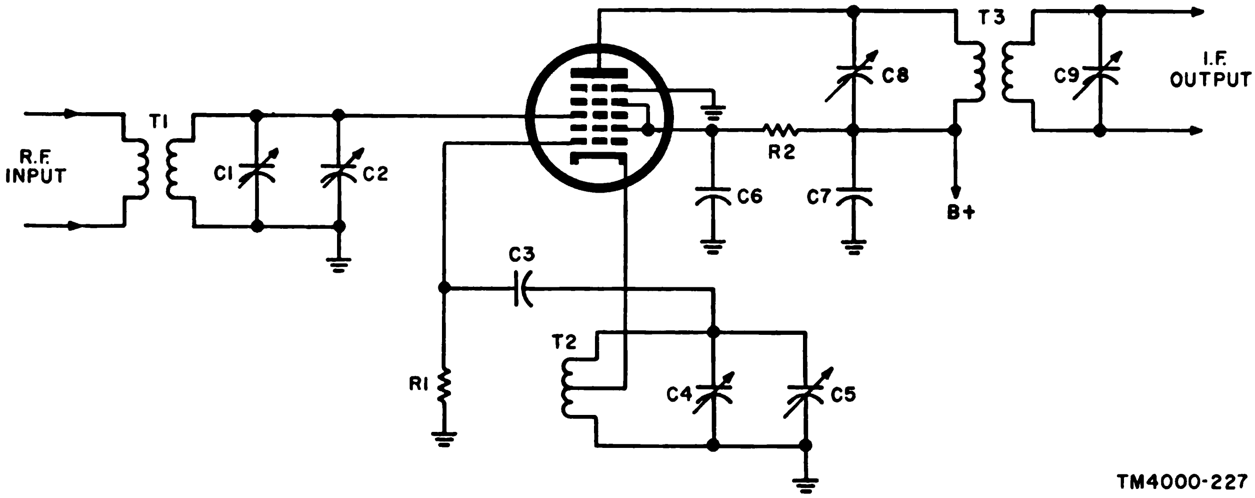


Figure 54. Pentagrid converter circuit.

the controlled stages, and the output will probably increase on strong signals. If avc filter capacitor C4 short circuits, the avc voltage will be reduced to zero, and the output may increase, depending on the value of the grid-return resistor in the controlled stages.

103. Isolating Trouble in Power Supply

a. A power supply delivers operating voltages to the various stages in receivers and transmitters. The majority of troubles in a power supply occur in the high-voltage rectifier and filter sections.

b. The most widely used power supply is the full-wave type (fig. 56). The rectifiers are often contained in the envelope of one tube. Troubleshooting is done almost entirely by voltage and resistance measurements.

c. An open circuit in the primary or secondary winding of transformer T will result in no dc output. Also, if the windings are intact, an open in choke L1 or L2 will open the high-voltage circuit.

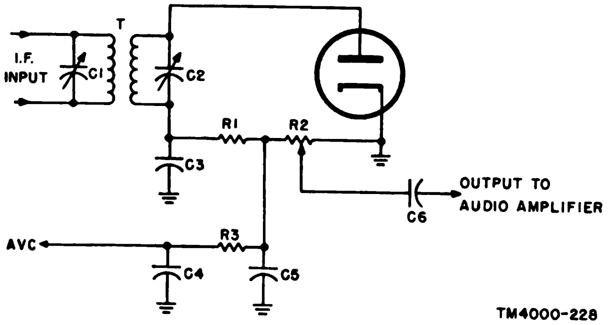


Figure 55. Diode detector.

d. If filter capacitor C1 short circuits, the current through tubes V1 and V2 will be very high and will cause the high-voltage winding to smoke, or burn out the tubes. If output capacitor C2 short circuits there will be no dc output, but because of the resistance of the two chokes, the amount of current flowing will be less than if C1 short circuits.

e. The filter capacitors keep hum out of the operating circuits. Therefore, if either one should open, the output voltage will contain a ripple, and hum will result. There will be a large drop in the output voltage if C1 opens.

f. Bleeder R discharges the filter capacitors when the power is turned off. This is a safety measure. If the bleeder opens, the dc output point will be dangerous to touch because the capacitors will be fully charged. The bleeder also keeps a load on the output when the regular load is removed.

104. Sample Oscillator Circuit

a. The circuit in figure 57 is that of a widely used oscillator. It is used to assist in troubleshooting oscillators. The parts referred to in the text are marked on the diagram.

b. In general, the method for troubleshooting an oscillator is the same as that used for an amplifier, because an oscillator is basically an amplifier that has provisions for positive feedback.

105. Isolating Trouble in Receiver Oscillator

a. Connect the test prods of an electronic

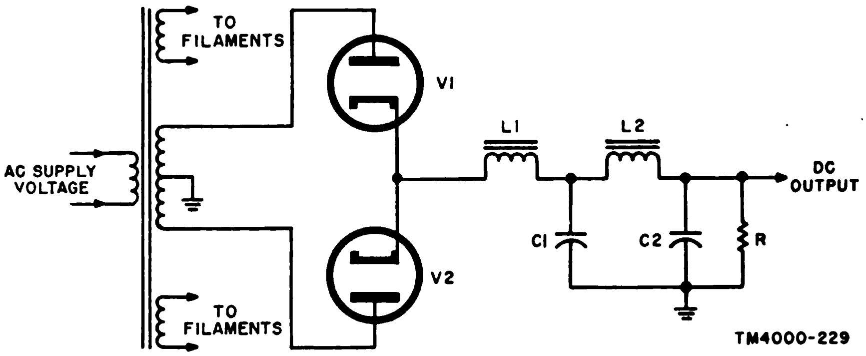


Figure 56. Full-wave rectifier power supply, schematic diagram.

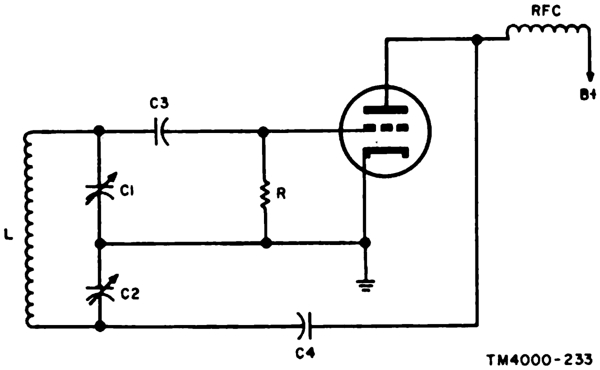


Figure 57. Oscillator circuit.

multimeter across grid-leak resistor R (fig. 57). The grid will be several volts negative with respect to the cathode if the stage is oscillating. If it is not oscillating, there will be little or no voltage present. Do not use a low-resistance meter; the circuit will be loaded down and the stage will cease oscillating if it had been in operating condition.

b. If the above test shows that the oscillator is not operating, voltage checks must be made. This is a shunt-fed circuit and there is nothing in the B+ line to burn out except the RF choke. If the plate voltage is normal, make resistance checks on the other components.

c. Capacitor C4 connects the plate of the tube to the lower end of indicator L. If C4 opens, oscillation would probably cease because the feed-back circuit will be broken.

106. Isolating Trouble in a Transmitter Oscillator

a. Transmitter oscillators are similar to receiver oscillators, but they usually generate more power. There are additional tests that can be made on transmitter oscillators.

b. A rapid method for determining whether a transmitter oscillator is operating is to couple a simple RF indicator (fig. 58) to it. If the indicator is used with high-powered equipment, the lamp should be mounted on a long dry stick to prevent possible shock or burns.

c. Hold the indicator loop near inductor L (fig. 57); if the circuit is operating and is tuned to resonance, the bulb will light. Do not hold the loop too close to L, because the lamp may burn out. This method cannot be used with receiver oscillators because there usually will not be enough energy to light the lamp.

d. Another quick check is to detune the oscillator slightly by rotating C1 or C2 (fig. 57) a small amount in either direction. If the stage is oscillating, detuning will cause a change in the meter indications in the buffer or final amplifier circuits. If the oscillator is not operating, there will be no change in the meter indications as the circuit is detuned.

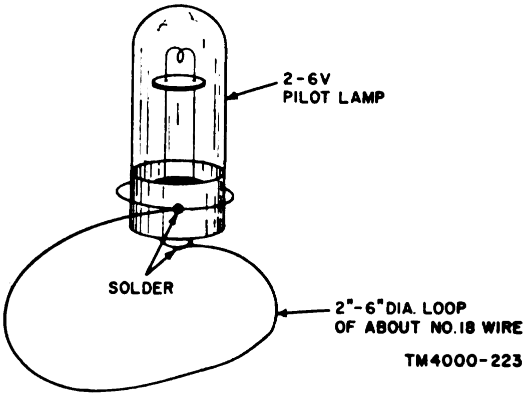


Figure 58. Simple RF indicator.

107. Isolating Trouble in RF Power Amplifier

a. The troubles encountered in an RF power amplifier are similar in some respects to those found in receiver RF amplifiers. A schematic diagram of an RF power amplifier is shown in figure 59. It is not necessary to make voltage measurements because milliammeters are a permanent part of the circuit. However, if an abnormal condition is indicated by the meter readings, resistance measurements must be made to determine whether there is an open or a short circuit.

b. If there is no plate current flowing, it could be due to no operating voltages being supplied by the power supply, an open choke RFC2, a burned-out tube, or a defective plate milliammeter. If the stage is of the low-power type, an open circuit in the upper half of the primary winding of T2 would open the plate circuit. In many high-powered amplifiers, the inductors are made of copper tubing; therefore, they cannot burn out.

c. If the plate current is abnormally high, the antenna loading is too heavy, the circuit is not tuned to resonance, neutralizing capacitor C3 is not adjusted properly, or the excitation to the grid is insufficient. Low excitation produces a low bias, causing the plate current to be high.

d. If the grid-current milliammeter indicates zero current, there is no excitation to the grid, the secondary of T1 is open, or there is an open circuit in RFC1, the grid milliammeter, or R, the grid-bias resistor.

e. In some high-powered RF amplifiers, the plate current is such that the plate of the tube is a cherry red during normal operation. If the plate gets excessively red, the cause could be a gassy tube, the tank circuit is not tuned to resonance, there is no grid drive signal, or the loading is too great. If there is a plate milliammeter in the circuit, it will indicate an abnormally high current.

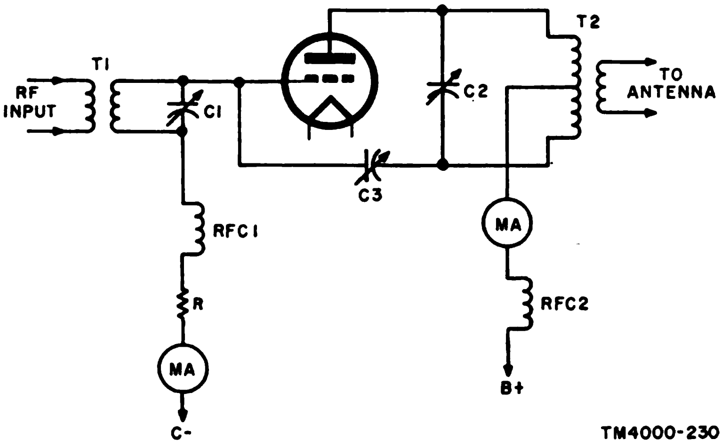


Figure 59. RF power amplifier.

CHAPTER 5

TROUBLESHOOTING VEHICULAR INSTALLATIONS

108. Vehicular Installations

a. Radio sets installed in tanks, trucks, and jeeps present special problems. A typical installation is shown in figure 60. Frequently trouble appears in the installation only while the vehicle is in motion. This is usually the result of a poor connection which shows up because of the vibration of the radio equipment. To locate the source of the trouble, check all cabling for looseness and improperly tightened plugs and connectors. While the equipment is in operation, the cabling should be wiggled and the basic components of the radio set should be rocked so that any abnormal result may be noted.

b. Before troubleshooting an installed radio set, the technician must first be familiar with the location of the basic components of the equipment and the battery switches, radio switches, fuses, and circuit breakers. The radio equipment usually requires the same voltage as the electrical system of the vehicle, normally 12 or 24 volts.

109. Operating Vehicular Equipment

a. Before the radio equipment can be operated, it may be necessary to turn on one or more master switches in the vehicle. For example, some tanks require that both the battery master switch and the radio master switch be turned on before power can be applied to the radio sets. In such vehicles, remember to turn the radio equipment off when it is not in use. In other vehicles, it may not be necessary to turn on the battery master switch.

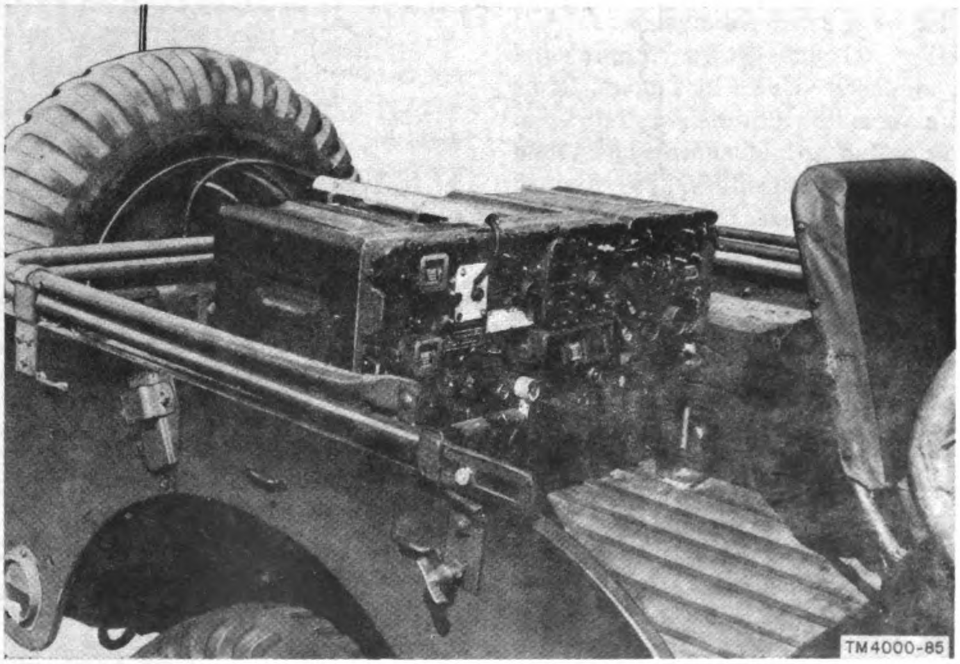


Figure 60. Radio set installed in rear of vehicle.

b. When operating radio equipment in a vehicle, observe the following cautions:

(1) To prevent possible damage to the radio equipment, turn it off while the engine is racing. Turn off all radio equipment to prevent damage from abnormally high voltage.

(2) Do not run the vehicle battery down by unnecessary or lengthy use of the radio equipment when the engine is not running. If long periods of testing are required, keep the vehicle engine running at a speed that maintains the battery charge. Use the auxiliary engine and generator in vehicles that have them.

(3) Be sure to turn off all equipment when not in use. Do not turn off the radio equipment by just turning off the battery master or radio master switch; turn off *all* individual switches.

110. Electrical Noise

a. One of the most difficult troubles to sectionalize in a vehicular installation is noise, especially the noise generated by the vehicle ignition system. Ordinarily, the vehicle electrical system is adequately shielded and bonded, to effectively eliminate all noise generated in the vehicle, and also to permit interference to other radio equipment in the immediate vicinity. Sometimes, the bonding breaks loose and causes noise. Before a radio set is removed from a vehicle for repairs because of noise, first eliminate the vehicle itself as a possible source of noise by turning the engine off.

b. A visual inspection can reveal such obvious faults as loose or broken bonding or shielding, loose plugs, couplings, ground clamps, and loose or disconnected noise bypass capacitors on the generator or voltage regulator. In general, any portion of the shielding on the installation that might permit exposed wiring to radiate noise from ignition or the generator systems should be examined carefully. After a technician has had experience with a certain vehicle he may be able to recognize its own perculiar noise characteristics. In some cases, the noise source can be located by performing certain simple tests which are given in the paragraphs that follow.

111. Sectionalizing Electrical Noise Troubles

a. Preliminary Instructions. When noise interference enters the radio set, the vehicle should be moved to an open space away from high-tension power lines, radio or radar installations, other vehicles, and electrical equipment that could cause noise disturbances.

b. Interference Present With Vehicle Engine Off.

(1) If noise is present in the radio receiver output when the engine is turned off and all other electrical accessories are turned off (including any other radio sets), disconnect the antenna and ground the antenna terminal of the set being checked. If the noise continues, the trouble is in the radio set. Reconnect the antenna; if grounding the antenna terminal stops the noise, the noise was coming in on the antenna. If other radio equipment using a similar frequency range is installed in the vehicle, repeat this test to verify that the noise is caused externally. If the noise is external, move the vehicle to a new location, free from electrical noise, before continuing with further tests.

(2) If no noise is present in the receiver with the antenna connected, turn on each of the accessories (including any other radio equipment) one at a time, and note whether any noise appears. Turn off each accessory before turning on the next one so that the vehicle battery is not drained excessively. If noise appears, check any input noise filter capacitors or chokes associated with the accessory producing the noise. These filter components usually are located in the junction box that brings in the primary voltage for the operation of the accessory. With the accessory turned on, disconnect one side of the filter capacitor temporarily; if the noise level rises, the capacitor in question is good.

c. Interference With Engine Running and Vehicle Stopped. If a rhythmic, periodic popping noise is heard that changes in frequency as the speed of the engine is changed, the disturbance is probably caused by the ignition system. If trouble is traced to the ignition system, check all wiring for proper shielding and bonding. Tighten all cable clamps, conduit coupling connectors, and see that all ground wires are securely in place. In general, ignition noise is caused by defective bonding, loose, burned or improperly gapped spark plugs, burned distributor points, or burned magneto breaker points.

(1) *Induction-coil system.* If the vehicle is equipped with an induction-coil ignition system, run the engine at a fast idle and momentarily turn off the ignition switch. If the noise in the receiver is reduced for the interval that the ignition is off, the trouble is in the ignition system. A typical induction-coil ignition system is shown in figure 61.

(2) *Magneto system.* If the vehicle is equipped with a magneto system, run the engine at a fast idle speed and switch off the magneto while listening for any change in the noise level in the receiver. If turning off the magneto reduces the noise, the interference is coming from the components of the ignition system in which the magneto is operating. A typical magneto system is shown in figure 62.

d. Generator Noise. If a whining, squealing sound is heard in the receiver while the engine is running, the cause may be a defective generator. Run the engine at a fast idle speed, then let it slow down. If the interference decreases and

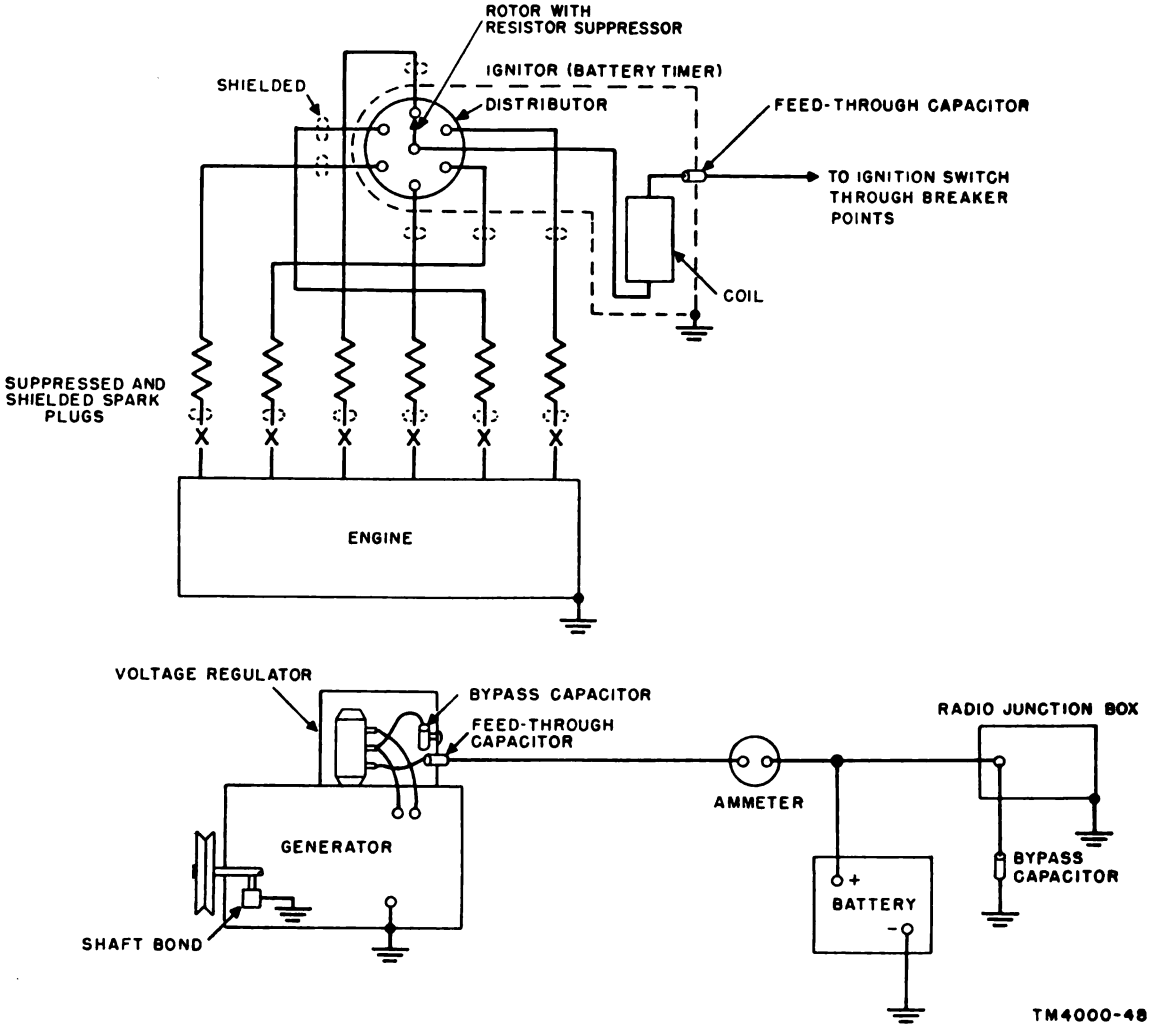


Figure 61. Ignition-coil ignition system.

goes to a lower pitch as the engine and generator slow down, the generator is probably causing the noise. See that the generator is not loose. Look for excessive sparking at the brushes. See that the bypass capacitor is properly grounded. See that all leads connected to the generator are tight.

e. Regulator Noise. If an intermittent clicking sound is heard in the receiver, the interference may be coming from a faulty voltage regulator. The spring that holds the armature open when the solenoid is not energized may have lost some of its tension, and it will cause the armature contact to be intermittent. On certain types of regulators, this spring can be bent back to its normal position. All wiring to and from the regulator should be checked for positive contact and the bypass capacitors should be bridged with good ones to eliminate them as a possible cause of noise. All shielding and bonding to the regulator should be checked for positive contact.

f. Interference Caused by Static Noises. Certain types of interference can occur when the engine is turned off and the vehicle is still in motion, as when going down grade. If excessive, irregular, cracking noises occur in the receiver only when the vehicle is in motion, the trouble could be caused by a loose connection or static electricity generated by friction. See that all ground straps and lockwashers are secure and making good contact. Any two metal surfaces that are not bonded together and that are scraping or rubbing can cause scratch noises. Correct this by connecting all suspected points with heavy braid shielding.

g. Interference From Auxiliary Equipment. In vehicles equipped with auxiliary engine-generators ignition noise can be caused only when the auxiliary engine-generator is in operation. To find the exact source of the noise, turn off the vehicle engine and follow the procedure in *d* above to locate interference caused by a running engine.

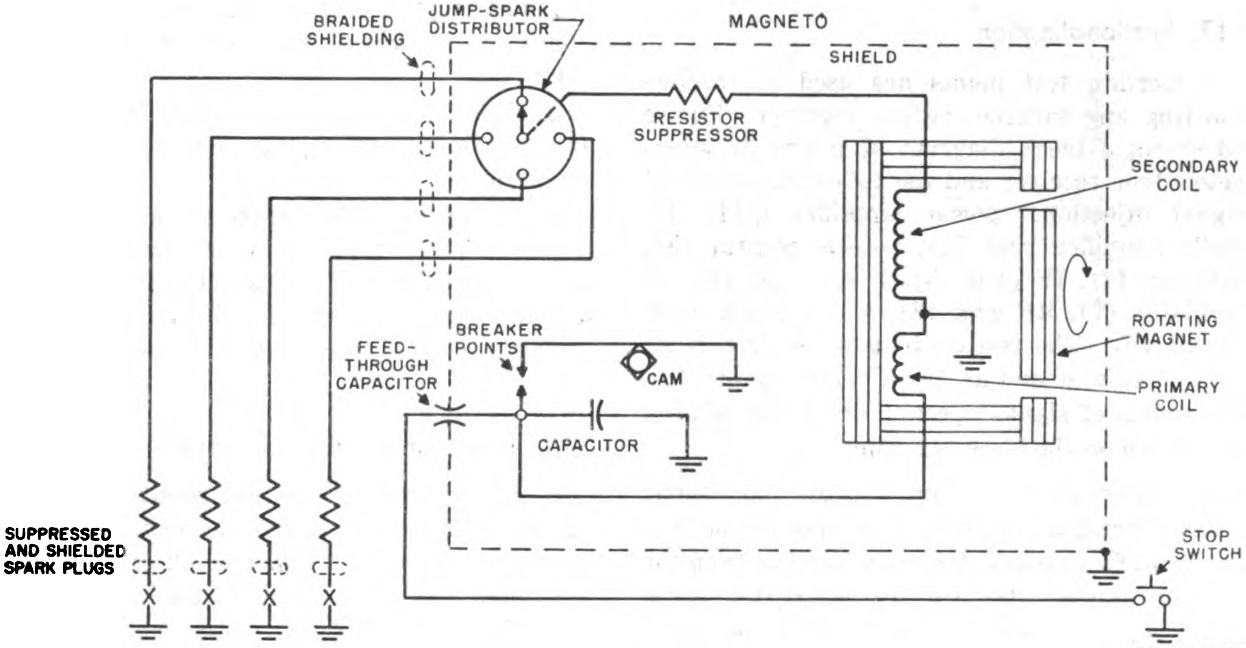


Figure 62. Magneto ignition system.

CHAPTER 6

TROUBLESHOOTING RECEIVERS

Section I. GENERAL RECEIVER TROUBLESHOOTING TECHNIQUES

112. General

There is no single procedure for troubleshooting all of the different kinds of receiver failure. It is possible to set up a general procedure for each of several categories of receiver trouble. When the nature of the trouble has been discovered, the technician should select the appropriate procedure. The procedures are explained in the paragraphs that follow by using successively the block diagrams of a simple superheterodyne receiver and of a typical Army am receiver.

113. Sectionalization

a. Certain test points are used in troubleshooting any superheterodyne receiver. Figure 63 shows a block diagram of a simple superheterodyne receiver and the following points of signal injection: power amplifier grid (1), audio amplifier grid (2), volume control (3), detector (4), IF grid (5), mixer grid (6), hf oscillator (7), RF grid (8), and antenna input circuit (9). The test equipment required is an audio oscillator and an IF-RF signal generator. The points of signal injection and order of tests are shown on the block diagram.

b. Apply an audio signal across the volume control terminals at point 3. If there is no output from the speaker, the audio section from the volume control to the speaker is defective. The power supply could also be defective. Measure the B+ output to find out. Feed a modulated signal of the IF frequency into point 5. If there is no output, the IF section is defective. Feed an RF signal of the proper frequency into point 9. If there is no output the defect is in the RF section, which includes the input circuit, mixer, and hf oscillator.

114. Localization

a. Localization can be accomplished by using the same diagram and test equipment used in paragraph 113. The method used in localization is similar to that used in sectionalization but the trouble can be traced to a stage.

b. For example, feed an audio signal into point 1; if there is an output, the power amplifier and power supply are operating. Feed a signal into point 2; if there is no output, the defect is in the audio amplifier stage.

c. Feed a modulated IF signal into point 6, the mixer input. If there is an output, all of the stages to the right of the mixer are in operating condition.

d. Feed a modulated RF signal into point 6. If there is no output, the defect is in the hf oscillator.

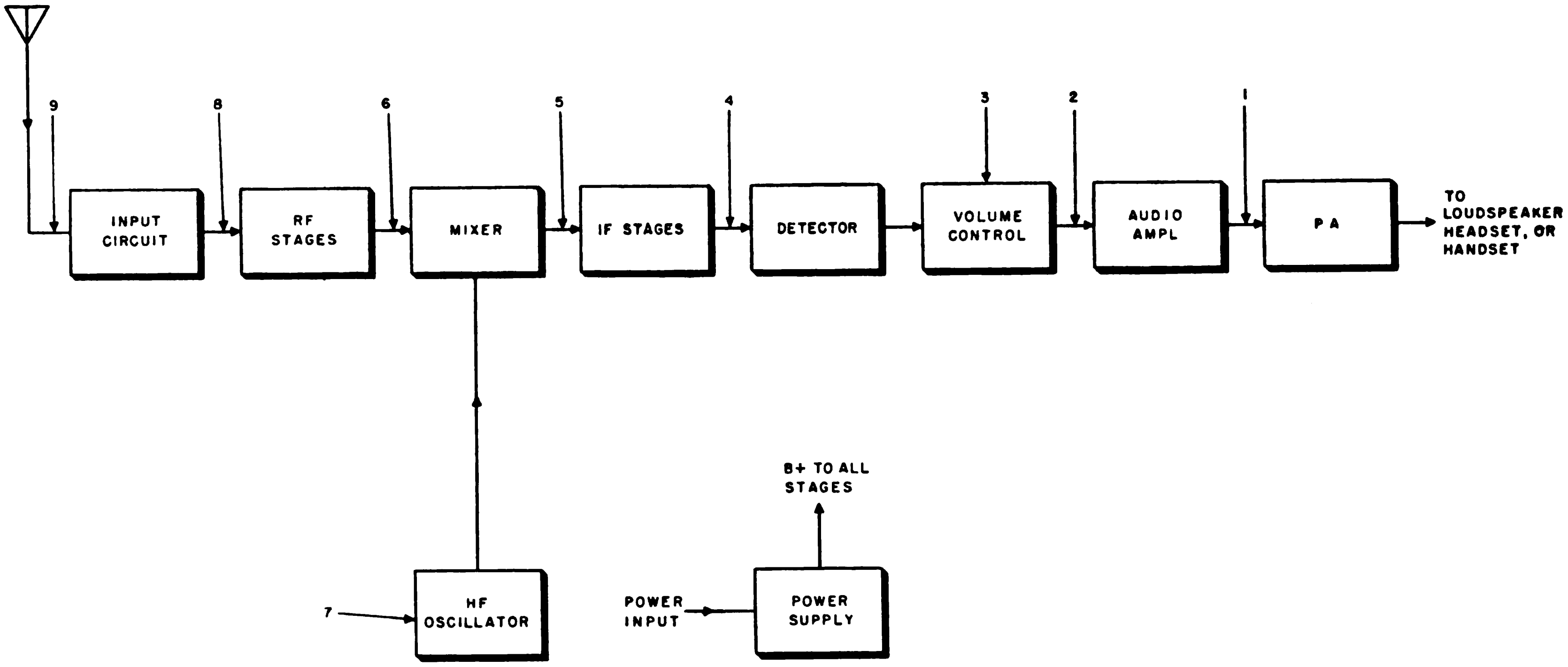
e. In general, when there is no output, the defect is between the point of signal injection and the speaker, or other output indicator. When a point is reached where a defect is indicated, measure the B+ voltage in that stage to isolate the defect.

115. Types of Troubles Covered

a. Dead Receiver. A dead receiver, which is probably the easiest to troubleshoot, is one that produces no sound at either or all of its outputs and does not respond to adjustment of its controls.

b. Weak Receiver. A weak receiver is one with low output volume that can be heard only with difficulty when its gain and volume controls are turned on full.

c. Distorted Receiver. A distorted receiver has garbled output, and cannot be easily understood.



ORDER OF TESTS:

1,2,3. INJECT AUDIO SIGNAL
4,5. INJECT MODULATED IF SIGNAL
6. INJECT MODULATED RF SIGNAL
7. MEASURE GRID BIAS
8,9. INJECT MODULATED RF SIGNAL

Figure 63. Simple superheterodyne, block diagram.

d. Intermittent Receiver. An intermittent receiver loses volume intermittently or acts abnormally in some other respect for short periods of time.

e. Hum. A humming receiver has either a slight hum mixed with the signal, or a hum so great that it overcomes the signal completely.

f. Preliminary Rapid Checks. Certain checks can be made on a receiver before removing the chassis from the cabinet. Chassis have often been removed from cabinets, then after the defect was located, it was found that the chassis could have been left in the cabinet. Some of the checks are listed below.

(1) Determine first whether the *fault* is due to the operator, especially if he is not familiar with the receiver. See that the power switch is in the ON position, the frequency-range switch is in the correct position, the headset is plugged in, and the antenna changeover switch is in the proper position. These and other items must be checked before the equipment is considered defective.

(2) If there is no filament glow in any of the tubes, be sure that power is being supplied to the receiver. Also check the line fuse.

(3) If the receiver is dead, wiggle the power output tube in its socket; if there are no clicks coming from the speaker, the speaker or power supply may be defective. Detecting a bad power supply when the receiver chassis is in the cabinet can save time and work, especially if the power supply is a separate unit. It can be worked on without disturbing the receiver.

(4) If the receiver has an S meter or other indicator, and it does not show any variations as the signal is being received, the trouble is between it and the antenna. Since the indicator is usually in the agc circuit, the trouble is between the agc tube and the antenna. If the indicator does show a variation as the signals are received, the defect is between the agc tube and the speaker.

(5) Turn up the sensitivity and audio gain; if noise is heard from the speaker, but no signal is present, the RF or mixer tube may be defective. This same symptom may also mean that the local oscillator tube is inoperative, or the antenna has become disconnected. Another cause for this symptom is misalinement to the extent that the proper IF frequency is not produced.

(6) If the receiver is noisy or intermittent, shake or move the chassis. There may be a loose shield can or a loose connection on top of the chassis.

Section II. TROUBLESHOOTING DEAD AM RECEIVER

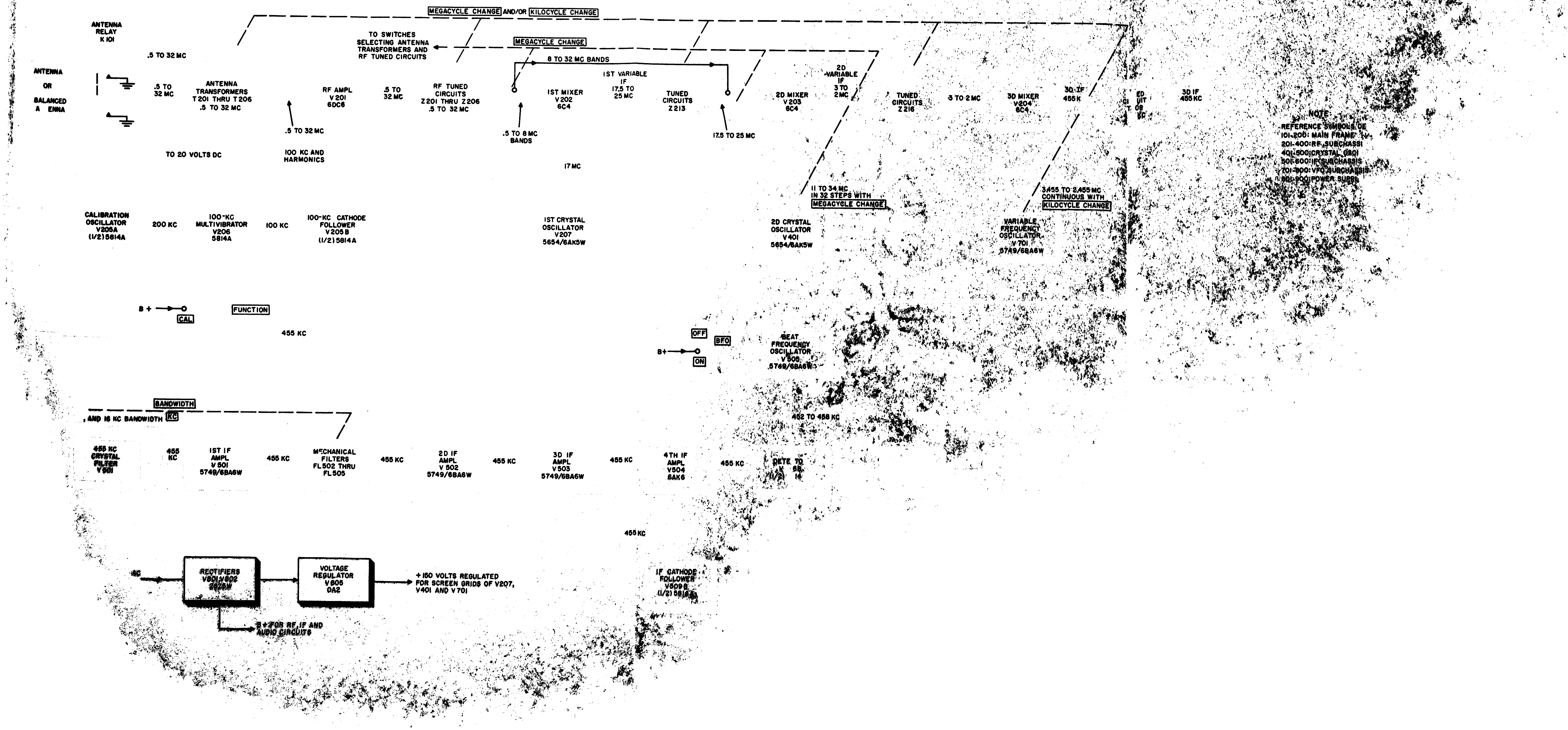
116. General

a. The receiver shown in figures 64 and 65 is more elaborate and complicated than the one in the previous figure. It uses double conversion on some bands and triple conversion on others. It has special features, such as six tuning bands, crystal-controlled hf oscillators, variable bandwidth, and a crystal calibrator circuit.

b. This receiver has two audio channels. If one or both of these channels is inoperative, the receiver is considered dead. Figure 64 is a block diagram of the am receiver.

117. Preliminary Inspection

The best way to begin a troubleshooting assignment is to inspect the receiver thoroughly. See that the power plug is in place, examine the fuses, and turn on the receiver. Look and smell for evidence of burning. See that all tubes are in the right sockets. Check with the operator and maintenance personnel to find out whether the set has been burning or smoking. Burning can be the result of arcing from the chassis through the wire insulation, an overloaded resistor, or a shorted transformer winding. A resis-

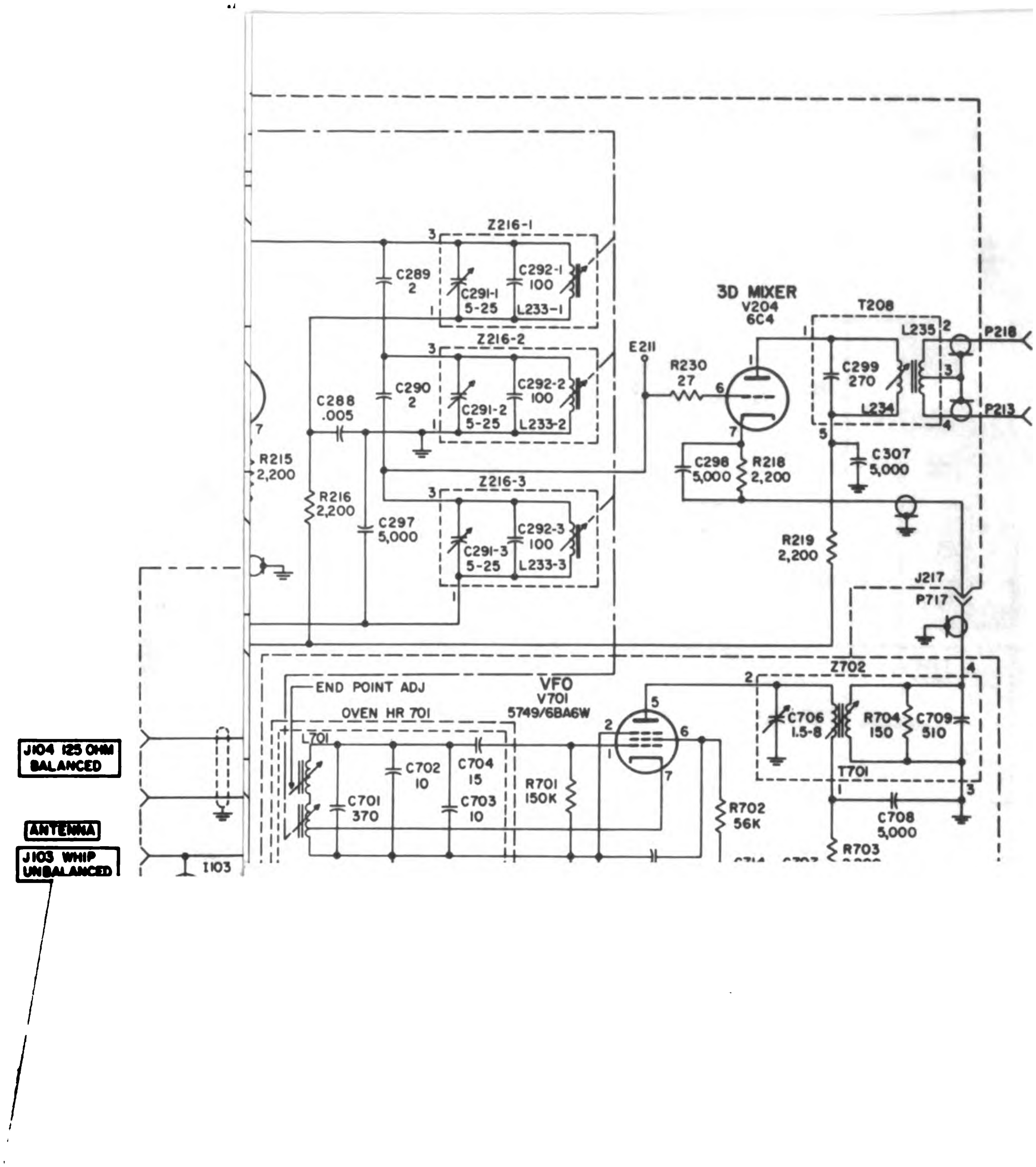

MEGACYCLE CHANGE AND/OR KILOCYCLE CHANGE
ANTENNA RELAY K101
ANTENNA OR BALANCED A ENNA
.5 TO 32 MC
.5 TO 32 MC
ANTENNA TRANSFORMERS T201 THRU T206 .5 TO 32 MC
.5 TO 32 MC
TO 20 VOLTS DC
100 KC AND HARMONICS
TO SWITCHES SELECTING ANTENNA TRANSFORMERS AND RF TUNED CIRCUITS
MEGACYCLE CHANGE
8 TO 32 MC BANDS
RF AMPL V201 6DC6
.5 TO 32 MC
RF TUNED CIRCUITS Z201 THRU Z206 .5 TO 32 MC
.5 TO 8 MC BANDS
1ST MIXER V202 6C4
1ST VARIABLE IF 17.5 TO 25 MC
TUNED CIRCUITS Z213
17.5 TO 25 MC
17 MC
2D MIXER V203 6C4
2D VARIABLE IF 3 TO 2 MC
TUNED CIRCUITS Z216
3 TO 2 MC
3D MIXER V204 6C4
3D IF 455 K
CI T
ED UIT 08 KC
3D IF 455 KC
NOTE:
REFERENCE SYMBOLS DE
101-200: MAIN FRAME
201-400: RF SUBCHASSI
401-500: CRYSTAL OSCI
501-600: IF SUBCHASSIS
701-800: VFO SUBCHASSIS
801-900: POWER SUPPL
11 TO 34 MC IN 32 STEPS WITH MEGACYCLE CHANGE
3.455 TO 2.455 MC CONTINUOUS WITH KILOCYCLE CHANGE
CALIBRATION OSCILLATOR V205A (1/2) 5814A
200 KC
100-KC MULTIVIBRATOR V206 5814A
100 KC
100-KC CATHODE FOLLOWER V205B (1/2) 5814A
1ST CRYSTAL OSCILLATOR V207 5654/6AK5W
2D CRYSTAL OSCILLATOR V401 5654/6AK5W
VARIABLE FREQUENCY OSCILLATOR V701 5749/6BA6W
B+
CAL
FUNCTION
455 KC
OFF
BFO
B+
ON
BEAT FREQUENCY OSCILLATOR V505 5749/6BA6W
452 TO 458 KC
BANDWIDTH
, AND 16 KC BANDWIDTH KC
455 KC CRYSTAL FILTER V501
455 KC
1ST IF AMPL V501 5749/6BA6W
455 KC
MECHANICAL FILTERS FL502 THRU FL505
455 KC
2D IF AMPL V502 5749/6BA6W
455 KC
3D IF AMPL V503 5749/6BA6W
455 KC
4TH IF AMPL V504 6AK6
455 KC
DETE TO V 6B (1/2) 14
455 KC
IF CATHODE FOLLOWER V509B (1/2) 5814A
AC
RECTIFIERS V801,V802 26Z5W
VOLTAGE REGULATOR V605 OA2
+150 VOLTS REGULATED FOR SCREEN GRIDS OF V207, V401 AND V701
B+ FOR RF, IF AND AUDIO CIRCUITS

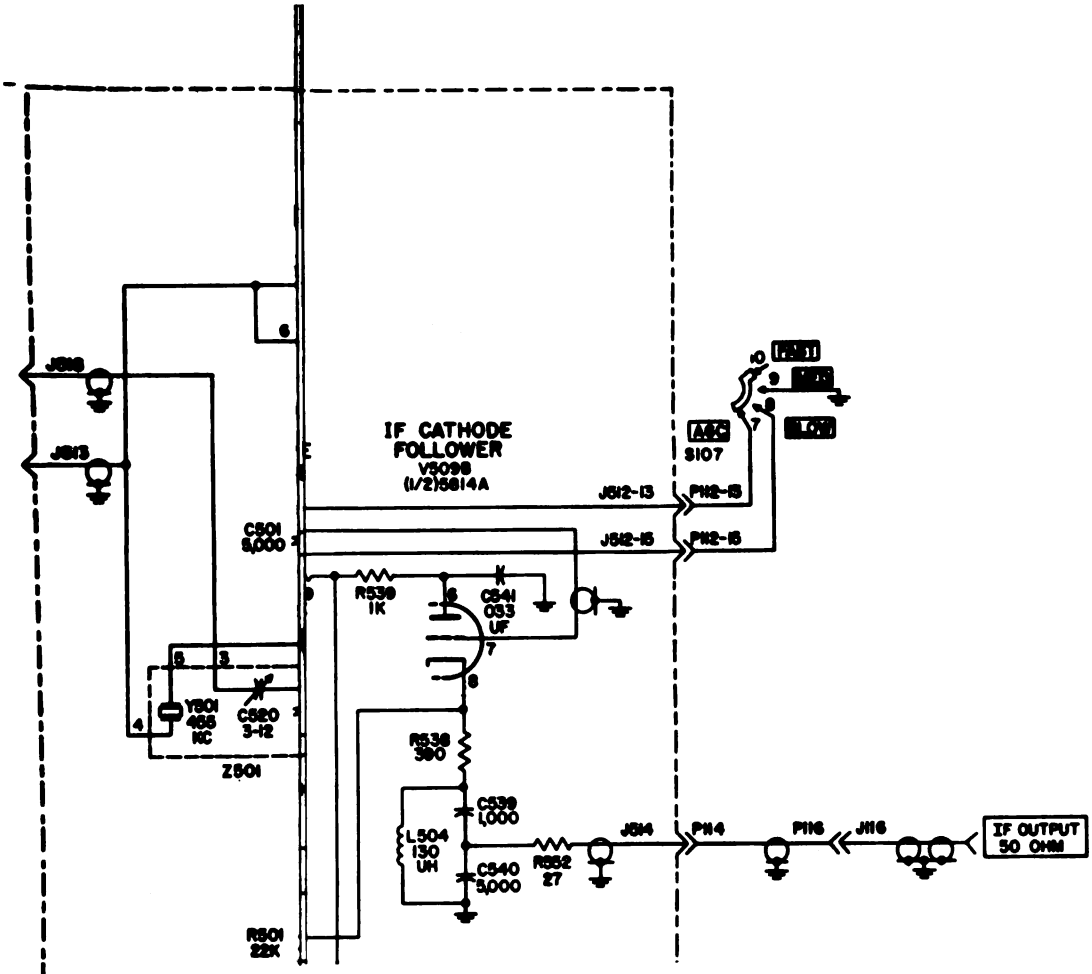
detecting a bad
the receiver chassis
time and
power supply is
worked
receiver.
meter or other
not show
signal is being re-
between it and
the indicator is
the trouble is
the antenna.
show a variation
the defect
and the

ivity and audio
heard from the
is present, the
may be defective.
may also mean
tube is inoperative
has become dis-
cause for this
amount to the ex-
IF frequency is
or intermittent,
There may
capaci-
ers.

troubleshooting as-
receiver thoroughly.
place, examine the
Look and smell
that all tubes are
with the operator
find out whether
smoking. Burning
from the chassis
overloaded resis-
winding. A resis-

Figure


Z216-1
C289
2
C291-1
5-25
C292-1
100
L233-1
3D MIXER
V204
6C4
T208
L235
P218
Z216-2
C290
2
C288
.005
C291-2
5-25
C292-2
100
L233-2
E211
R230
27
C299
270
L234
P213
R215
2,200
C298
5,000
R218
2,200
C307
5,000
Z216-3
R216
2,200
C297
5,000
C291-3
5-25
C292-3
100
L233-3
R219
2,200
J217
P717
Z702
END POINT ADJ
OVEN HR 701
VFO
V701
5749/6BA6W
L701
C702
10
C704
15
C701
370
C703
10
R701
150K
R702
56K
C706
1.5-8
R704
150
C709
510
T701
C708
5,000
R703
J104 125 OHM BALANCED
ANTENNA
J103 WHIP UNBALANCED
I103


J518
J513
6
IF CATHODE FOLLOWER
V509B
(1/2)5814A
J512-13
P112-13
J512-15
P112-15
S107
AGC
10
FAST
9
MED
8
SLOW
7
C501
5,000
R539
1K
C541
.033
UF
9
6
7
8
5
3
4
Y501
455
KC
C520
3-12
Z501
R538
390
C539
1,000
L504
130
UH
C540
5,000
R552
27
J514
P114
P116
J116
IF OUTPUT
50 OHM
R501
22K

tor becomes greatly overloaded and will smoke, usually because of a shorted filter or bypass capacitor, but the smoking can also be caused by a winding shorting to the chassis or to another winding.

118. Checking Supply Voltage

If the voltage of the power source is not definitely known, check it with an ac voltmeter. Be sure to follow the instructions that tell how to make connections in the set so that it can operate on the available voltage. On the schematic diagram (fig. 65), the connections for 115 or 230 volts are shown on TB801. If the connections are made for 115 volts and the plug is inserted into a 230-volt outlet, the set will burn or blow a fuse. If the connections are made for 230 volts and the plug is inserted into a 115-volt outlet, the set will operate very weakly or not at all.

119. Tubes Do Not Warm Up

When the power is applied, set all controls for maximum output. Be sure that all switches are in their proper positions. All tubes should glow, indicating that they are lighted. If none of the tubes lights, the trouble is probably in the power supply. This condition may be caused by any one of the following: open power input cable, defective component in FL101, open power switch (part of FUNCTION switch), open fuse F101, open primary or filament winding in power transformer T801. If only one of the tubes requiring 6.3 volts fails to warm up, either the tube is burned out or there is a bad connection at the socket. If the pilot lamp fails to glow and the tubes requiring 6.3 volts warmup, the pilot lamp is burned out or there is a bad connection at its socket.

120. All Tubes Warm Up

The warmup of all tubes is an indication that the components mentioned in the previous paragraph are all good. The fact that a tube lights does not necessarily mean that it is not defective. The tube may have low emission, shorted elements, an intermittent condition, or it could be gassy. When trouble has been isolated to a stage, however, the tubes should be tested either in a tube tester or by substitution before other troubleshooting is undertaken. Do not rely on information from the operator or maintenance personnel that the tubes are good.

121. Sectionalizing Trouble

a. Before the defective stage can be located, the section that contains the trouble must be found. Turn on the calibration oscillator; if there is an indication on the CARRIER LEVEL meter, the stages from RF amplifier V201 through the fourth IF stage V504 and the agc circuits are operating. The defect is therefore between the antenna and the RF stage or in the audio section.

b. Set a modulated signal generator to any frequency within the range of the receiver. Connect the signal generator to J104 125 OHM BALANCED antenna terminals and set the receiver to the frequency of the signal generator. If a signal is heard in the receiver output, the input circuit between the antenna and RF stage V201 is operating. This also means that the power supply and audio sections are good. By using the above tests, the defect can be sectionalized before the receiver cabinet is opened.

122. Localizing Trouble

The following paragraphs localize and isolate trouble in the entire receiver, but in actual troubleshooting, the repairman should use the information in paragraph 121 that tells him which section (audio, RF, IF) of the receiver is at fault, and then go directly to that section and apply isolation and localization techniques.

123. Signal Output Indication on LINE LEVEL Meter but no Output From LINE AUDIO Terminals

LINE LEVEL meter M101 and LINE METER switch S105 are connected across the LINE AUDIO output terminals. This can help determine the location of the trouble. When switch S105 is rotated to position 9 or 10 and the meter indicates that a signal is present, but there is no output from the LINE AUDIO terminals, there is either an open resistor R111, R112, R114, or R115 or broken leads on TB103.

124. Signal Output From LOCAL AUDIO Terminals but not From LINE AUDIO Terminals, and no Indication on LINE LEVEL Meter

When there is no output at the LINE AUDIO terminals and no indication on the LINE LEVEL meter, the trouble is probably in some circuit common to both of these circuits. The circuits from P120 (where the meter and audio circuits are divided) to the outputs are probably satisfactory. However, these circuits may be checked conclusively by disconnecting P120 from J620 and applying an audio signal across pins 8 and 12 of P120 and checking for continuity across pins 9 and 10. If audio is obtained at the LINE AUDIO terminals, and indicated on the LINE LEVEL meter and there is continuity between pins 9 and 10, all the circuits beyond P120 may be assumed to be in good working order. If any of these results are not obtained, one or more defects exist in these circuits. If there are no bad contacts at P120, and resistance checks show that the secondaries of output transformer T602 are neither shorted nor open, proceed with the following signal substiution test.

a. Connect the output of an audio signal generator across the primary of T602. Do this from the top of the chassis by connecting one lead to pin 5 and the other to pin 6 of V604. Connect a .05-μf capacitor in series with the hot lead of the generator to protect the generator in case of accidental contact with high-voltage circuits. Turn the generator output on full; if even a weak audio signal is heard, the primary winding is intact. If the signal is not heard at all, the primary probably is open. If it is open, the screen grid in V604 will be red hot, and the power must be turned off at once.

b. Measure the voltage at the plate (pin 5). If the voltage is normal, the winding is good; if not, and the voltage at the screen grid (pin 6) is about normal, the winding is open.

c. Move the generator hot lead to pin 1 of V604. If a signal output is present, the stage is in operating condition; if there is no output signal, R623 or R625 may be faulty. Move the generator lead to pin 6 of V602B; if there is a signal output, coupling capacitor C608 is good. If there is no signal output, C608 is open; this can be verified by bridging it with a good capacitor.

d. Move the generator lead to pin 7 of V602B; an output indicates that this stage is in operating condition. No output indicates trouble in this stage. Measure the voltage at the plate (pin 6); no voltage may be caused by open resistor R622, because the other side of R622 has B+ present, which was measured at pins 2 and 5 of V604. Check R622 for an open with an ohmmeter.

e. If measuring the voltage across cathode resistor R621 shows a reading equal to B+, R621 probably is open. The higher-than-normal voltage is present because the voltage divider is open (R626, R621, and R623) and there is no plate current flowing; therefore, no voltage drop appears across R621 or R623, and the full B+ voltage is between pin 6 and ground.

f. Move the generator lead from pin 7 to the other side of C607; if a signal does not get through, C607 is open. Connect the generator lead to terminal 1 of LINE GAIN potentiometer R105; no signal output means R104 is open, or P120–3 and J620–3 are not making good contact. This is the point from which audio is fed to both audio channels and therefore will affect both channels.

125. Signal Output From LINE AUDIO Terminals but not from LOCAL AUDIO Terminals

The procedure in this case is similar to that used in paragraph 102, because the circuits are identical, with the exception of those portions beginning with the secondaries of the output transformers (T601 and T602). Therefore, in addition to troubleshooting the local audio channel in the same manner as was done for the line audio channel, be sure P119 and P120 connections to T601 are tight, and check R101, R102, and the connections to TB102.

126. No Output From Either LOCAL or LINE AUDIO Output Terminals

A defective power supply could cause both audio channels to fail. Even though tubes V602, V603, and V604 heat up, the power supply may not be providing plate voltage. Check for plate voltage on these tubes. If it is present, apply an audio signal to pin 14 of J620. If an output is not obtained, the trouble is in the audio stages that are common to both audio channels (V601A, first AF amplifier, and V601B af cathode follower).

127. No Output When Signal is Fed to Gain Controls

a. In paragraph 126 the two audio channels were the subject of the troubleshooting. The search now narrows down to a single audio input that is applied to both channels. If there is no output when a signal is fed to terminal 1 of LOCAL GAIN control R105 or LINE GAIN control R104 and other tests indicate that the circuit should operate, break-in relay K601 may be at fault.

b. If contacts 2 and 6 of relay K601 short together, no signal will enter the audio channels. A continuity check from any point on the AF line to ground will show a dead short if the relay is defective. If the relay can be reached easily, open and close the contacts by hand to test it.

c. If there is an output when the signal is fed into the gain controls, move the signal generator lead to pin 8 of AF cathode follower V601B. If the signal is heard, R627 is intact.

d. Apply the audio signal to pin 7 of V601B. If the output is about the same as it was when the audio was applied to pin 8, V601B is operating. The output is no stronger than when the signal was passed through V601B, because a cathode follower does not amplify the signal, but reduces it by a small amount. If there is no output, voltage and resistance measurements are necessary. Possible causes are a shorted C603A or C603B, or open R606, R607 or R608.

128. No Output When Audio Signal is Applied to Pin 1 of V601A When AUDIO RESPONSE Switch is Set to SHARP Position

a. Both the block diagram and the schematic show that the output (pin 1) of first AF amplifier V601A is coupled to the input (pin 7) of af cathode follower V601B through band-pass filter FL601 when AUDIO RESPONSE switch S104 is in the SHARP position.

b. If there is an output at the audio terminals when an audio signal is applied to pin 1 of V601A, FL601 is in good condition. If there is no audio output, FL601 is probably defective, or coupling capacitor C602 may be open. Filter FL601 can be checked by setting S104 to the WIDE position; this shunts FL601 and connects the output of V601A directly to the input of V601B. If there is now a signal in the output, FL601 or switch S104 is defective.

129. No Output When Audio Signal Is Applied to Pin 2 of V601A

If there is no audio output when the signal is applied to pin 2 of V601A, it may be caused by an open cathode-biasing resistor R604 or plate load R605. Resistor R606 is not open because it would cause V601B to be inoperative. A shorted C603B is not suspected either, because it would ground out the AF B+ line and would have been isolated before.

130. No Output When Audio Is Applied to Output of Limiter V507

Applying the audio signal to this point will give results similar to those obtained in paragraph 129. If there is an audio signal present in the output, the line from pin 2 of V601A to pin 2 of V507 is intact. If there is no output, it may be caused by an open R601 or C549. No output also may be caused by poor contact between P120–14 and J620–14 or between P112–7 and J512–7.

131. No Output When Audio Is Fed to Pin 6 or 7 (Limiter Input) of V507

If the audio output has about the same amplitude as it had in the preceding step, the limiter stage is operating. The output is no greater than the input because there is no amplification in a diode circuit. If there is no output and the LIMITER switch is in the OFF position, dc voltage from the switched RF–IF B+ line may not be reaching the diode plates. This may be caused by an open R532, R533, R534, or R535 or by a shorted C531 or C532. Other possibilities are poor contact at J512 or a defective S108.

132. No Output When a Modulated RF Signal Is Applied to Pin 6 or 7 of Detector V506B and BFO Switch S101 Is Set to OFF

a. This is the stage where the audio is separated from the carrier; therefore a signal applied anywhere ahead of the detector will be in the RF range. A signal applied to the detector will be demodulated and the audio will appear in the output of the receiver. If there is no output during this test, it may be caused by an open secondary winding in IF transformer T503, open RF filter choke L502, R527, or R526.

b. Other possible sources of trouble are a shorted C562, C563, or a loss of the jumper across terminals 14 and 15 on TB103. No dc voltage is applied to this stage; therefore, few breakdowns will occur.

133. No Output When Unmodulated Signal Is Applied to Pin 6 or 7 of Detector V506B and BFO Switch S101 Is Set to ON

a. When the bfo (V505) is operating at its correct frequency, the output will beat with the unmodulated signal and produce an audible beat note. If there is no output, the bfo is not operating, or the signal is not reaching pin 7 of V506B. If C535 is open, the bfo signal will not be applied to V506B.

b. If the voltages at the plate (pin 5) and screen grid (pin 6) of V505 are low, the trouble is in the RF–IF B+ line or R529, R530 or R531 may have changed in value. This path is through P112–11 and J512–11, BFO switch S101, and FUNCTION switch S102, to the power supply at choke L602.

c. If there is normal voltage at L602, then L602 and C606 are not defective. An open choke would cut the B+ supply to the bfo. Other possible causes of an inoperative bfo are a defective FUNCTION switch S102 or BFO switch S101, a shorted or leaky C533, or C534, or an open R529, R530, or R531.

d. An open screen-grid bypass C533 will cause oscillation to cease, because normally it connects the screen grid (pin 6), which is the anode of the oscillator, back to terminal 3 of Z502 to complete the oscillatory circuit.

e. If the plate and screen-grid voltages are normal, check the dc voltage across grid-leak resistor R528; if the circuit is oscillating, bias is present. Other possibilities are defective Z502 or open C526.

f. Another possible trouble is that the frequency of the bfo is not close enough to the frequency of the IF signal to produce an audible beat note. The off-frequency operation may be caused by shorted turns in L508 or L509, or a leak or change in capacitance of C554, C555, or C556. These components are in a sealed can (Z502), and must be replaced as a unit.

134. No Output When Modulated 455-kc Signal Is Fed to Input (Pin 1) of Fourth IF Amplifier V504

a. This stage amplifies the signal before it is demodulated. The audio output should be considerably stronger than it was in the previous step. If there is no output, the trouble must be between the point of signal injection (pin 1 of V504) and the secondary of IF transformer T503. Therefore the possible defect could be an open primary winding in T503, and open R523, R524, or R525, or a leaky C525, C561, C562, or C530.

b. If there is no indication that one of the components is defective, try retuning T503. Check the primary of L512, part of T503, for proper resistance, because shorted turns can change the resonant frequency so much that the signal cannot get through.

135. No Output When Modulated 455-kc Signal Is Applied to Input (Pin 1) of Third IF Amplifier

This stage is similar to the stage considered in paragraph 134; therefore, the troubleshooting procedure will be similar. The components to suspect are an open R518, R519, R520, or R551. A leaky C523 or C522 or an open or shorted primary winding L510 could also cause the same symptoms.

136. No Output at IF OUTPUT 50 OHM Jack J116 When Modulated 455-kc Signal Is Applied to Input (Pin 7) of IF Cathode Follower V509B

a. The IF OUTPUT 50 OHM jack is connected to IF cathode follower V509B. If there is output at the jack, a reading will be obtained on a vtvm when its RF probe is connected across the jack. If there is no reading, C539 may be open.

b. Other possibilities are an open R538, R539, or L504. Any opens in these parts would open the B+ circuit to the plate. Also, if C541 should become shorted, it would ground the plate and B+, causing the stage to become inoperative.

137. No Output When Modulated 455-kc Signal Is Fed to Input (Pin 1) of Second IF Amplifier V502

The second IF amplifier stage is similar to the third and fourth IF amplifier stages, and the method of troubleshooting the second IF amplifier is the same as described in paragraphs 134 and 135. There will be no plate or screen-grid voltage if either R515 or R521 is open. If L506 is open, the plate voltage will still be present, but it will be low because R511 is in parallel with L506.

138. No Output When Modulated 455-kc Signal Is Applied to Plate (Pin 5) of First IF Amplifier

a. The position of the BANDWIDTH switch determines which mechanical filter is in the circuit. Therefore, if there is no output on only one of the switch settings, the trouble can be isolated to the mechanical filter that is connected into the circuit at that setting. A continuity check of the circuit through the switch will reveal the defective part.

b. For example, with the switch set on position 1 as shown in the diagram, S502 front connects the 2-kc mechanical filter to the plate circuit of V501 and S503 front connects the output of the filter to the input of V502. There is a path from the grid of V502 to the coupling capacitor (C553) connected to the plate of V501. If there is continuity through this path, check C553. It may be open.

c. The same procedure can be used for the other filters, which are connected into the circuit at other settings of the switch. The rear sections of S502 and S503 are used to short out the filters that are not in use.

139. No Output When a Modulated 455-kc Signal Is Applied to Input (Pin 1) of First IF Amplifier V501

If the stage is operating, the output will be considerably louder than the output heard in the previous step because of the amplification of the stage. If there is no output, the B+ could be opened by a defective R504, R506, R508, L501, or L505. An open jumper between terminals 1 and 2 on TB102, or a defective RF GAIN control R103, would open the dc line and it would affect other stages because it is common to them. A leaky screen-grid bypass C506 would decrease the screen-grid voltage to the extent that there would be no output; the same effect could be caused by an increase in R506 or a short in C511. A leaky plate bypass C511 would decrease the plate voltage to zero or nearly zero.

140. No Output When a Modulated 455-kc Signal Is Applied to J513 or J518 and BANDWIDTH Switch S501 Is Set to .1 KC or 1 KC Position

a. When BANDWIDTH switch S501 is set to the .1 KC or the 1 KC position, crystal Y501 is in the circuit and tuning is very critical. If there is an output signal of about the same amplitude as during the previous step, the input circuit to the first IF amplifier is operating. If there is no output, the possible causes of the trouble are a defective BANDWIDTH switch S501 or crystal Y501, open C503, R501, or L503. The parts in Z501 cannot be replaced separately; Z501 must be replaced.

b. When S501 is in any of the other four positions, the crystal is still in the circuit, but C501 is in parallel with it. Thus, the crystal can be eliminated as a source of trouble by setting the switch to the 2 KC, 4 KC, 8 KC or 16 KC position. The tuning will be broader as the switch is set to the higher numbers. Therefore, if the tuning becomes much sharper as the switch is set to the .1 KC or 1 KC position the crystal circuit is operating.

141. No Output When a 455-kc Modulated Signal Is Applied to Input (Pin 6) of Third Mixer V204

a. Test point E211, on top of the chassis is connected to pin 6 through R230. The output will be slightly above the level it was in the previous step if the stage is operating properly. A no-output condition may be caused by an open or shorted secondary L235 of T208. Dc voltage and resistance measurements may show that the primary (L234) of T208, R218, or R219 is open. A shorted C308 will remove the plate and screen-grid voltages, but would affect other stages also.

b. The signal is fed into the cathode circuit from the variable frequency oscillator (vfo) V701 through the secondary of T701; therefore, an open secondary in T701 could open the cathode circuit to V204 and keep the stage from operating. The same conditions could be caused by a leaky or shorted plate bypass C307, but the circuit would not be opened; the plate voltage would be shorted out.

142. No Output When Modulated 2.5-mc Signal Is Fed Into Input (Pin 6) or Third Mixer V204

a. In the previous step, a modulated 455-kc signal fed into this stage produced the proper output, proving that the stage was operated properly. Apply a modulated 2.5-mc signal to pin 6 of third mixer V204, and vary the frequency of the vfo stage until an output is produced. If an output is not produced, the vfo is not operating. If the vfo is operating, the output from it would beat with the input signal to the mixer and produce a beat frequency of 455 kc in the output of the mixer.

b. Measure the bias voltage across R701. If there is a voltage present, the stage is oscillating; if there is no voltage, the stage is not operating.

c. Another way of checking the oscillator is to note any change in the plate voltage when the bias resistor is shorted out; no change means that the stage is not oscillating. Possible causes of an inoperative vfo are: an open primary winding (T701) of Z702, R702, or R703 or a shorted bypass capacitor C705 or C708. Shorted decoupling capacitors C707 and C714 also are possibilities, but they would have been isolated previously because the RF–IF B+ line or the regulated 150-volt line would have been shorted out.

d. If C705 opens, the connection for RF between the screen grid, which is the anode of the oscillator, and tank coil L702 would be broken, causing the circuit to cease oscillating. Shorted turns in either L701 or L702 would change the frequency of oscillation, thereby producing an output that gives a resultant beat frequency other than 455 kc in the third mixer. If tests show that the defect is in one of the parts in L702, the sealed unit must be replaced. A large change in the resistance value of grid leak R701 will stop oscillations.

143. No Output When Modulated 2.5-mc Signal Is Applied to Input (Pin 6) of Second Mixer V203

a. Tune vfo stage V701 until an output is produced. Normally, the only trouble would be an open plate circuit. This would be caused by an open L233–1 in Z216–1 or an open plate dropping resistor R216. If plate bypass capacitor C288 should develop a leak or a short circuit, the plate voltage would go to a low value, and possibly to zero. The plate current would be interrupted if either R215 or the secondary (L404) of T401 opens, because they are both in the circuit between the cathode (pin 7) of V203 and ground.

b. The other two tuned circuits (Z216–2 and Z216–3) are in parallel with Z216–1 but no direct current passes through them; therefore, a defect is rare. If C289 or C290 should open, the signal would go to zero. If trouble should occur in one of them, the signal output would not be reduced to zero, but the pass band of the circuit will be affected.

144. No Output When Modulated 8- to 32-mc Signal Is Applied to Input (Pin 6) of Second Mixer V203

a. In the signal-tracing process, a modulated signal will be applied to the control grid of second mixer V203. The signal should be in the 8- to 32-mc range because this range will check the operation of the second mixer and second crystal oscillator V401, as well as the stages that follow. To get the signal through, either tune the signal generator through the 8- to 32-mc range or set the signal generator at some frequency within this range and tune the receiver throughout the same range. If there is an output, it should be about as strong or slightly stronger than it was during the previous step.

b. If there is no output, no signal is coming from second crystal oscillator V401. Measure the bias across grid-leak resistor R404 to determine whether the circuit is oscillating. If there is no bias, the circuit is inoperative.

c. If the crystal oscillator does not operate, there may be an open primary winding (L403) of T401, and open R405, R406, R407, or L401. Other causes of trouble would be a shorted C410, C411, C412, or C413. A defect in crystal selector switch S401 or capacitor selector switch S402 could also prevent the stage from operating.

d. Unless the defect is in the center arm of the switches, the switches can be set to other positions to connect other crystals and capacitors into the circuit; if the oscillator operates at all positions except one, one of the switches, a crystal, or one of the capacitors that S402 connects into the circuit is defective. An open secondary winding (L404) of T401 or cathode resistor R215 would keep the oscillator signal from reaching the second mixer, but because they are in the cathode circuit of the second mixer, it would have been detected in the troubleshooting of the second mixer in paragraph 143.

145. No Output When a Modulated 17.5- to 25-mc Signal Is Applied to Input (Pin 6) of First Mixer V202

a. This stage is similar to second mixer V203; therefore, the troubleshooting is similar. The plate current flows through the load, L232–1; it follows, therefore, that if L232–1 should burn out, the stage will go dead. Another cause of trouble might be an open R209 or L231, which is in the output of first crystal oscillator V207.

b. A short circuit in C280, in addition to grounding the plate voltage may cause R212 to smoke. The block and schematic diagrams show that the output of this stage is fed to the second mixer through a switch (S208); therefore, if S208 becomes defective, it can keep the signal from reaching V203, which means there will be no output.

146. No Output When Modulated .5- to 8-mc Signal Is Applied to Input (Pin 6) of First Mixer V202

a. In the previous step, a signal of the mixer output frequency range produced an audio signal in the loudspeaker. Now that the .5- to 8-mc signal produces no output, it means that the output of the first crystal oscillator V207 is not beating with the input signal to produce a different frequency in the mixer output.

b. This oscillator circuit is similar to the one used in the second crystal oscillator V401, but there is no wide frequency selection because only one crystal is used. Measure the bias across grid-leak resistor R207 first to determine whether the stage is oscillating. If there is no oscillation, check the crystal by substituting one of identical characteristics. If either C324 or C325 should open, the capacitive voltage divider between the grid and screen grid (the anode) would become inoperative.

c. Because this is an electron-coupled circuit, the screen grid serves as the anode. The anode is connected to the anode side of the voltage divider through C326. Thus, if C326 should open, the oscillations would cease. There is also a possibility of R207 changing value; this could also stop the circuit from operating. The first mixer and the first crystal oscillator are inoperative in the frequency range between 8 and 32 mc; that is, the signal is fed from RF amplifier V201 to the second mixer. The troubleshooting therefore can be simplified. If the receiver operates normally in the 8- to 32-mc range, but is inoperative in the .5- to 8-mc range, the trouble could be in the first mixer or the first crystal oscillator.

147. RF Amplifier V201

a. Apply a modulated test signal having a frequency between .5 and 1 mc to test point E208; set the MEGACYCLE CHANGE switch to the proper position. Tune in the signal by turning the KILOCYCLE CHANGE dial. If an output is produced, repeat the procedure using signals between 1 and 2 mc, 2 to 4 mc, 4 to 8 mc, 8 to 16 mc, and 16 to 32 mc. If there is no output at any of the above frequencies, the RF amplifier is dead.

b. In all positions of the MEGACYCLE CHANGE switch, plate voltage to V201 is applied through parasitic suppressor E212 and decoupling resistor R205. If either of these burns out, the stage will go dead. Other possibilities are a defective switch S206, open screen-grid dropping resistor R204, or a shorted bypass capacitor C229. The cathode circuit could be open because of a defective RF GAIN control R103. Poor contact at switch S206 in the plate circuit of V207 or S207 in the input circuit of V207 could also cause the circuit to open.

c. When the MEGACYCLE CHANGE switch S206 is set to position 11 (fig. 65), Z201–1 is in the circuit, and, if defective, could cause the trouble.

d. When the MEGACYCLE CHANGE switch is set to position 12, 1, 6, 7, or 8, the circuits to suspect are Z202–1, Z203–1, Z204–1, Z205–1, Z206–1, respectively. The MEGACYCLE CHANGE switch may also be defective.

148. No Output When a Modulated Signal Is Applied to J104 125 OHM BALANCED ANTENNA Jack with MEGACYCLE CHANGE Switch in Any Position

a. Relay K101A, when energized during periods of transmission, break-in, or calibration, disconnects the antenna and grounds it. If the contacts on the relays close, no signal will be fed to RF amplifier V201. Actuate the relay by hand to be sure it is operating properly before proceeding. A bad contact in switch S204 could also cause this trouble.

b. With the switch in position 11, the suspected components are S201, S202, T201, R233, C255, and C226. When the switch is set to the five other ranges, the same troubles in *a* above are possible, except that the frequency of the applied signal will be different for each setting.

149. No Output When Modulated Signal Is Applied to J103 WHIP UNBALANCED ANTENNA Jack

a. When antenna jack J103 is being used, switches S201 and S202 of the MEGACYCLE CHANGE switch are not in the circuit; therefore, they are eliminated as possible sources of the trouble. The antenna jack is connected into the circuit through relay K101B, which could be defective. Resistor R121, at the antenna jack, cannot be considered as a cause of trouble unless it is damaged; it drains off charges of static electricity accumulated during mobile operation.

b. Lamp L103 grounds static or lightning charges built-up across the antenna. The whip antenna is connected to the RF amplifier through switches S204 front and S205. These may cause trouble and must be checked.

Section III. TROUBLESHOOTING WEAK AM RECEIVER

150. General

a. The procedure for troubleshooting a weak receiver is basically the same as that used for a dead receiver; that is, it is a matter of localizing the trouble by stages. When a weak set is encountered, refer to the section on troubleshooting a dead set. But note this difference: When troubleshooting a dead set, you are not too concerned about the amount of output that results from a particular test, so long as there is an output; but when troubleshooting a weak set, you will most often find it important to know the precise amount of output produced when a signal is injected into the stage. First, set the FUNCTION switch to MGC, because the gain of the set will vary when the agc circuit is used. In sets with agc but no switch to cut it in and out, the agc circuit must be grounded out. It is assumed that the tubes in the suspected stages have been tested before stage gain tests are made.

b. Before troubleshooting procedures are begun, there are some preliminary steps that should be taken to insure that the defect is not an operating fault. Listed below are some checks that the operator can make before he calls the repairman.

(1) See that the receiver is tuned properly.
(2) Be sure that all switches are properly set.
(3) Check the line voltage to see that it has not dropped.
(4) Determine whether signals are weak on only one or more stations.
(5) Check the antenna to see that it is still up.
(6) Observe the indications on the S meter, carrier-level meter, or other indicators that could localize the trouble.

receiver. It is important to set all controls and switches as the technical manual recommends.

b. To test the stage gain in the RF and IF sections (fig. 65), connect a vacuum-tube voltmeter between the designated output point and ground. Connect a .05-μf capacitor in the hot lead of the signal generator to protect the generator from possible damage if the hot lead comes in contact with a high dc voltage point. Connect a vtvm between DIODE LOAD terminal 14 and ground. Apply the unmodulated 455-kc signal to test point E211, at the top of the chassis. The signal generator output should be between 20 nd 40 microvolts to produce —7 volts on the vtvm.

c. As the tests progress toward the antenna section, there is less signal input required to produce the same output; this is because the signal is being amplified by passing through more stages. The output of the signal generator should be compared with the information in the chart at all test points shown in table I. Readings that are outside of these limits by a small amount do not necessarily indicate that the receiver is not operating properly.

d. The gain of the individual stages of a receiver over a period of time will vary. If the difference is great and the receiver's overall output is weak, the stage probably is at fault. When a stage lacks gain by a considerable amount, voltage and resistance checks may be necessary to locate the faults.

151. Troubleshooting Without Stage Gain Data

It is possible to locate the trouble in a weak receiver without stage gain information. In such cases, a signal is injected into the various stages as in the dead set procedure, the point being noted at which the signal input must be *increased* instead of *decreased* to produce the same output. For example, an audio signal applied to the plate of an audio amplifier produces a certain output from the receiver. When the same signal is applied to the input of the same stage, it should produce a stronger output than before; the signal generator output must be reduced to keep the output at the same level. If the generator output must be increased to produce the same output, the trouble is between the input and output of this stage.

152. Troubleshooting by Using Stage Gain Data

Sometimes it is almost impossible to determine whether a stage has the proper gain, either because it is normally low, or because the slight difference from normal output cannot be noticed. Then make detailed stage-gain measurements to determine which part of the receiver is not amplifying properly.

a. The technical manual for a receiver will specify the minimum and maximum signals required at certain points to produce a given output. Tables I and II are for each type of stage-gain test and contain such information for this

Table I. RF Stage-Gain Tests

Signal generator output connection	BALANCED ANTENNA connector	Test point E208, grid of V201	Test point E209, grid of V202		Test point E210, grid of V203		Test point E211, grid of V204	
Frequency (mc)	.5–32	.5–32	.5–8	17.5–25	–3	8–32	2–3	.455
Signal generator output (microvolts).	less than 4	4 to 16	15 to 60	15 to 16	13 to 40	20 to 65	50 to 125	20 to 40

e. To test the stage gain of the fixed IF section, the procedure is identical with that used in the RF stage-gain tests. Connect the vtvm to the same terminals, but leave the signal generator at a frequency of 455 kc for injection into the points shown in table II. Compare the output in microvolts of the signal generator that is needed to produce the required —7 volts output on the vtvm with the information in table II. Any great deviation from the requirements of the table means that resistance and voltage checks must be made.

Table II. IF Stage-Gain Tests

Signal generator output connection	Signal generator output (microvolts)
1st if ampl (V501) grid, pin 1	100 to 200
2d if ampl (V502) grid, pin 1	250 to 500
3d if ampl (V503) grid, pin 1	10,000 to 20,000
4th if ampl (V504) grid, pin 1	300,000 to 400,000

f. To test the gain in the audio section, connect the output of a calibrated output audio signal generator through a .05-μf capacitor to the DIODE LOAD terminal of TB103 and turn the LOCAL GAIN control fully clockwise. Turn the RF GAIN control fully counterclockwise. Adjust the frequency of the generator to 400 cycles. Set the AUDIO RESPONSE switch to the WIDE position. Connect an ac vtvm in parallel with a 600-ohm noninductive resistor across LOCAL AUDIO terminals 6 and 7. Increases the output of the generator until 500 milliwatts (17.3 volts rms across 600 ohms) is indicated on the vtvm. The output of the generator should be approximately 1 volt.

g. Transfer the vtvm and the 600-ohm resistor to LINE AUDIO terminals 10 and 13 and turn the LINE GAIN control fully clockwise. Adjust the signal generator to produce an output of 10 milliwatts (2.45 volts across 600 ohms) on the vtvm. The output of the generator should be less than 1 volt.

h. In the case of a weak receiver, the tubes should be checked before any other action is taken. Voltage and resistance measurements will show such faults as leaky bypass capacitors, and resistors that have changed in value. These conditions can reduce the plate and screen-grid voltages to the extent that the output will decrease and cause the signals to become weak.

i. Capacitor C603A can cause the above troubles in the plate circuit of first AF amplifier V601A and AF cathode follower V601B.

j. An open bypass capacitor is hard to locate, because there is no telltale indication of its condition in the dc voltage and resistance readings. But there are other symptoms that can be detected.

(1) Capacitor C609 is the cathode bypass in V601A, the first af amplifier. If C609 should open, there would be a signal voltage drop across cathode-biasing resistor R604, the voltage drop will cause degeneration, and this in turn will reduce the output noticeably.

(2) Capacitor C505 is the cathode bypass in V501, the first IF amplifier. If C505 should open, the signal would be considerably weaker than it would have been in the cable of C609. This is because any signal present in the IF section of a normally operating set is considerably weaker than it is in the AF section, and any loss occurring in the IF section is therefore the more noticeable.

k. An open coupling capacitor between stages usually will cause the output to drop to zero, but in the case of a very strong signal, the signal may get by the open capacitor and produce a weak output. However, signals other than the very strong ones will not get through with very much strength; then the set can be considered weak.

Section IV. TROUBLESHOOTING DISTORTED AM RECEIVER

153. General

Only a few defects can cause distortion, and they can usually be identified by the sound of the receiver output. Distortion is present when the output signal is muffled or raspy, or does not sound as it should. The experienced technician can often tell from the sound just what type of distortion is present and what causes it. In most cases the distortion will be in the audio section. Distortion, in most cases, is caused by an upset in bias, or by overloading of a stage.

154. Types of Distortion

a. Frequency distortion occurs when all frequencies are not amplified to the same extent. For example, if the high and low audio frequencies originally were of the same strength, but in the output of the receiver the flow frequency notes are reproduced louder than those of the high frequencies, frequency distortion is present. (In this receiver this type of distortion will not be present, because it is designed for a limited frequency response.)

b. Amplitude distortion is present when there is a change in the harmonic content of the signal after it passes through one or more stages. This type of distortion is the more bothersome because the signal sounds unpleasant, whereas frequency distortion is only a matter of some frequencies being stronger or weaker than others. It will be noticed during voice reception but probably not when cw signals are being received.

155. Common Causes of Distortion

a. Leaky Coupling Capacitor. One of the most common causes of distortion is a leaky audio coupling capacitor such as C605 (fig. 65), which couples the signal from the local AF amplifier V602A to the local AF output amplifier V603. If C605 becomes leaky, it will act as a resistor in series with grid resistor R613 and plate load R611. This series circuit is connected across the B+ line, making the grid end of R613 less negative than it was, or even positive. The tube now operates on the upper portion of the Eg-Ip curve, producing distortion.

b. Gassy Tube. If the local output tube V603 or any other tube becomes gassy, amplitude distortion will result. The bias will be reduced, the grid may draw current and produce distortion.

c. Other Causes. Other causes of distortion are misalinement, poor power supply filtering, warped speaker diaphragms, oscillation, excessive strength of input signals, and interference from cross talk.

156. Localizing Distortion

a. Localizing distortion is more difficult than troubleshooting a dead or weak receiver. Signal substitution can be used, but it is more convenient to use a form of signal tracing. Connect an antenna to the receiver input and connect a locally constructed audio signal tracer (fig. 46) to various points to determine where the trouble lies.

b. Assume that the output at the LINE AUDIO terminals is normal but the output at the LOCAL AUDIO terminals is distorted. This pinpoints the trouble to the local audio channel, which includes V602A and V603, and LOCAL gain control R105. Connect the prods of the signal tracer to pin 5 of V603 and ground. If the signal is present at the output, the secondary of the output transformer and all components from it to terminal board TB102 are probably in good condition. Move the hot prod from pin 5 to pin 1 of V603.

c. If the output is not clear, the plate circuit of V602A is not operating properly, and the trouble could be in the input circuit of V602A.

d. A more positive method of detecting distortion is by using an oscilloscope and an audio signal generator. The equipment setup is shown in figure 66. Connect the signal generator to the vertical amplifier terminals of the oscilloscope by setting S1 to position 1. This switch is set to position 2 to connect the oscilloscope across the plate load resistor of the stage being checked.

e. The testing procedure follows: Adjust the signal generator to 400 cps. Set S1 to position 1 and adjust the oscilloscope frequency controls to produce on the screen two sine waves that look like those at A figure 67. Adjust the oscilloscope controls to show clean sine waves. We are assuming at this point that trouble is not present. Compare the results with the patterns shown in figure 67.

f. Assume that the trouble has been isolated to the local audio channel. Connect the output of the signal generator across LOCAL GAIN control R105 and set S1 to position 2. Connect the test probe to the plate (pin 5) of V603 and observe the wave form. If, for example, the wave form is unlike pattern A when the probe is con-

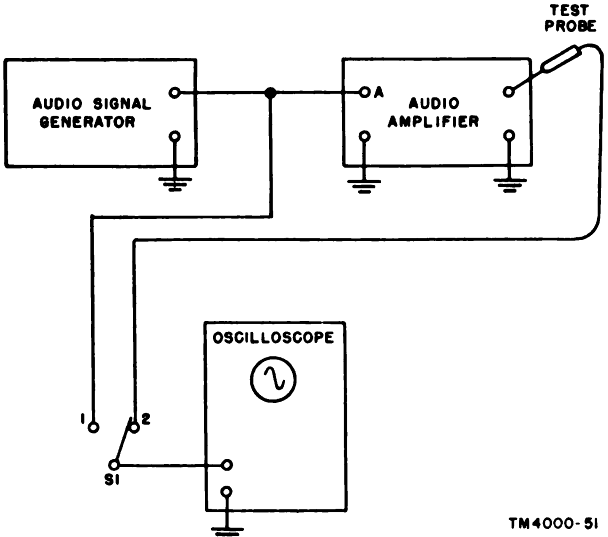
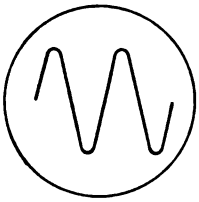


Figure 66. Setup for checking distortion.

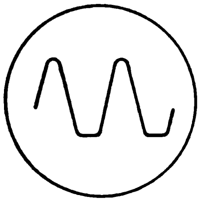
nected to pin 5 of V603 and is like pattern A when the probe is connected to pin 2 of V602A, the distortion is between those two points. The patterns in B, C, and D show the wave forms that will appear on the oscilloscope screen when there is distortion; they also indicate some of the causes of distortion.

g. Diagram D in figure 67 shows a distorted sine wave as it appears on an oscilloscope. When such a condition arises, the trouble is probably in the agc system, because the agc normally prevents overloading by keeping the output from all signals at a constant level. If the agc is at fault, switching to mgc will not eliminate distortion. The operating point about which the agc works is determined by the setting of the RF GAIN which is the sole control when the agc is turned off.

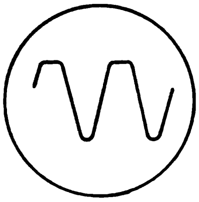
h. An example of a trouble would be an open R516, the agc decoupling resistor, or the agc decoupling capacitor C519, both of which are in the grid circuit of the 3d IF amplifier V503. One of these troubles would prevent the agc action from controlling the stage and overloading could be the result. Any trouble in the agc system would prevent the agc voltage from affecting the controlled stages, which include the 1st, 2nd, and 3rd IF amplifiers V501, V502, and V503. Other controlled stages are the 1st, 2nd, and 3rd mixers, V202, V203 and V204, and RF amplifier V201.



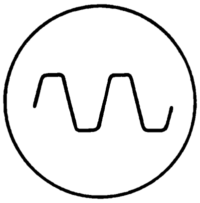
UNDISTORTED SINE WAVE OUTPUT



TOO HIGH BIAS OR TOO LOW PLATE OR SCREEN VOLTAGE



TOO LOW BIAS OR TOO HIGH PLATE OR SCREEN VOLTAGE



OVERLOADED STAGE, CAUSED BY TOO MUCH SIGNAL INPUT

TM4000-52

Figure 67. Oscilloscope patterns showing distorted sine wave.

Section V. TROUBLESHOOTING INTERMITTENT AM RECEIVER

157. General

A receiver is operating intermittently if from time to time it operates normally but between times goes dead or develops any other type of trouble. Intermittent troubles include all types to which a receiver is subject, but they appear and disappear at irregular, or even regular, intervals. Such troubles are hard to trace, because they do not exist when the set is operating normally, and because the set may resume normal operation before the technician can finish testing it.

158. Causes of Intermittent Operation

a. Capacitors. A frequent cause of intermittent operation is the haphazard opening and closing of a connection within a fixed capacitor. For example, the circuit would open if a pigtail lead pulled loose from the foil, and then a slight jarring of the set might cause the contact to be made again; or that same effect might be caused by a sudden switching of the voltage off and on. If capacitor C607 (fig. 65) which couples the audio from LINE GAIN control R104 to the grid of line AF amplifier V602B should become intermittent, the signal level would vary up and down. If the opening and closing condition is at a rapid rate, the effect may appear as noise. If the screen-grid bypass C529 in the 4th IF amplifier V504 should open and close at slow intervals, oscillations will occur. If it opens and closes in rapid succession, noise will be produced. Variable tuning capacitors can short intermittently because of dust, dirt, or other foreign particles becoming lodged between the plates. The plating on the plates sometimes peels off in slivers which are often long enough to cause intermittent short circuits. The rotor wiping contacts may have improper spring tension, or corrosion that could cause intermittent high resistance contact to the capacitor frame. In the very small types of variable capacitors the plates have extremely close spacing; these plates can become bent and may short if the frame should warp because of heat or twisting of a subchassis. Small air capacitors, used as trimmers, and commpression-type trimmers also collect dirt. The troubles will be of the same types as those in tuning capacitors.

*b. Loose Connections.*_ A loose connection in any portion of the set can cause intermittent operation. Vehicular vibration may shake loose a connection, or the cause of looseness may be a factory fault, such as an unsoldered or poorly soldered joint.

c. Resistors. Wire-wound resistors sometimes develop intermittent open circuits at the junction of the resistance wire and the terminals. Carbon resistors may develop opens, but they usually occur after the resistor becomes hot during a long period of operation. Some carbon resistors are insulated and have the resistance element in the form of a carbon rod in the center. The carbon rod can crack and cause intermittent operation.

d. Tubes. Normally, in trouble shooting, the tubes are suspected first. If a tube is intermittent it may be normal when tested, and the test will be of no value. An intermittent tube can sometimes be found by tapping the suspected one. Elements in a tube may expand because of heat and short to other electrodes momentarily. The filament may expand and break, then as it cools, the ends may come together again, and current flows, producing normal results. Depending on conditions, this may occur several times in a minute for a particular tube.

e. Inductors. RF and ac coils that carry dc are especially susceptible to intermittent opens. The form on which the coil is wound may expand from the heat and snap the winding. Moisture on the surface of the wire produces a chemical action which causes corrosion that will eat away the conductor. An arc may form and close the circuit momentarily; then when the carbonized area breaks down, the circuit opens again.

f. Potentiometers. Carbon volume or gain controls often have resistance strips that may become pitted because of wear. Only a small portion of the moving arm may be in contact with the strip, and a slight jarring of the set may break the contact momentarily. This condition will be present especially in controls where dc current flows, and arcing could occur.

g. Solder Joints. Original solder joints often appear good to the eye, but under the surface there may be a looseness which, if subjected to vibration, could cause intermittent operation. Technicians often introduce intermittents by poor soldering. Therefore, carefully examine all solder joints, particularly those that have been made during repairs.

159. Isolating Intermittent Troubles

a. Audio Signal Substitution. In this receiver the CARRIER LEVEL meter can be of great assistance in troubleshooting. The meter is in the output circuit of the fourth IF amplifier. Therefore, if during intermittent operation the meter needle remains steady, the trouble is between the fourth IF amplifier and the audio output. An arcing in the power supply would have an effect on the output. If the trouble is traced to the audio section, the signal tracer that was used to trace distortion can be used by following the instructions given in paragraph 156. Rather than use the incoming signal from a transmitter in this procedure, however, it is better to apply an audio signal from a signal generator between terminal 15 on TB 103 and ground. This is because the signal from the generator will normally be at a fixed amplitude, while the incoming signal may vary over a wide range. If the CARRIER LEVEL meter needle varies in step with the output signal, the intermittent condition is somewhere between the fourth IF amplifier and the antenna.

b. RF Signal Substitution. The same procedure is used as in troubleshooting a dead set. A signal of the proper frequency is fed into J104 125 OHM BALANCED antenna jack with the antenna disconnected. A modulated or unmodulated signal can be used. If it is modulated, the signal can be heard in the speaker. If the signal is unmodulated, a vtvm connected across the detector load, (between 15 on TB103 and ground) will indicate an output. When the set is intermittent, the trouble will show up as variations on the meter. Move the signal generator lead to pin 1 of V201, the RF amplifier grid. If the meter needle is now steady, the intermittent is between pin 1 of V201 and the antenna jack. If the output is still intermittent, the trouble is between the signal generator and the detector load. Move the signal generator output to the grid (pin 6) of the first mixer, V202. Test point E209 (on top of the chassis) is a convenient place to do this. If the meter needle does not fluctuate in step with the intermittent signals, the trouble is between this point and the RF amplifier grid. If the meter needle follows the variations, the trouble is between the first mixer grid and the detector load. This procedure is used to localize the defective stage, working toward the meter connection.

c. Forcing Troubles to Reappear. There are times when the intermittent condition does not reappear for hours or even days. Often it can be made to reappear by placing a cardboard box over the receiver to concentrate the heat. This trick works best when the condition is caused by shorts or opens that are due to heat under the chassis. If the receiver is sensitive to jarring, rap the chassis at several points to make the intermittent reappear.

(1) If one end of the chassis seems more sensitive to rapping, the trouble is probably, though not necessarily, at that end. Moving resistors and capacitors around with an insulated prod will often reveal poor contact in the components. If there is a sharp disappearance of the signal or a sudden change in noise, move the wiring around with the prod. Do not move the wires too far out of place, as this may cause other troubles. Poor solder connections can often be found by wiggling the wiring at the sockets and other terminals.

(2) The chassis may seem to be equally sensitive to jarring at all points. It is then necessary to keep prodding around, stage by stage, until the bad point is found.

(3) Certain components will open intermittently during line voltage surges and will later be restored to normal. Remove and replace tubes one at a time. If the receiver becomes insensitive to tapping when a particular tube is removed, the trouble is in that stage or a stage closer to the antenna. The input voltage to power transformer T801 can be increased by connecting a variable transformer in the line and increasing the voltage to 125 volts or more. This increase in the voltage often will show up intermittents that ordinarily would not appear for hours at the normal input voltage.

Section VI. TROUBLESHOOTING RECEIVER FOR HUM

160. General

a. Before the receiver can be freed of hum, it is first necessary to know what hum is and how to recognize it. The experienced technician recognizes it as a steady low-pitched sound. Hum is produced by power line ac variations, and is usually 60 or 120 cycles. It is a tone that has a constant amplitude and is of one frequency. This distinguishes it from noise, which consists of an unpleasing sound of many random frequencies and is constantly changing in amplitude. Hum can also be regarded as a low-frequency audio voltage. In this receiver, as in most other ac receivers, the hum will have a frequency of 60 or 120 cycles.

b. Hum may develop directly in the audio frequency section of a receiver because of—

(1) Inadequate filtering in the power supply.

(2) Stray coupling from the ac power leads.

(3) Short circuit between the heater and cathode of a vacuum tube.

(4) The signal present in the RF and IF circuits being modulated by the hum.

161. Causes of Hum

a. Filter Capacitors. The most likely cause of hum in any ac receiver is an open filter capacitor. The capacitors are in the filter circuit for removing the hum that is present in the output of the rectifiers. Capacitors C606A and C606B (fig. 65) are examples of filter capactors. If either capacitor should open, the hum level would rise considerably. The schematic diagram shows that C606A and C606B are mounted in the same can. If leakage should develop *between* the two capacitors, the result would be similar to connecting a resistor across choke L602. This would reduce the effectiveness of the choke and cause a ripple in the output of the filter, producing hum. Excessive dc can be forced through choke L601 if filter capacitor C606A becomes leaky. The excessive dc through the choke causes core saturation, which lowers the inductance, and makes the choke less effective as a filter. These last two examples show that the hum is apparently caused by the choke, but the actual trouble is a leaky capacitor.

b. Filter Chokes. If any one of the filter chokes becomes shorted internally, the receiver will hum. Internal shorting seldom occurs; test required to determine whether the coil is defective should be carried out only after other componnts have been checked. Iron-core chokes usually have an air gap in the core to prevent core saturation. The gap is kept open by a wedge of non-magnetic material such as paper, copper, or brass. If the gap material should drop out or if it were not there in the first place, the gap could close up from vibration of the core laminations. This would allow core saturation which would produce hum.

c. Power Transformer High-Voltage Winding. This power supply uses a full-wave rectifier, which means that the frequency of the rectifier output (input of the filter) will be 120 cycles if the power line frequency is 60 cycles. If the winding numbered 5, 6, 7 should open between points 5 and 6 or between 6 and 7, an abnormal hum would result. Testing and replacing all chokes and filter capacitors will not correct the trouble, because the opening of one leg of the high-voltage winding changes the circuit to that of a half-wave rectifier. The output frequency is now 60 cycles and the chokes and capacitors are not large enough to filter such a low-frequency hum. This condition could also be caused by a cathode-to-plate short in a full-wave rectifier tube.

d. Tube Cathode-to-Heater Leakage. A 60-cycle hum can be caused by cathode-to-heater leakage in a tube, especially in the audio stages, which can readily pass low frequencies. As an example, the first audio frequency amplifier V601A would produce a 60-cycle hum if the cathode were to short to the heater. This tube is shown in figure 68. If the cathode and heater should touch, the heater and the cathode-bias resistor R604 would be in parallel as shown by the connection at point A. This would put 6.3 volts ac across R604. The 60-cycle voltage would modulate the electron stream and cause hum. This could happen in an RF tube also, in which case the 60-cycle signal would modulate the RF when a signal is tuned in and be demodulated by the detector. If a stage has no cathode-bias resistor and the cathode is grounded, the same defect would not be noticed

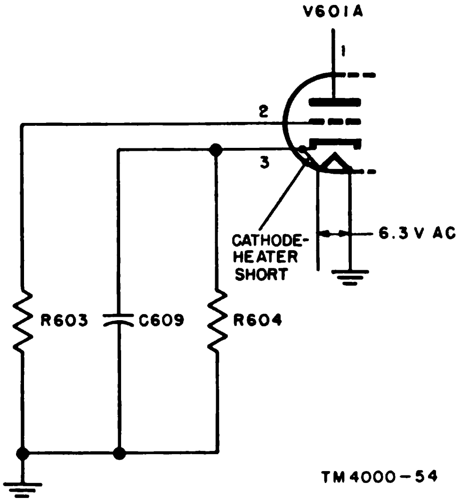


Figure 68. Heater-to-cathode short.

because there is no place across which the 60-cycle voltage can be developed.

162. Determining Frequency of Hum

a. When a hum is heard in the output of a receiver, the first step is to determine its frequency. In a set using a half-wave rectifier, there can be only one hum frequency, that of the line voltage. In this receiver (fig. 65), the rectifier is a full-wave type, and the rectifier output is 120 cycles when the input voltage frequency is 60 cycles.

b. If the technician does not have sufficient experience to be able to recognize the frequency, the audio signal tracer shown in figure 46 may be used. Connect the tracer across a 6.3-volt ac source. In this set one lead can be connected to the chassis and the other one to the ungrounded filament terminal of a 6.3-volt tube such as V603. A loud 60-cycle hum will be heard in the headset. If the hum in question sounds like the hum just heard it is of the same frequency; if the frequency is higher, it is a 120-cycle hum.

c. If a 120-cycle hum is present, it means that the defect is probably in the power supply filter and that the filtering is inadequate. If a 60-cycle hum is present, the defect is not in the power supply. It is probably a cathode-to-heater short in a tube, or stray ac pickup by a tube grid. The one exception to this rule is covered in paragraph 161*c*.

163. Tracing Power Supply Hum or Audio Hum

a. Sectionalization. In this receiver there are two audio channels; therefore they must be covered separately. Turn the LINE GAIN control R104 and the LOCAL GAIN control R105 all the way counterclockwise. If the hum is still heard, it is coming from the power supply or one of the audio channels. Disconnect the speaker from the LINE AUDIO terminals 11 and 12 on TB 103. If the hum stops, it is in the line audio channel. If the hum is present in both audio channels and it is a 120-cycle hum, it is due to inadequate filtering in the power supply. If the hum is present in both audio channels with both gain controls turned on, and it is a 60-cycle hum, it *could* be from a cathode-to-heater short in a tube, or stray coupling to a grid, but it is more probably in the common audio section. The common audio section is composed of the detector, V506B, the limiter, V507, first AF amplifier, V601A, and the AF cathode follower, V601B.

b. Isolation. If the hum has been traced to the audio section and is a 60-cycle hum, it will be necessary to find the stage where it originates. A quick and easy method of hum isolation is one that uses an audio signal tracer such as the one shown in figure 46. Connect one probe of the tracer to a convenient point on the chassis. Touch the other probe to pin 1 of local AF output tube V603. If the hum is not heard, it is originating between this point and the speaker. If the hum is heard, it is coming from somewhere between this point and the detector. Touch the probe to pin 2 of V602A. If the hum is not heard, the hum is originating between this point and the previous test point. If the hum is heard, it is originating somewhere between this point and the detector. Move the probe successively to the input of the remaining stages toward the detector until the hum is not heard. This system eliminates the stages between the test point and the speaker whenever the hum is heard.

164. Tracing Modulation Hum

Modulation hum modulates, or varies, the RF carrier at the hum frequency. Since the carrier is RF, it can pass through the RF and IF sections; the detector will then demodulate the signal and the hum will be heard.

a. Sectionalization. Turn both audio gain controls to the maximum clockwise (on) position. If the hum is present with either control turned on but is not present when the controls are off, the hum is originating between the controls and the antenna. The entire audio section from the detector to the output was covered in paragraph 141. Pull out the fourth IF amplifier tube, V504. This will stop the hum from getting through. Any hum originating in the RF section can get through only by modulating the RF carrier, and will have a frequency of 60 cycles. Therefore the hum discussed in *b* below will have a frequency of 60 cycles.

b. Stray Coupling Hum. One of the most important causes of hum is induction into the

RF or IF section. There are usually filter circuits or capacitors at the ac power input to prevent this. If a capacitor in this circuit should open, hum would result. Capacitors C104, C105, C106, and C107 are examples. The simplest method of determining which of them is at fault is to bridge them, one at a time with a good capacitor.

Section VII. TROUBLESHOOTING NOISY AM RECEIVER

165. General

A receiver is noisy when the output, in addition to the desired signals, contains crackling, sputtering, or frying sounds. Noises fall into two general categories—external and internal. External noise is from a source outside the receiver. Internal noise is from a source inside the receiver. Noise is made up of many frequencies ranging from audio to rf; therefore, it can pass through any stage even though it does not modulate the carrier.

166. Causes of External Noise

External noise is divided into two classes—atmospheric and man made.

a. Atmospheric noise is caused by lightning and other electrical disturbances that are produced by nature. Little can be done to reduce noise from atmospheric conditions; usually it can be avoided by moving the receiver to another location, or by changing the operating frequency to one that is relatively free from interference.

b. Man made noise can be produced from many sources, such as loose or arcing power lines, gasoline-engine ignition systems, electric motors and generators, other radio sets, diathermy machines, etc. Frequently, this type of noise can be suppressed.

c. Loose or corroded connections in the antenna and ground systems are a frequent cause of external noise.

167. Causes of Internal Noise

a. Transformers. Noise in transformers is frequently caused by corrosion-coated breaks in the windings. Primary windings in IF, RF, and radio transformers are the worst offenders. The corrosion causes the winding to open, leaving a small gap across which the current may be conducted by the corrosion itself or an arc may jump intermittently, producing sharp, rapid changes in current, and therefore noise. Transformer windings can work loose from their terminals, producing noise resulting from intermittent connections.

b. Wire-Wound Resistors. Wire-wound resistors are subject to the same noise troubles that occur in transformers. When a resistor winding works loose from a terminal, the result is a rapid rate of intermittent operation which causes noise.

c. Potentiometers. Potentiometers are among the main sources of noise. The constant friction between the sliding arm and the resistance element causes wear and noise. As the resistance element becomes badly worn, the contact becomes very poor and, ultimately, intermittent, and noise results even when the control is not being adjusted.

d. Band Switches. When the contacts on a band switch or a similar switching device become corroded and worn, a noise will be generated when it is set from one position to another. When the switch is dirty, it may be noisy. The contacts may become bent, causing an intermittent condition that produces noise.

e. Tuning Capacitors. Though it seldom happens, tuning capacitors can become noisy, especially when the rotor plates are turned. Warping of the plates, shifting of the rotor shaft, and particles of metal slivers peeling from the plates are common sources of noise. Dust and dirt often carry fine metal particles, and if they become lodged between plates, noise results as the rotor is turned.

f. Tubes. Electron tubes generate noise that has several possible causes.

(1) *Shot effect* is produced because electron current consists of separated particles that leave the cathode in a random fashion, producing fluctuating currents uniformly distributed over all frequencies.

(2) *Flicker effect* is a low-frequency noise caused by small emitting areas of the cathode constantly changing their emission characteristics.

(3) In tubes having more than one collector element, such as the screen and plate of a pentode, the random division of current produces uniform noise currents over the whole frequency spectrum of a tube output.

(4) *Microphonics* are low-frequency noises produced by motion of the elements of a tube. These are heard when the tube is subjected to vibration.

(5) Other sources of noise in tubes are positive-ion-emission currents, positive-ion currents produced as the result of gas ionization, and secondary-electron emission.

g. Poorly Soldered Joints. Poorly soldered joints may be a very serious cause of noise. Such noise would result from movements of the joint beneath a soldering job which looks good on the surface but which was not well done.

h. Mechanically Caused Noises. Tube shields that are not securely locked in place can move and cause scraping noises when the set is jarred. Loose screws and subchassis cover plates will produce the same scraping noises. The thing to remember is that noise is always caused by the rapid making and breaking of a circuit somewhere. Some common types of noise, and their probable causes, are listed in the chart below.

Type of noise	When noticed	Probable causes
Scratching	When signal is being tuned in.	Dirty tuning capacitors.
Scratching	When adjusting gain control.	Worn gain control.
Scraping	When changing bands.	Worn wave-band switch.
Intermittent crackling, scraping	When chassis is jarred.	Loose tube elements, screw or shield can.

168. Isolating External Noise

a. Refer to figure 65. Turn LOCAL GAIN control R105 to a point where the noise is heard in the headset. Disconnect the antenna from the J104 125 OHM BALANCED ANTENNA terminals. Short out the terminals with a jumper. If the noise stops or is reduced considerably, it is originating outside of the receiver. Remove the jumper and reconnect the antenna. Shake the transmission line; if the noise gets worse, the transmission line has a break in it or it is rubbing against a tree, pole, or other object. It is also possible that the antenna is rubbing against something or a connection between the antenna and the transmission line is loose.

b. If the preceding tests indicate that the noise source is outside of the receiver, the noise is probably radiated noise picked up by the antenna. The trouble now is in the immediate vicinity and may be coming from a nearby power line, vehicle ignition system, motor, generator, or hospital equipment. If a portable or mobile receiver is available, it can be taken to various areas that may be radiating noise. When a point is reached where the noise level increases in the test receiver, the noise source is near by.

c. Disconnect the ground wire; if the noise *decreases,* the ground connection is probably poor or the ground lead is too close to a noise source. If the noise *increases,* it is probably coming in over the power line.

169. Localizing Internal Noise

a. Turn LOCAL GAIN control R105 to a point where the noise is heard. Disconnect the antenna from the J104 125 OHM BALANCED antenna terminals. Short out the terminals with a jumper. If the noise continues, it is originating in the receiver.

b. Turn LOCAL GAIN control R105 to the extreme counterclockwise position. If the noise continues, it is originating between the gain control and the speaker. If the noise does not continue, it is originating between the antenna and the gain control. Use the method described in paragraph 170*b* for locating this source of noise.

170. Isolating Noise

a. Signal Tracing. In the audio stages, the audio signal tracer shown in figure 46 can be used to localize noise by the same method used to localize distortion and hum. Connect the ground terminal of the signal tracer to a convenient point on the chassis. Remove one of the AF output tubes. Insert the signal tracer probe in pin 5 or 6 of the socket. If noise is heard, the power supply may be at fault. Check the power-supply tubes by substitution, and inspect all connections, particularly the connecting plugs and jacks. If noise is not heard, replace the AF output tube. Touch the signal tracer probe to pin 5 of local AF output tube V603. If the noise is not heard in the headset, the noise originates in the secondary of T601 or between the speakers. If the noise is heard, it originates in the primary of T601 or between pin 5 and the gain control. Move the probe to pin 1 of the same tube. If the noise is not heard, it is coming from the V603 stage. Keep touching the probe successively to the input or output of the various stages, working toward the gain control.

b. Stage Blocking. The signal tracing method just described can be used with the signal tracer in the audio circuits only. If a signal tracer with tuned circuits and a demodulator is available it can be used in the RF and IF sections. A simpler and quicker method is stage blocking, which is similar to that used in troubleshooting hum defects. It can be used also in the audio section. Connect a clip to a test lead and fasten the clip to a convenient point of the chassis. Turn the LOCAL GAIN control R105 so the noise can be heard with good volume. Touch the lead to the grid (pin 1) of V603. If the noise continues, it is in the V603 stage. If the noise stops, it is between pin 1 and the antenna. Touch the probe successively to the control grids of the various stages, working toward the antenna. If the noise continues when a point is shorted out, the noise is originating between that point and the last point that was shorted out. If the noise stops when a point is shorted out, the noise is originating between that point and the antenna.

Section VIII. TROUBLESHOOTING AM RECEIVER THAT SQUEALS OR MOTORBOATS

171. General

Squealing and motorboating are terms sometimes used to describe unwanted sounds or noises in the output of receivers. Very low-frequency sounds are classified as motorboating because they sound like the "put-put" of a motorboat. Motorboating is usually the result of a component failure in the audio section of the receiver that produces regenerative feedback in the audio amplifiers. Squealing may be produced by anything that causes regenerative feedback in any of the amplifiers of the receiver; however, it is sometimes produced by interfering radio signals. Disconnect the antenna and short circuit the antenna terminals to determine whether the squeal is caused by external interfering signals or internal troubles. If the squealing stops with the antenna disconnected, the trouble is usually external.

172. Squealing Caused by Internal Conditions

The squealing sounds described in this section are high-pitched audio sounds. They are usually caused by unwanted oscillations in one or more stages of the RF or IF section of the receiver. Squealing may originate also in the audio section. In either case, the squealing is the result of unwanted oscillations. The difference is that the oscillations, if in the audio circuits, would occur at the same frequency as the squealing sounds. While in the RF or IF circuit the oscillations would occur at or near the frequency to which the circuits are tuned. The audible squealing sound is then produced by the heterodyning of two or more frequencies of unwanted oscillations with each other or the unwanted oscillations with a received signal.

173. Causes of Unwanted Oscillations

The causes of unwanted oscillations are many but they have one thing in common. They each produce regeneration. Component failure in decoupling filters sometimes causes regeneration. If the capacitor becomes open or reduced in value or the resistor changes to a lower value, the filtering action is reduced and signal variations will occur in the voltage that was previously decoupled by the filter. These decoupling filters are used in dc voltage sources, such as avc, agc, plate, screen, and bias supplies that are common to two or more stages of amplification. Poor shielding, a tube shield left off its tube after replacing the tube or lead dress not being restored to its orignal condition after replacing a component, are all causes of undesirable coupling that may be regenerative and cause unwanted oscillations.

174. Sectionalizing Source of Oscillations

a. Audio Signal Tracing. Refer to figure 65. If the oscillating condition is present whether a signal is tuned in or not, and does not vary when the set is tuned, it probably is originating in the audio section. The audio section includes the detector V506B through the local audio output V603, or the line audio output, V604. Turn the LOCAL GAIN control R105 to the extreme counterclockwise (off) position. If the squeal stops, it is originating between the gain control and the detector. If the squeal continues, it is originating between the gain control and the local audio output terminals on terminal board TB103.

b. RF Signal Tracing. If the squealing is present only after a signal is tuned in, and it is heard with all signals, the oscillation is most likely in the RF section. In this receiver it would be between the first IF amplifier V501, and the detector, V506B. If the squeal is heard only when the set is receiving a signal and it occurs mostly at one end of a tuning stage, the RF amplifier, V201 is probably at fault.

175. Localizing Squeal or Motorboating

The stage blocking method described in paragraph 170*b* can be used. If the trouble is thought to be in the audio section, short out pin 6 of the detector, V506B. If the squeal stops, the trouble is between the antenna and detector; if it continues, it is between the detector and the audio output. The shorting probe can be moved to any of the audio tube grid terminals. Whenever a point is found where the squeal stops, the squeal is originating ahead of that point. It is possible for the squeal to be caused by troubles in two stages. Therefore, if the trouble is corrected in one faulty stage, and it still squeals, another stage nearby may also be causing the defect. Stage blocking can also be accomplished by removing tubes one at a time. Remove the local AF amplifier V602A; if the squeal stops, the trouble is originating between this stage and the detector. If the squeal does not stop, it is originating between this stage and the output.

Section IX. TROUBLESHOOTING CALIBRATION-OSCILLATOR SECTION

176. General

The receiver being considered (fig. 65) provides for accurate indication of the frequency to which it is tuned. A system is used to generate calibrating signals at 100-kc intervals over the receiver tuning range; the operator can check and adjust the frequency indicator.

177. Receiver Picks Up External Signals, but Calibration Signals Are Not Present

If external signals are received when the FUNCTION switch is in the MGC or AGC position, the normal receiving circuits are in operating condition; therefore, calibration signals are not being applied to RF amplifier V201. Assuming that FUNCTION switch S102 is in position 5 (the CALIBRATE position), the 100-kc multivibrator V206, and 100-kc cathode follower V205B, stages should be suspected first. Test the tubes.

178. Trouble in V206

Connect an ac vtvm between pin 6 of the 100-kc multivibrator and ground. If a signal voltage is not present, check the dc voltages at the tube socket. Possible causes for the absence of dc voltages at the plates (pins 1 and 6) could be open resistor R224 or R226. In addition, an open in L211 or any one of the grid resistors could cause the stage to be inoperative. An open coupling capacitor C314 or C315 would open the feed-back circuit and oscillations would cease.

179. Trouble in V205B Stage

a. Connect an ac vtvm between pin 8 of the 100-kc cathode follower and ground. If the required signal voltage is present, the stage is operating; if there is no signal voltage present, the stage is defective. Measure the dc voltage at the plate, pin 6. If there is no dc voltage present, it could be due to an open R228 or an open L211. An open component in the cathode circuit, for example L210 or R229, would keep the plate current from flowing and stop operation.

b. If the stage is found to be operating, check the connections between pin 8 of V205 and pin 1 of V201. This part of the circuit includes coupling capacitor C228, which could be open or have a broken lead.

180. Calibration Signals Present in Output, but Are Not Stable

a. The fact that the calibration signals are heard means that the 100-kc cathode follower stage is operating. The multivibrator, however, is not a stable circuit and must be controlled by a stable device. The calibration oscillator V205A is a stable crystal oscillator that keeps the multivibrator on frequency by triggering the multivibrator at precise intervals. Therefore, if the calibration oscillator becomes defective, there will be no control of the multivibrator and it would become unstable.

b. Measure the dc voltage across bias resistor R220 with a vtvm. If the proper voltage is present, the stage is operating. If the voltage is not present, or is very low, the oscillator is not operating. Measure the dc voltage at the plate of V205A (pin 1). If the voltage is lacking completely, the possible source of trouble can be an open R221 or a shorted C312. An open bias resistor R220, an open C311, or a defective crystal would also cause the circuit to be inoperative.

c. There is also a possibility that C310 is leaky; this would short the grid to ground and stop oscillations. If the oscillator is operating, but the calibration signals are still not being controlled, an open coupling capacitor C313 would prevent the signal from reaching the multivibrator.

Section X. TROUBLESHOOTING FM RECEIVERS

181. General

a. A frequency-modulation receiver is basically like the standard am superheterodyne. The audio stages in the two types of receivers are identical and the only differences between th RF and IF stages are the frequencies and the pass band characteristics. Because these stages and parts are similar, troubleshooting procedures described in previous sections covering am receivers are applicable to fm receivers and are not repeated.

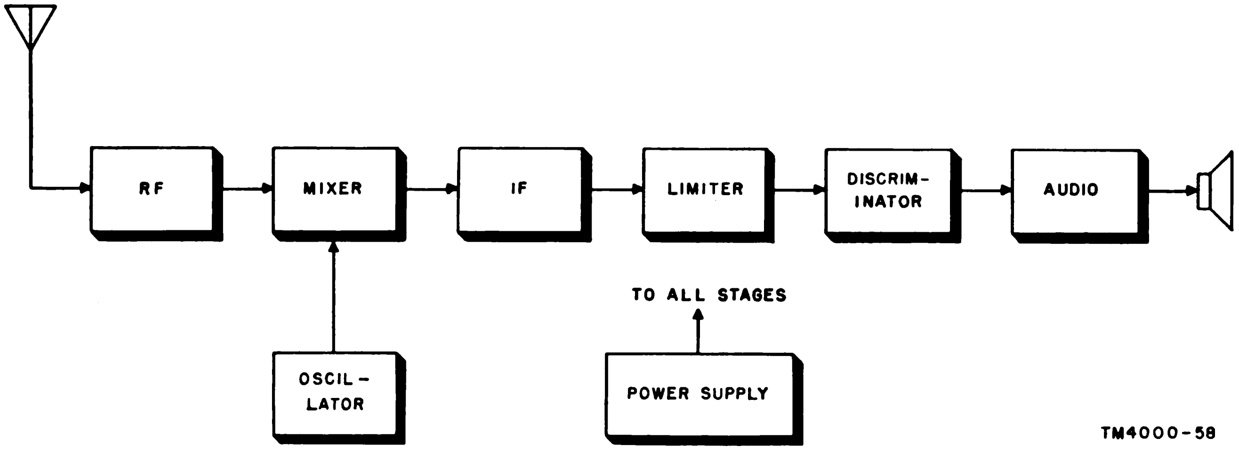


Figure 69. Fm receiver, block diagram.

b. The fm receiver has two stages not found in the am receiver: the limiter and discriminator stages (fig. 69). Troubles and troubleshooting procedures peculiar to these stages are covered in this section.

182. Signal Substitution

a. The signal substitution method can be used in troubleshooting a weak or dead fm receiver. For troubleshooting by signal substitution, a sweep signal generator is preferable, because its signal can be heard in the output of the receiver. If such a signal generator is not available, the same type of instrument that is used for am receivers may be employed, although it is not as convenient as the type that produces a sweep signal. The signal generator must produce frequencies that are equal to the tuning range of the receiver and to its intermediate frequency (or frequencies).

b. When testing a weak receiver, checking stage gain by listening to the output is not a dependable procedure. An increase in signal input level may not result in a corresponding increase in output level because of the limiting action of the limiter stage. Also, identical output levels for a signal injected in the plate circuit and for a weaker signal at the grid do not indicate that a stage is amplifying. The limiter may have reduced the signals to the same level. The best way to check the gain of the RF and IF stages is to measure the strength of the signal that is applied to the control grid of the limiter. This can be done in two ways:

(1) Use a vtvm with an RF probe and measure the RF voltage directly.

(2) If the limiter stage is the type that develops grid leak bias, use a vtvm to measure the dc voltage between control grid and ground. The voltage will increase with an increase in signal strength. An alternative method with this type of limiter is to open the grid circuit and insert a 0–200 microammeter. The meter will indicate grid current; an increase in signal strength will cause an increase in grid current.

c. Begin signal substitution by feeding an unmodulated signal from a signal generator to the grid of the limiter stage. Set a vtvm to indicate dc volts, with the needle at zero center. Connect the vtvm across the discriminator load resistors; these are R1 and R2 in figure 70 and the connection points are A and C. Set the output frequency of the signal generator to the resting frequency of the receiver (the intermediate frequency); the vtvm should read zero. Alternately tune the signal generator above and below the resting frequency. If the vtvm swings to one side and then the other of zero as the frequency is varied, the limiter and the discriminator are operating. (At the resting frequency there is no output from the discriminator.)

d. If the vtvm needle does not follow frequency variations, the trouble is in either the limiter or the discriminator.

Note. If a vtvm is not available, high-resistance multimeter can be substituted, but the test leads must be reversed each time the polarity of the voltage changes.

e. Connect the signal generator to the input of the discriminator and vary its frequency as described in *c* above. In figure 70 the signal is applied between point D and ground. If the voltage indication on the vtvm does not follow the frequency variations, the discriminator or coil L1 is defective.

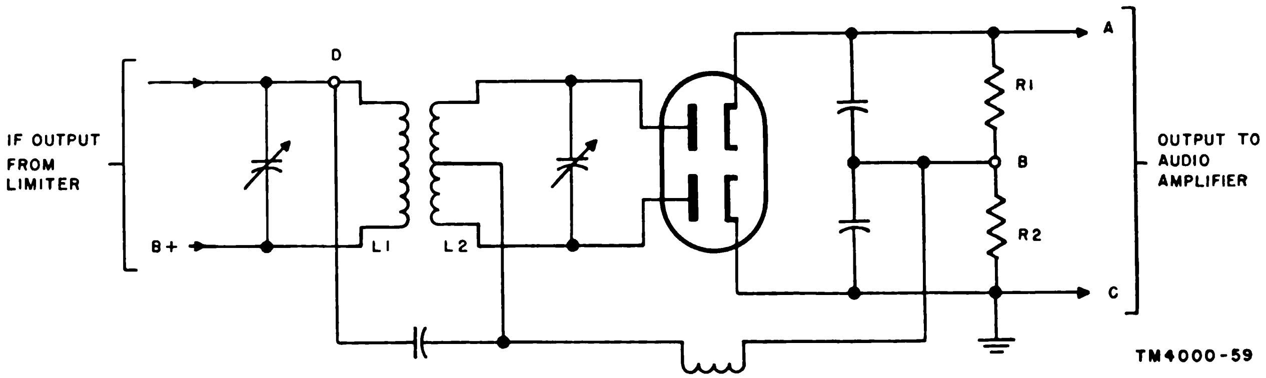


Figure 70. Discriminator, showing test points.

183. Receiver Troubleshooting Charts

a. The receiver troubleshooting charts that follow will be of assistance in locating troubles quickly. The information is general and can be applied to any receiver. The technician can get an idea as to what the trouble is, regardless of the equipment.

b. Consult the chart when troubles arise, and when the general location of the troubles has been decided upon, use the specific information in the equipment technical manual to pinpoint the defective circuit and component part.

Typical Capacitor, Resistor, and Inductor Failures in a Receiver Stage

Symptoms	Dc voltage measurements	Resistance measurements	Defective part
1. Feedback or hum	*a.* Normal	*a.* Capacitor does not charge *	Plate bypass capacitor *a.* Open
No output or very weak output	*b.* Zero or very low from plate to ground	*b.* Partial or direct short from the B+ line to ground	*b.* Shorted
2. Decreased output and motor-boating	*a.* Normal	*a.* Capacitor does not charge *	Screen bypass capacitor *a.* Open
No output or very weak output. Hot screen resistor.	*b.* Zero or very low from screen to ground	*b.* Partial or direct short from screen to ground	*b.* Shorted
3. Weak output	*a.* Normal	*a.* Capacitor does not charge *	Cathode capacitor *a.* Open
Distorted output	*b.* No reading across capacitor	*b.* Partial or direct short from cathode to ground	*b.* Shorted
4. No output or weak output	*a.* Normal	*a.* Capacitor does not charge *	Coupling capacitor *a.* Open
Distorted output	*b.* High reading from grid to ground. Positive polarity at grid	*b.* Low reading across coupling capacitor	*b.* Shorted
5. Severe hum or blocking	*a.* No reading across component part	*a.* Open circuit reading from grid to ground or to bias line	Series grid resistor, coil or secondary winding. *a.* Open
No output or very weak output	*b.* No reading across component part	*b.* Partial or direct short from grid to ground or to bias line	*b.* Shorted
6. No output or very weak output	*a.* No reading from plate to ground	*a.* No reading from plate to B+ line	Series plate resistor, coil, or primary winding *a.* Open
No output or very weak output	*b.* High reading from plate to ground	*b.* Partial or direct short from plate to B+ line	*b.* Shorted coil
7. No output or very weak output	High reading across resistor	Open circuit reading across terminals of resistor *	Cathode resistor Open
8. No output or very weak output	No reading from screen grid to ground	Open circuit reading from screen grid to B+ line	Screen-grid dropping resistor Open

* Test to be made with one end of part detached from circuit.

CHAPTER 7

TROUBLESHOOTING AM TRANSMITTERS

Section I. GENERAL TRANSMITTER TROUBLESHOOTING

184. General

All the general principles of troubleshooting (ch. 4) apply to the troubleshooting of am transmitters. In the case of a large transmitter, the many built-in meters are of particular aid to the troubleshooter. Defects can often be sectionalized and localized without the use of additional test equipment.

185. Key Test Points

a. All transmitters have key test points. These are places where, for testing or troubleshooting purposes, currents and voltages are measured or signals are injected. When the defective stage is found, B+ voltages are measured to aid in isolating the trouble. In the simple transmitter represented in figure 71, the key test points are:

(1) Oscillator grid circuit.
(2) Oscillator plate milliammeter.
(3) Buffer plate milliammeter.
(4) Power amplifier plate milliammeter.
(5) Antenna ammeter.
(6) Modulator plate milliammeter.
(7) Driver output.
(8) Driver input.
(9) Speech amplifier input.

b. Test No. 7 in figure 71 requires the injection of an audio signal. Usually, this is practi-

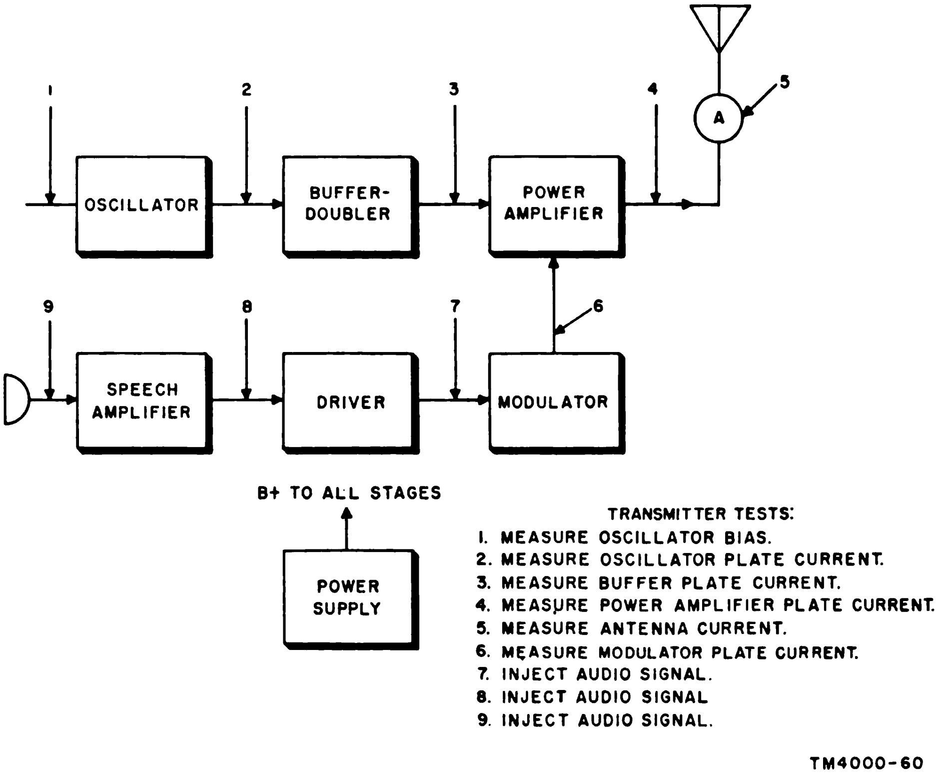
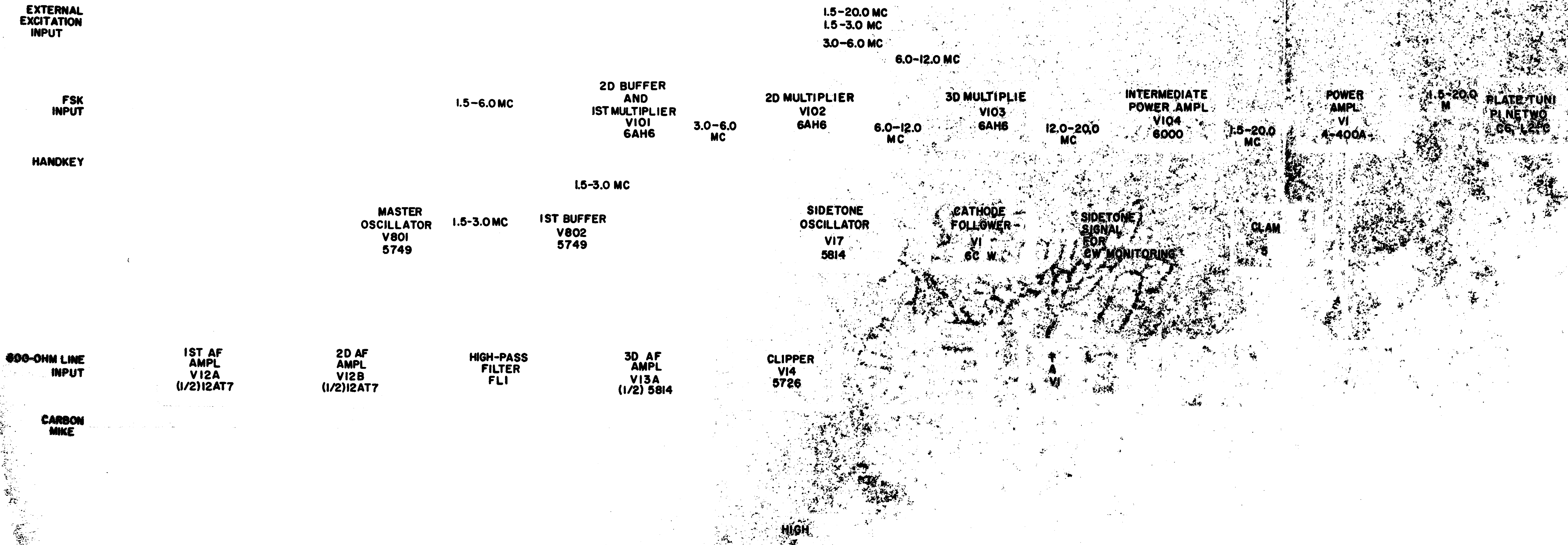
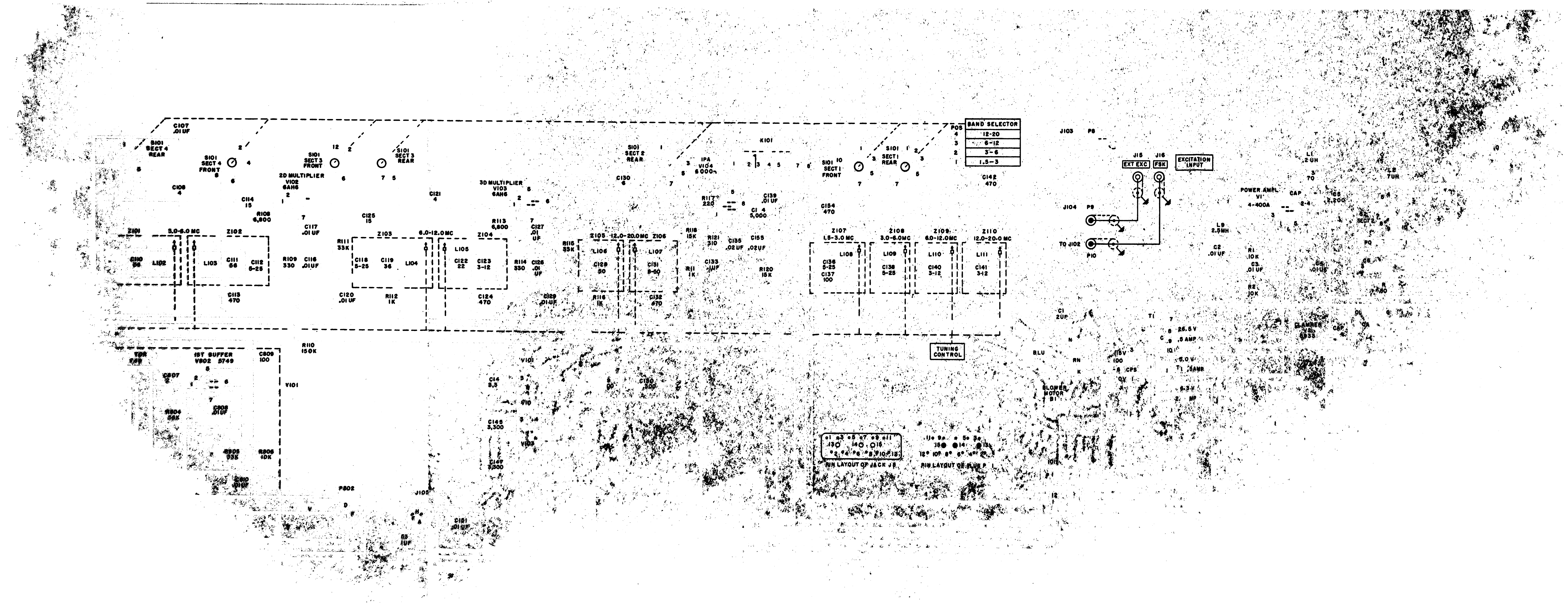
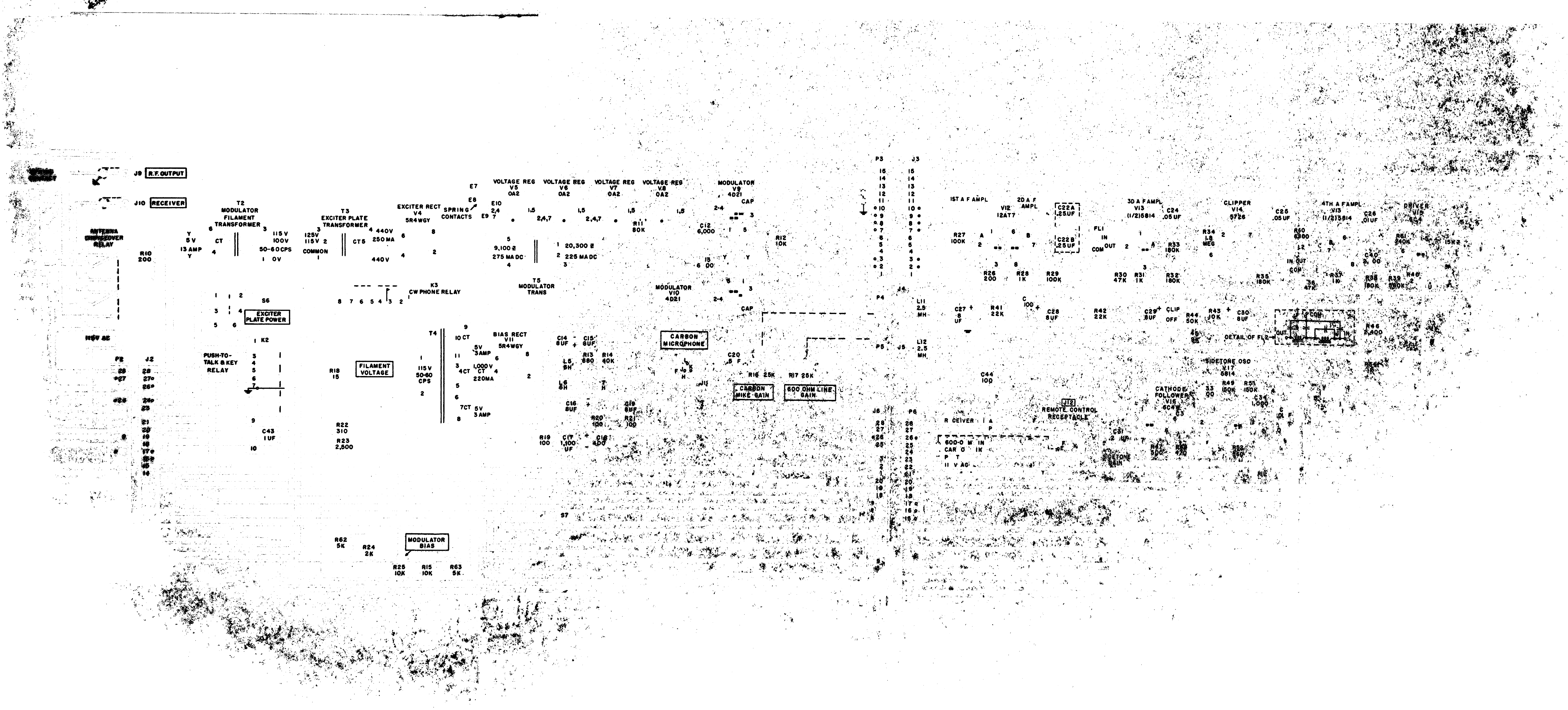


Figure 71. Simple transmitter, block diagram.


EXTERNAL EXCITATION INPUT
FSK INPUT
HANDKEY
600-OHM LINE INPUT
CARBON MIKE
1.5-20.0 MC
1.5-3.0 MC
3.0-6.0 MC
6.0-12.0 MC
1.5-6.0 MC
2D BUFFER AND 1ST MULTIPLIER V101 6AH6
3.0-6.0 MC
2D MULTIPLIER V102 6AH6
6.0-12.0 MC
3D MULTIPLIE V103 6AH6
12.0-20.0 MC
INTERMEDIATE POWER AMPL V104 6000
1.5-20.0 MC
POWER AMPL V1 4-400A
1.5-20.0 M
PLATE TUNI PI NETWO C6, L2, C
1.5-3.0 MC
MASTER OSCILLATOR V801 5749
1.5-3.0 MC
1ST BUFFER V802 5749
SIDETONE OSCILLATOR V17 5814
CATHODE FOLLOWER V1 6C W
SIDETONE SIGNAL FOR CW MONITORING
CLAM 5
1ST AF AMPL V12A (1/2)12AT7
2D AF AMPL V12B (1/2)12AT7
HIGH-PASS FILTER FL1
3D AF AMPL V13A (1/2) 5814
CLIPPER V14 5726
A V1
HIGH


C107 .01UF
S101 SECT 4 REAR
S101 SECT 4 FRONT
S101 SECT 3 FRONT
S101 SECT 3 REAR
S101 SECT 2 REAR
S101 SECT 1 FRONT
S101 SECT 1 REAR
C108 4
C114 15
2D MULTIPLIER V102 6AH6
R108 6,800
C117 .01 UF
C125 15
C121 4
3D MULTIPLIER V103 6AH6
R113 6,800
C127 .01 UF
C130 6
IPA V104 6000
K101
R117 220
C139 .01 UF
C1 4 5,000
C154 470
C142 470
BAND SELECTOR
POS
4 12-20
3 6-12
2 3-6
1 1.5-3
Z101
3.0-6.0 MC
Z102
C110 56
L102
L103
C111 56
C112 5-25
C113 470
R109 330
C116 .01UF
R111 33K
Z103
6.0-12.0 MC
Z104
C118 5-25
C119 36
L104
L105
C122 22
C123 3-12
R114 330
C126 .01 UF
C120 .01 UF
R112 1K
C124 470
C129 .01UF
R115 33K
Z105
12.0-20.0 MC
Z106
L106
C128 50
L107
C131 8-50
R116 1K
C132 470
R118 15K
R121 310
C135 .02UF
C155 .02UF
R11 1K
C133 .1UF
R120 15K
Z107 1.5-3.0 MC
L108
C136 5-25
C137 100
Z108 3.0-6.0 MC
L109
C138 5-25
Z109 6.0-12.0 MC
L110
C140 3-12
Z110 12.0-20.0 MC
L111
C141 3-12
TUNING CONTROL
R110 150K
TOR
1ST BUFFER V802 5749
C809 100
C807 2
C808 .01UF
R804
R805
R806 10K
C810 .01UF
V101
P802
C14 3.3
C150 300
C165 3,300
C167 3,300
J105
C161 .01UF
C5 1UF
J103
P8
J15 EXT EXC
J16 FSK
EXCITATION INPUT
J104
P9
TO J102
P10
POWER AMPL. V1 4-400A
CAP
L1 2 UH
L9 2.5MH
C2 .01 UF
R1 10K
C3 .01 UF
R2 10K
C1 2UF
T1
26.5 V
.5 AMP
6.0 V
.5AMP
6.3 V
115V
100
CPS
BLU
RN
BLOWER MOTOR B1
CLAMPER
PIN LAYOUT OF JACK J1
PIN LAYOUT OF PLUG P


J9 R.F. OUTPUT
J10 RECEIVER
ANTENNA CHANGEOVER RELAY
115V AC
R10 200
P2
J2
T2 MODULATOR FILAMENT TRANSFORMER
5V 13 AMP
CT
115V 100V 50-60 CPS 0V
T3 EXCITER PLATE TRANSFORMER
125V 115V COMMON
CT5
440V 250 MA
440V
EXCITER RECT V4 5R4WGY
SPRING CONTACTS
E7
E8
E9
E10
VOLTAGE REG V5 0A2
VOLTAGE REG V6 0A2
VOLTAGE REG V7 0A2
VOLTAGE REG V8 0A2
MODULATOR V9 4D21
CAP
9,100 Ω 275 MA DC
20,300 Ω 225 MA DC
T5 MODULATOR TRANS
R11 80K
C12 6,000
R12 10K
K3 CW PHONE RELAY
S6
EXCITER PLATE POWER
K2
PUSH-TO-TALK & KEY RELAY
C43 1UF
R18 15
FILAMENT VOLTAGE
R22 310
R23 2,500
T4
115V 50-60 CPS
10 CT
4CT
7CT
5V 3AMP
1,000V CT 220MA
5V 3 AMP
BIAS RECT V11 5R4WGY
C14 8UF
C15 8UF
L5 8H
L6 8H
R13 680
R14 40K
C16 8UF
C19 8UF
R20 100
R21 100
R19 100
C17 1,100 UF
C18 400
MODULATOR V10 4D21
CARBON MICROPHONE
C20 .5 F
R16 25K
R17 25K
CARBON MIKE GAIN
600 OHM LINE GAIN
J11
P3
J3
P4
J4
P5
J5
J6
P6
L11 2.5 MH
L12 2.5 MH
1ST A F AMPL
V12 12AT7
2D A F AMPL
C22A .25UF
C22B .25UF
R27 100K
R26 200
R28 1K
R29 100K
C27 8 UF
R41 22K
C 100
C28 8UF
C44 100
FL1
IN
OUT
COM
3D A F AMPL V13 (1/2)5814
C24 .05 UF
R30 47K
R31 1K
R32 180K
R33 180K
R42 22K
C29 8UF
CLIP
OFF
CLIPPER V14 5726
R34 1.8 MEG
R44 50K
R43 10K
C30 8UF
C25 .05 UF
R35 180K
R60 6800
4TH A F AMPL V13 (1/2)5814
R37 1K
C26 .01 UF
C40
DETAIL OF FL2
DRIVER V15 6C4
R61 240K
R38 180K
R39 560K
R40
R46 2,400
SIDETONE OSC V17 5814
R49 150K
R51 150K
C34 1,000
CATHODE FOLLOWER V16 6C4W
J12
REMOTE CONTROL RECEPTACLE
C31
SIDETONE GAIN
R47 500
R50 470
R52 560
S7
R62 5K
R24 2K
MODULATOR BIAS
R25 10K
R15 10K
R63 5K


FILAMENT POWER
CB1
20 AMP
6 AMP
F1
I1
BLOWN FUSE INDICATOR
I
3 AMP
F2
125V
3
2
115V
1
EXCITER PLATE TRANS T3
SPEECH AMPLIFIER FILAMENT TRANS T7
115V
100V
MODULA FILAMENT TRANS T2
SERVICE SELECTOR SWITCH
1,7 FSK
2,8 FSK-AM.
3,9 EXT EXC
4,10 AM.
5,11 CW
S1 SECT 1
PLATE POWER
CB2
15 AMP
S1 SECT 2
S1 SECT 3
150V REG FROM EXC PLATE SUPPLY
26.5V AC FROM SEC OF T1
TO V501
FROM ATHODE F V104
IPLIER
OM J104
CARBON
SIDETON
ORH
EXCITER PLATE POWER
S6
T5 SEC
-385V MOD BIAS
CW-PHON RELAY K3
-35V FROM BIAS SUPPLY
SLOW-RELEASE RELAY K1A
TIME DELAY RELAY K7
OVERLOAD RESET RELAY K5
HIGH VOLTAGE FILAMENT TRANS T8
S4
MIC
AC
FILAMENT POWER
I3
G
FROM L4
R66
TO J10
TO J9
ANTENNA CHANGEOVER RELAY K1B
BIAS TRANS T4
115V
100V
0V.
EXCITER AND TRANSMITTER FILAMENT TRANS T1
GRN
ORN
BLK
B1
BL
C1
2UF
S13
THERMAL RESET
C36
2.75 UF
RED
WHT
B2
BLK
FROM BLOCKED GRIDS OF V101 AND V104
R18
15
FILAMENT VOLTAGE

cable only in low-power transmitters. Connect an output meter to the output of the modulator and apply an audio signal to the grid. If the modulator requires more voltage than an audio oscillator can provide, apply the output of the oscillator through a step-up transformer (such as a microphone transformer) or use a line isolation transformer that has a variable output, and apply its output to the grid; start with 0 volts and gradually increase the voltage.

Caution: Be sure that the output meter used is suitable for the plate voltage present at the output of the modulator.

186. Symptoms of Trouble

a. No Output. A dead transmitter does not produce any radio-frequency energy from its output stage.

b. Weak Output. A weak transmitter output signal is weaker than it is under normal operating conditions; otherwise it is normal in all respects.

c. No Modulation. A transmitter with no modulation has no intelligence on the carrier. It is normal in all other respects.

d. Distorted Output. A transmitter with distorted output is defective in respect to the waveform, bandwidth, frequency, etc. of the signal it transmits. It is normal in all other respects.

Section II. TROUBLESHOOTING DEAD AM TRANSMITTER

187. General

The transmitter shown in figures 72, 73, 74, and 75 is more elaborate and complex than the one in figure 71. It has many additional and special features including remote control operation, sidetone oscillator, frequency multipliers, protective clamper, ganged tuning, audio clipper, low-pass filter, high-pass filter, pi-network plate loading, separate bias power supply, and separate antenna tuning unit.

188. Preliminary Inspection

a. When there is no output from a transmitter, there are many defects that could cause the trouble. First give the transmitter a thorough inspection. Inspect by sight, smell, and hearing. Check meter indications—the check will often spot the trouble immediately.

b. The schematic diagram of this transmitter is in two parts (figs. 73 and 74). The technician must study it carefully and must understand the operation of the various circuits. A trouble as comparatively simple as the one described in the next paragraph requires circuit tracing from one end of one sheet to the opposite end of the other. Refer to the simplified diagram in figure 75 for the points covered in the following paragraphs.

189. Green Pilot I 3 FILAMENT POWER Lamp Does Not Light; No Indication on FIL VOLTAGE Meter

a. If the transmitter is dead, two symptoms of what is wrong may be instantly observed; the green pilot I 3 FILAMENT POWER lamp is not lighted, and the FIL VOLTAGE meter indicates no voltage. This combination of symptoms indicates a probable failure of the power supply.

b. In addition to a more serious trouble, it is possible that the FILAMENT POWER lamp is defective. To make a quick check, unscrew the 6 AMP fuse. If ac power is applied as far as the FILAMENT POWER lamp, the BLOWN FUSE INDICATOR will glow. If it does not glow, the trouble is in the ac power source, the power cable, the FILAMENT POWER circuit breaker, the ac input jack J14, or the associated wiring.

190. Green Pilot Lamp Lights, No Indication on FIL VOLTAGE Meter

a. From the schematic diagram, it can be seen that there is ac power reaching the pilot lamp and fuses. This suggests that the FILAMENT VOLTAGE rheostat R18 is open. Other possibilities are an open 5-volt secondary winding in filament transformer T1. An open primary produces the same symptoms, and, in addition, the filaments of the tubes fail to warm up.

b. If R18 is open, blower motor B1 will be inoperative. The condition of the 5-volt secondary can be checked by observing whether the filament in power amplifier VI is lighted. If it is, the defect must be in meter M1.

191. Red Pilot Light Lamp I 4 Does Not Light

a. If the green pilot lamp is lighted and the FIL VOLTAGE meter indication is normal when the red pilot lamp is out, power is reaching the filaments. If PLATE RELAY switch S10 is closed, the trouble could be in the circuit of PLATE POWER circuit breaker CB2. Any one of interlock switches S5, S7, S8, or S11 will also open the circuit if not seated properly. Plate relay K6 completes the circuit back to receptacle J14; therefore, if relay contacts 3 and 4 of K6 separate, the trouble will appear. The coil in relay K6 could have opened because of corrosion in the winding. Make a continuity check to determine whether the winding is open.

b. If the K6 winding is intact, time-delay relay K7 should be suspected, especially if more than 30 seconds have passed since PLATE POWER circuit breaker CB2 has been closed. On the simplified diagram (fig. 75), the power circuit can be traced through winding 6–7 of time-delay slave relay K8, to contacts 3 and 4 of overload reset relay K5, to microswitch S4, PLATE RELAY switch S10, through winding 5–6 of plate relay K6, and back to terminal 6 of the time-delay slave relay. Completion of the plate power circuit depends on relay K8. Contacts 1 and 2 must be closed to heat K7; then contacts 2 and 3 have to close.

192. ANTENNA CURRENT Meter Does Not Indicate Current Flow

a. If all observations show that the transmitter is normal but that there is no antenna current, the trouble must be in the antenna tuning unit (fig. 76), or else the antenna is disconnected.

b. Assuming that the antenna is intact and that it is connected, antenna change-over relay K1B (fig. 74) should be checked, because the transmitting antenna is connected through contacts 9 and 10 to antenna loading coil L4 (fig. 73).

c. The source of energizing voltage for relay K1B cannot be suspected because it also supplies the voltage for blower motor B1. If B1 were not operating, the power amplifier tube (V1) would run very hot, and this presumably would cause THERMAL RESET switch S13 to open the ac circuit.

d. Transmitter antenna contact 9 on relay K1B connects the antenna to L4 through spring contacts E5 and E6. Make sure that the chassis is set secure in its case and that E5 and E6 make good contact, otherwise the circuit may be broken.

e. Failure in the antenna tuning unit may be caused by an open coupling coil L5, an open ANTENNA CURRENT meter M4, or a defective switch SW9. Other possible component failures will depend on the setting of SW 9. When SW9 is set to the 210 MC position, L44 is in series with M4 and C22; other components are not used. When SW9 is set to the 10–20 MC position L44 is in series with M4; other components are not used. When SW9 is set to the LONG WIRE position C30 and L6 are in series with M4; other components are not used. It is evident that certain components are not used in some frequency ranges; therefore they are eliminated as causes of the trouble. This is another instance where changing frequency bands can be of great assistance in locating the defect.

f. The inductance of L44, L5, and L6 is varied by a pulley making contact with the bare wire on the inductor when the inductor rotates. The contact at these points must be positive at all times; otherwise the circuit will be broken.

193. No Reading on PA PLATE Meter; No Reading on ANTENNA CURRENT Meter

a. The plate circuit of power amplifier V1 (fig. 73) is traced through the parallel combination of L1 and R3, inductor L2, choke L3, meter M3, spring contacts E1, E2, E7, and E8 (fig. 74), and then to contact 1 of cw-phone relay K3. This relay is in the cw position, which means that the plate current flows through contact 2. This shorts out the modulation transformer T5 secondary. The current follows through E9 back to E11 and E12 to the high-voltage filter circuit and the high-voltage transformer T9. If there is no high voltage being applied to V1, a voltage and concontinuity check will aid in localizing the defect.

b. If the cw-phone relay K3 is in the phone position, the plate current will flow through the secondary of modulation transformer T5. An open secondary winding would therefore stop plate current from flowing.

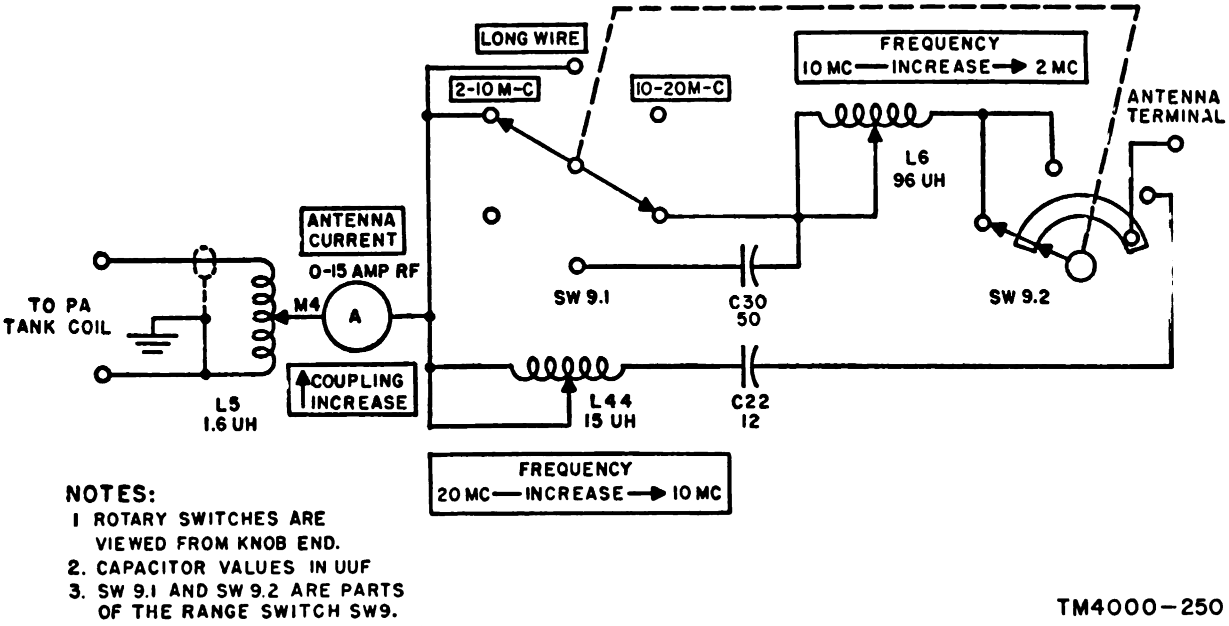


Figure 76. Typical antenna tuning unit.

194. No PA Plate Current with S12 in TUNE Position

If there is an indication on the PA PLATE meter when TUNE-OPERATE switch is in the OPERATE position, but none when the switch is in the TUNE position, the trouble is caused by a defective S12 switch or an open resistor R55. The purpose of R55 (fig. 74) is to decrease the voltage applied to high-voltage transformer T9, and decrease the dc voltage applied to the plate and screen grid of power amplifier V1 when S12 is in the TUNE position. The reason is to keep the plate current from reaching dangerous values when the circuit is tuned off resonance.

195. No Power Amplifier Grid Current and Plate Current Below Normal

a. If there is no pa grid current, and plate current is low, V1, the power amplifier tube, is defective, or the excitation to V1 has failed. If the tube is good, make a quick check by setting the EXCITATION METER SWITCH to the PA GRID position. If there is no reading, intermediate power amplifier stage V104 is likely to be defective, resulting in no drive to V1.

b. With switch S101 in the position shown in figure 73, the plate voltage path to V104 can be traced through contacts 1 and 2 of switch S101, section 1, rear, and through Z107, through contacts 9 on P101 and J8, R7, R64, terminal 6 on J1, P1, J2 and P2, to filter choke L5 in the exciter power supply rectifier V4. An open circuit in any of these components could cause the trouble.

c. The below-normal plate current that results from loss of excitation is explained as follows: When the V1 excitation fails, clamper tube V2 is no longer at cutoff. Clamper V2 has as its plate-load resistor R4, which is also the screen-grid dropping resistor for V1. With the decreased bias, the clamper conducts, causing an increase in the voltage drop across R4. This reduces the screen-grid voltage on V1 to keep the V1 plate current to a safe value.

d. It s possible that the dc readings at the tube sockets will be normal but there will be no signal output. For example, if coupling capacitor C142 which couples the output of V104 to the input of V1, opens, there will be no signal fed to the grid of V1. Poor contact or an open circuit at J103 or P8 would also cause the same trouble. The symptoms would be the same as those in the paragraph heading, because this trouble is due to lack of excitation..

196. No Power Amplifier Grid Current with SERVICE SELECTOR Switch in EXT-EXC Position

a. With the switch in the EXT-EXC position the signal to be transmitted comes from an external source directly to the IPA stage V104.

External excitation relay K101 is energized by the 26.5-volt winding on filament transformer T1. The voltage for coil K101 is applied through P101, J8, and section 3 of S1. When K101 is energized, contacts 4 and 5 separate, disconnecting the output of all preceding stages from the input of V104. Relay K101 also connects the EXT-EXC jack J104 to the input of V104 through contacts 5 and 6 and coupling capacitor C154. In this mode of operation, if there is no drive to V1, do not suspect the stages before V104; they are not being used.

b. The IPA tube V104 filament is lighted by the same filament winding that operates relay K101. Therefore the filament should be checked, and if it is lighted, the 26.5-volt secondary of T1 is known to be good. One side of the K101 winding, terminal 7, is connected to the transformer at terminal 7 through contact 4 on J8 and P101. The other terminal on coil K101 is number 8; it is connected to terminal 9 on the transformer through contacts 11 on P101 and J8, and terminals 12 and 9 in section 3 of SERVICE SELECTOR switch S1. If coil K101 and contacts are found to be in good condition, the defect is in one of the above components.

197. Power Amplifier Grid Current with SERVICE SELECTOR Switch in Fsk Position Only

a. If there is no pa grid current when the SERVICE SELECTOR switch is set for cw or am operation, but fsk operation is normal, sectionalizing the trouble is comparatively easy. During fsk operation, the signal is fed into FSK jack J16. From J16, it is fed through a coaxial cable to the input of 2d buffer V101 through P10 and J102. The fact that operation is normal in the FSK position of the SERVICE SELECTOR switch means that the trouble is not in stages V101 through the power amplifier. With the SERVICE SELECTOR switch in the CW or AM position, the signal is obtained from master oscillator V801 and first buffer V802; the lack of signal indicates that one or both of these stages are not operating. The output of the master oscillator-buffer section (V801 and V802) is fed to 2d buffer V101 through P801 and J101. The trouble is therefore in V801 or V802.

b. Begin troubleshooting by testing the tubes. If they are good, measure the bias of V801, with a vtvm, from pin 1 to ground. If normal voltage is present, the stage is operating.

c. The filament circuit probably is in good condition because V101, V102, and V103 filaments operate from the same winding. These three tubes are in stages that are known to be operating. As far as the filament circuit is concerned, the only possible troubles could be in the contacts in P802 and J105.

d. The dc voltages are applied to V801 and V802 through P802 and J105; therefore, any dc defects will be between P802 and the tubes, or possible C152 at terminal A of J105.

e. Measure the dc voltage at the plate of V801. An absence of dc voltage could be due to an open load resistor R803, choke L802, or a shorted bypass C810. Now plate voltage could be caused by a shorted screen-grid bypass capacitor C806. The cathode circuit is completed back through L801. An open circuit in L802 would keep the circuit from operating.

f. If the master oscillator V801 is operative, the next step is to check the first buffer, V802. The dc applied to the plate is through R806 and the screen-grid voltage is applied through R805. A shorted screen-grid bypass C808 would not only kill the screen-grid voltage but would cause R805 to become very hot. In *e* above an open choke L802 was pointed out as a defect that would break the plate circuit. It is common to both V801 and V802, so if there is an open circuit at this point, both stages would be affected.

g. If all dc voltages are normal, a logical suspect would be an open coupling capacitor. Examples are C807, which couples the signal from the output of V801 to the input of V802, and C809, which couples the output of V802 to P801. As with other capacitors suspected of being open, the quickest and easiest method of checking them is by bridging them, one at a time, with a capacitor of the same value that is known to be good.

198. No Power Amplifier Grid Current on the 12.0-20.0-mc Band with Fsk or Internal Excitation

When there is no pa grid current with the BAND SELECTOR switch set at 12.0–20.0 and the transmitter adjusted for FSK or internal excitation, follow the troubleshooting procedures given in *a* through *c* below.

a. There are no provisions for switching the multiplier, buffer, and oscillator stages to the panel meter. It is therefore necessary to try different switch positions to sectionalize and localize the trouble. The block diagram (fig. 72) will clarify the situation.

b. The fact that there is no grid drive in the 12.0–20.0 mc range on fsk means that the trouble could be in the 2d buffer, 1st multiplier V101, 2d multiplier V102, or 3d multiplier V103. The same symptom is present with internal excitation; this would include the master oscillator V801, and the 1st buffer V802. It is unlikely that both inputs would go bad at the same time. This narrows the trouble down to V101, V102, or V103.

c. Because operation on the 6.0–12.0 mc band is normal, this factor can help in tracing the trouble. The V101 and V102 stages are used in this range and are fed directly to the IPA V104 stage; therefore they are normal. This narrows the trouble down to the 3d multiplier stage, V103. Measure the V103 plate voltage. The circuit in question includes L106 and R116. At this point the dc line feeds the screen-grid of V104, and because V104 is in operating condition, one of these two components must be the only possible cause of an open circuit. In addition, screen-grid bypass C129, if shorted, could be a cause of trouble. If screen-grid dropping resistor R115 should open, the stage would not operate.

199. No Power Amplifier Grid Current on 6.0- to 12.0-mc Band with Fsk or Internal Excitation

a. With the BAND SELECTOR switch set at 6.0–12.0, second multiplier V102 is brought into the circuit. The V101 stage is known to be trouble-free because the 3- to 6-mc signals pass through it. The trouble, therefore, must be in the added circuit.

b. Grid resistor R108 can be suspected, but grid resistors rarely open in a circuit where comparatively low current flows. If they do, it will probably be caused by mechanical damage.

c. Because the plate current path is through L104, R112, and cathode resistor R109, an open in any of these components would break the circuit. The screen-grid current path is through dropping resistor R111. The two paths join at R112, which is common to both circuits. A short circuit in bypass capacitor C117 would decrease the screen-grid voltage to zero. A short circuit in C120 would reduce the plate voltage to zero and would likely cause R112 to overheat.

200. No Power Amplifier Grid Current on 3.0- to 6.0-mc Band with Fsk or Internal Excitation

a. The circuits used in the 3- to 6-mc band were described in the previous paragraph. When operating in the 1.5- to 3-mc band, the circuit is similar to that used in the 3- to 6-mc band except that resistor R106 is used as the plate load for V101 in the 1.5- to 3-mc band.

b. From these observations, it can be seen that the only causes of trouble could be an open L102, the plate load in the 3- to 6-mc band, contact 3 in section 4 rear of switch S101, or a shorted C109 or C110. Contact 9 in the switch is also a suspect, but, since it is used on both frequency ranges and one range is operative, it is considered to be in good condition.

201. Neither V1 Grid Current nor V104 Plate Current on Cw or Am Operation; All Other Socket Voltages Normal

a. If there is neither V1 grid current nor V104 plate current when the key is pressed in cw operation (or when the microphone switch is pressed in am operation), stage V104 should be suspected first. Test the tube; if it is good, measure the plate and screen-grid voltages while the key is held down. If the voltages are abnormally high, the full power-supply voltage is appearing at the socket. This means that no current is flowing in the circuits; there are no voltage drops between the B+ supply and the tubes. The plate and screen-grid circuits cannot be open, and they are not shorted. Check the cathode circuit; if the resistance between pin 3 and ground is about 300 ohms, the only cause for the abnormally high socket voltages is a high bias.

b. Stages V104 and V101 normally have their control grids blocked by a bias voltage that is applied from the output of bias rectifier 5R4WGY to V11 through R110 to the grid circuits. When the transmitter is keyed, the bias is shorted out by contacts 7 and 8 of push-to-talk and key relay K2. This means that if R110 is not grounded at this time, relay K2 may be defective, that its energizing source, bias rectifier V11, could be at fault, or that the path through R110 to the keyed tubes is open. It is also possible that contacts 7 and 8 of K2 are not making contact, even though the coil may not be energized.

c. This type of keying system is called blocked grid keying because in the key-up condition the grids of the keyed tubes are blocked by the fixed bias. Thus, anything that will keep the blocking bias from being removed will prevent the transmitter from operating.

d. The symptoms show that the same condition exists when switch S1 is in the AM position. Since the bias comes from the same source, the trouble must be in contacts 5 and 6 of K3; if they fail to close, the bias remains when it should be removed.

Section III. TROUBLESHOOTING FOR WEAK OUTPUT

202. General

a. Before he begins to troubleshoot a weak transmitter, the repairman can at once eliminate certain components from the list of possible trouble sources. These components include all power switches, pilot lamps, relays, fuses, interlocks, and other components that are part of the control circuits. They will be either open or closed, good or bad. A defect in one of these will not cause the transmitter output to be weak.

b. The main causes of a weak output are weak tubes, low terminal voltages caused by changes in the values of resistors, and tuned circuits that are not tuned to resonance. It is important to compare all voltages and resistance measurements with those specified in the equipment technical manual. Because the actual sectionalization will be similar to the method used in troubleshooting a dead transmitter, it will not be repeated here.

203. Transmitted Signals Weak at Distant Receiver

a. A receiving operator's complaint that signals are weak does not prove the transmitter to be at fault, but it does require a quick check. Check the antenna current meter. If this shows normal current, there is an immediate presumption that the transmitter is operating normally, and that the fading out reported by the receiving operator is caused by some defect in his own equipment or by atmospheric conditions.

b. A gradual variation in the strength of signals heard by the receiving operator is not necessarily caused by a defect in the transmitter. Take periodic readings of all the meters. If these readings do not vary, the output is constant and the defect is not in the transmitter,

c. If the receiving operator's complaint does reveal a defect in the transmitter, normal troubleshooting methods are in order.

204. Low PA Plate Current with All Settings of BAND SELECTOR and SERVICE SELECTOR Switches

a. Check the power amplifier grid current. If it is normal for all settings of the switches, all stages ahead of the power amplifier are normal. The trouble is probably in the plate or screen-grid circuits of the power amplifier V1.

b. The defect should be found in the plate circuit of V1 or in the high-voltage power supply. Measure the plate and screen-grid voltages at V1. Any deviation from the normal voltages is a clue. Any of the spring contacts in the plate circuit could develop high-resistance joints.

c. The screen-grid voltage has more control over the plate current than the plate voltage. Therefore, the defect is likely to be found in the screen-grid dropping resistor R4. There is also a possibility that a leak in screen-grid bypass C5 is reducing the screen-grid voltage.

d. Check the loading on the transmitter by adjusting the antenna coupling unit and the antenna system. Poor connections in the antenna or transmission line will change the loading. The loading includes coil L4 in the transmitter. Check the contacts of switch S2, section 1 At the same time, check the contacts of section 2 of the same switch; this is part of the tank circuit and can cause trouble.

205. Power Amplifier Grid Current Lower than Normal in FSK, FSK-AM, or EXT-EXC Operation

If pa grid current is normal when internal excitation is used, but lower than normal with external excitation, the cause for the low (or possibly no) grid current is not in the transmitter. External signals are fed into the grid circuit of V104, as are the internally generated signals; therefore if operation is normal when internal signals are used, trouble with external excitation must lie in the source of such signals.

206. Power Amplifier Grid Current Lower Than Normal in Any Type of Operation

a. Both internal and external signals are fed to the grid circuit of V104 (par. 205) ; therefore, if power amplifier grid current is low with all types of operation, it is not reasonable to suspect circuits ahead of V104, either internal or external. There are only a few components in the input circuit of V104 that could cause weak output; they are R117, R118, and R119. Because little or no current flows through them, their resistance values seldom change; however they should not be overlooked when troubleshooting is required.

b. Low plate or screen voltages are to be suspected first. The plate circuit can be traced through S101 front, S101 rear, the tank inductors, and then to the voltage regulator V3. From R64, the path leads directly to the output of exciter rectifier V4.

c. Screen-grid bypass C134, if leaky, would form a high resistance path to ground and reduce the screen-grid voltage. This voltage is obtained from the same source as the plate voltage, but from a lower tap on the voltage divider made up of R64, R6, and R65. Changes in the values of the divider resistors may reduce the screen voltage.

207. Power Amplifier Grid Current Lower than Normal with BAND SELECTOR Switch Set to Any Frequency Range

a. If the power amplifier grid current is lower than normal for any setting of the BAND SELECTOR switch, master oscillator V801, second buffer-first multiplier V101, and IPA V104 stages should be suspected first. The second and third multiplier stages (V102 and V103) are not part of the signal path in the 1.5- to 3-mc and the 3- to 6-mc bands; therefore, they would usually not contribute to the symptom being considered. The later stages cannot be eliminated from suspicion, because they are still connected to the power supply even when they are not being used; a defect in one of them, such as a leaky bypass capacitor, could lower the output from exciter rectifier V4. Check the tubes first; if they are good, measure the plate and screen voltages.

b. If further troubleshooting is required, the symptom is the result of a weak signal. Measure the control-grid voltage of each exciter tube. Low or no voltage means that the signal applied to the grid is weak or missing. A common cause of a weak or missing signal is an open coupling capacitor. A faulty capacitor C807, between the output of master oscillator V801 and the input of first buffer V802, or Capacitor C809, which couples the output of V802 to V101, could decrease the value of the signal voltage fed to V101. In addition, C101 connected to the grid (pin 1) of V101 is a suspect.

c. Follow the same procedure for checking the input to V101. Investigate any deviation from normal operation as described in the TM.

208. Power Amplifier Grid Current Lower than Normal in 6.0–12 mc Band Only

a. When operating in this frequency range, the 3d multiplier V103 is not in use. Since operation is normal on all other ranges, the most likely stage that can be at fault is the 2d multiplier V102.

b. A possible cause other than low dc voltages is an open coupling capacitor C108 between the plate (pin 5) of V101 and the grid (pin 1) of V102. This capacitor is connected through section 4, front and rear of switch S101. Consider the switch as a source of trouble; the contacts may break or separate because of corrosion.

209. Power Amplifier Grid Current Lower than Normal in 12.0- 20.0-mc Band Only

a. When the transmitter is operating in the 12- to 20-mc range, all exciter stages are used. If operation is normal in all other ranges, suspect third multiplier V103 because it is used only in the 12- to 20-mc range.

b. Possible causes of trouble, other than a bad tube and low dc voltages, are an open coupling capacitor C130, a defect in section 2, rear of S101, and poor contact between contacts 4 and 5 of relay K101.

Section IV. TROUBLESHOOTING FOR LACK OF MODULATION

210. General

If we have normal carrier output—as indicated by the antenna current meter and final amplifier plate and grid readings—but cannot modulate the carrier, the trouble must be in the modulating circuits, including the modulator, the preamplifiers, and the source of modulating voltage. The block diagram (fig. 72) shows that a defect can be anywhere from the audio input to V12A through the push-pull modulator tubes V9 and V10.

211. No Modulator Current with S3 Set to MOD PLATE X20 and S1 Set to Am

a. Check the modulator tubes V9 and V10 to be sure that the filaments light. If they do not, and the tubes are not at fault, the defect is in the secondary or primary of filament transformer T2.

b. Measure the voltages at the modulator tubes. If the voltage at the plates (the top caps on the tubes) is absent, the center tap of the modulation transformer T5 may be open or spring contact E9 may be defective. If the screen-grid voltage (pins 2–4) of V9 is absent, a logical suspect would be an open screen-grid dropping resistor R11 or a shorted bypass C12 or C13.

c. Contact E10, which connects to E9, cannot be defective because plate current is flowing in power amplifier V1, and contact E10 carries this current.

d. If cw-phone relay K3 contacts 1 and 2 do not separate when the push-to-talk switch on the microphone is pressed, the secondary of modulation transformer T5 will remain shorted out, as it normally is when operating on cw. This condition could be present if the contacts are stuck together or if the coil on relay K3 is open.

e. The only other open-circuit cause of zero modulator plate current would be an open connection on modulator filament transformer T2. The meter might be burned out, but there can still be full output from the modulator. This is because the circuit to ground is completed through shunt resistor R9.

f. If the plate and screen-grid voltages are higher than normal, the lack of modulator plate current is due to too high a bias. When the modulator is not being used, a heavy bias is being applied to the grids of the modulator tubes from bias rectifier V11. Under these conditions, the tubes are cut off and no plate current will flow.

g. If the bias reading from the grid (pin 3) of either modulator tube to ground is the same whether the push-to-talk switch on the microphone is pressed or not, the trouble has been isolated. The bias is applied through the center tap of input transformer T6 and contacts 4 and 5 of cw-phone relay K3. When the SERVICE SELECTOR switch is turned to the AM position, contact 5 is separated from contact 4 and connected to contact 6. This reduces the bias and allows the modulator plate current to flow. Therefore, one of the first things to look for when the bias cannot be reduced is a defect in relay K3. The lack of bias control also can be caused by an open circuit in R25 MODULATOR BIAS control.

212. Modulator Plate Current Does Not Increase During Modulation

a. Since the modulators operate as class AB amplifiers, there will be a small amount of modulator plate current when there is no signal input. When a signal is applied to the modulator grids, the fixed bias is overcome and plate current increases and varies as the signal strength varies. If the plate current does not vary as the microphone is spoken into, look for trouble between the audio input and the modulator stage.

b. Test tubes V9, V10, and V12 through V15. Measure the control-grid bias at pins No. 3 of V9 and V10. If bias is not present at one or both pins, suspect the secondary of T6. Check the resistance between terminals 4 and 5 and terminals 5 and 6 of T6. If the proper bias is present at both modulator controls grids, check the plate voltage of driver V15; this will check the primary of T6.

c. If plate voltage is absent, the primary winding may be open. Other possibilities are an open R46, poor contact at terminal 13 on P3 or J3, and an open R12. Since V4 supplies dc voltage to the RF exciter stages also, and they are operating, the V4 components must be in operating condition.

d. Check plate and cathode voltages at tubes V12, V13, and V15. If further troubleshooting is necessary, feed an audio signal into the grid, pin 6, of V15. At this point, connect a loudspeaker or an audio signal tracer to the plate of V15 and use it as an audio output indicator. If there is no output, there is probably a defect in the grid or cathode circuit of V15.

e. Move the audio signal to the grid, pin 7, of fourth af amplifier V13. If there is no output, the stage is defective. Check coupling capacitor C26. Measure for proper resistance of plate load resistor R138.

f. Feed the signal into low-pass filter L2. If there is no output, the filter is defective.

g. An audio signal fed to the cathode, pin 5, of clipper V14 will determine whether the stage is operating. If it is not operating, measure the voltage at the plates, pins 2 and 7. The voltage should vary with the setting of clip off control R44. Components to check are R34, R44, R45, and C25.

h. If there is no output when a signal is fed into the grid (pin 2) of the third AF amplifier V13, the possible defects could be an open coupling capacitor C24 or an open resistor R31 or R32.

i. Feed a signal into high-pass filter FL1 and note whether an output is produced. If there is no output, FL1 is defective.

213. No Modulation with 600-ohm Line Telephone Input, but Normal Output with Carbon Mike Input

a. The 600-ohm line telephone input signal applied to J12 is amplified by first AF amplifier V12A, and the carbon mike input is amplified by second AF amplifier V12B. The defect can be assumed therefore to lie between the remote control receptacle J12 and the input to high-pass filter FL1.

b. Check terminal D on J12 for good contact. Remove P5 from J5 and feed an audio signal into J5. If there is still no output from the speaker or signal tracer, it can be temporarily assumed that the 600-OHM LINE GAIN control R17 and terminals 25 in J6 and P6 are intact and that the trouble lies between J5 and FL1. Check the V12 plate voltage at pin 1. An absence of voltage at this point would be due probably to an open plate load resistor R27 or an open decoupling resistor R41. A shorted decoupling capacitor C27 would remove the plate voltage, but this would probably affect the other audio stages also, and R41 would smoke and possibly burn. An open in cathode-bias resistor R26 could also interrupt the plate current. Another suspect is coupling capacitor C22A.

214. No Modulation with Carbon Mike Input, but Normal Operation with 600-ohm Line Telephone Input

Though the components differ in value, the circuits of V12A and V12B are identical. Troubleshooting for the indicated condition, therefore, follows the procedure in paragraph 213.

Section V. TROUBLESHOOTING FOR DISTORTED OUTPUT

215. Overmodulation

a. A possible source of distorted output is overmodulation. A common cause of overmodulation is an excessive input of audio power into the modulator stage. During the process, the carrier is cut off during negative peaks of the modulating voltage.

b. To check for overmodulation, connect an RF ammeter with a range of 0–15 amperes between RF OUTPUT jack J9 and the antenna; then hum or whistle a steady note into the microphone. The ammeter will show an increase of 22½ percent at 100 percent modulation and less of an increase with less than 100 percent of modulation. If the ammeter indicates more than a 22½ percent increase during modulation, over-modulation is indicated.

c. Another means of checking for overmodulation is to observe the needle on PA PLATE meter M3. If there is overmodulation during otherwise normal operation, the needle will not remain stationary.

216. Cure for Overmodulation

The cure for overmodulation is to reduce the audio gain by turning the CARBON MIKE

GAIN control R16, or the 600-ohm LINE GAIN control R17, whichever is being used, counterclockwise until the audio signal is such that overmodulation does not result.

217. Distortion in Modulator

a. If the transmitter is not overmodulated, the cause of distortion may lie within the modulator section. This can be treated like any other audio amplifier and the same methods may be used to locate defects in it up to the modulator stage; that is, the same stage-by-stage procedure that was recommended for locating the defect in a dead modulator (pars. 210–214) should be followed.

b. Most distortion troubles are caused by tubes. These, therefore, will have to be checked.

c. To troubleshoot for distortion within the modulator section, connect the vertical input of an oscilloscope, in series with a .01-mfd capacitor, from the plate (pin 1) of V15 to ground and then—

(1) Feed a signal from an audio oscillator into the grid (pin 6) of V15, the driver stage, and observe the output. Keep the input signal low enough to avoid overloading the stage and introducing further distortion. If the output is distorted, measure the cathode voltage. A shorted cathode bypass will remove the bias and cause distortion. Check the continuity of the secondary of transformer T6; an open circuit from either end to the center tap will produce distortion.

(2) Feed a signal into the grid (pin 7) of fourth af amplifier V13B. If the output is distorted, it may be that coupling capacitor C26 is leaky. This can be checked by measuring the dc from the grid, pin 6, of V15 to ground. If there is a positive voltage present, C26 is leaky. A decrease in the resistance of cathode resistor R37 will reduce the bias, and therefore cause distortion.

(3) Feed a signal into the cathode (pin 1) of clipper tube V14. If the output is distorted, check coupling capacitor C25 for leakage. Leakage will make the grid of V13 positive and cause distortion. The purpose of low-pass filter FL2 is to reduce distortion produced by clipper V14; therefore, if any of the components in the filter should become defective, distortion will result. To check, disconnect FL2 at the IN terminal and connect a wire jumper from R60 to pin 7 of V13B. If there is no difference in the output, FL2 cannot be operating properly. If there is a change when the filter is shorted out, FL2 is operating properly.

(4) Feed the signal into pin 5 of V14. If the signal is distorted, check the adjustment of clip off control R44. Follow the instructions in the equipment technical manual. If the control can be properly adjusted, the distortion will be cleared up. If the control cannot be properly adjusted, check the values of R33, R44, and R45. Assuming a good tube and correct B+ voltage, these are the only parts that would prevent proper adjustment.

(5) Feed a signal into the IN terminal of high-pass filter FL1. If the output is distorted, check FL1. Follow the procedure outlined in (3) above for checking FL2. Other defects to look for are a change in the resistance of cathode-bias resistor R31 and a leaky coupling capacitor C24, which couples the signal from third AF amplifier V13A to clipper V14.

(6) Feed a signal into the grid (pin 7) of second AF amplifier V12B. If the output is distorted, look for leakage in coupling capacitor C22B or a change of value in cathode resistor R28. (This procedure deals with the circuit that is cut into service to make the microphone operative.)

(7) Feed a signal into the grid (pin 2) of first AF amplifier V12A. If the output is distorted, look for leakage in coupling capacitor C22A or a change of value in cathode resistor R26. If the plate voltage is low, look for a change in resistance of load resistor R27. The gain controls usually do not cause distortion, but if everything else is normal, they

can be checked for proper resistance. (This procedure deals with the circuit that is cut into service to make the 600-ohm line telephone operative.)

d. If tests show that the distortion is not between the audio input at J11 or J12 and output of driver V15, the distortion is definitely in the modulator stage. In high-powered stages such as this, it is too dangerous to connect any type of audio indicator to the output. The safest method is to measure resistance values. Check the primary winding (terminals 1, 2, and 3) for proper resistance. If either side of the winding is open, the circuit will become unbalanced and distortion will result. A deviation from the proper resistance in the secondary (terminals 4 and 5) will also cause distortion.

Section VI. TROUBLESHOOTING SPECIAL CIRCUITS

218. General

a. Certain circuits, though built into a transmitter, are not integral parts of the transmitter as such. They are serviceable to the operator, and they are aids to his efficient operation of the set; but they contribute nothing to its functioning as a transmitter. Such, for example, is a sidetone oscillator circuit, the function of which is to enable the operator to monitor his keying while operating on cw. A sidetone oscillator and similar circuits are independent of the modulator section, the RF section, and the power supply; and for this reason they are called special circuits. It is characteristic of special circuits that, if they develop trouble, the trouble does not affect the output of the transmitter.

b. A sidetone circuit, consisting of sidetone oscillator V17 and cathode follower V16, is the only special circuit in the sample transmitter (fig. 73).

219. No Sidetone Oscillator Output

a. If no sidetone signal is heard when it should be, check first to see whether the transmitter itself is operating. This may involve only a quick reading of the meters.

b. If the transmitter is operating normally, check V17; and if this also is in good condition, measure the dc voltages from the plates (pins 1 and 6) to ground with a vtvm. If there is no dc voltage at pin 6, the cause may be an open plate load resistor R51 or an open decoupling resistor R54. A leaky or shorted decoupling capacitor C35 would also make the circuit inoperative.

c. Measure the voltage between the cathodes (pins 3 and 8) to ground. If it is abnormally high, the circuit is open between either cathode and ground. Possible sources of the trouble are an open cathode resistor R52, a defective plug P1 or P2, or a defective contact 3 or 4 of relay K2. Another suspect is contact 5 or ground on SERVICE SELECTOR switch S1, section 4.

d. If the dc voltage at pin 6 is normal, the only component that could keep the dc from pin 1 is an open plate load resistor R49.

e. If all dc voltages are normal, check coupling capacitors C33 and C34 for open circuits. As a further check, connect a headset between pin 6 of cathode follower V16 and ground. If there is no audio output, coupling capacitor C31 is probably open. Other possibilities are open contacts P5, P6, or terminal H on remote control receptacle J12.

220. No Output from Cathode Follower V16

a. When you know that V17 is operating, check cathode follower V16. Plate voltage must be present at pin 1 or 5 unless the connection between the top of R49 and the plate of V16 is loose because of dc at the top of R49.

b. Connect a headset across cathode resistor R47. If there is normal output, the trouble is an open circuit in coupling capacitor C31 or an open at P5, P6, or terminal H on remote control receptacle J12.

CHAPTER 8

TROUBLESHOOTING FM TRANSMITTERS

221. General

a. Most of the circuits of an fm transmitter correspond to those of an am transmitter. This chapter concerns only the trouble shooting of circuits that are particular to fm transmitters.

b. The block diagram (fig. 77) is that of a simple fm transmitter. The stages that are particular to fm transmitters and do not appear in am transmitter are the reactance-tube modulator, the discriminator, and the mixer.

c. The schematic diagram (fig. 78) is of the same transmitter. Many of the circuits are the same as those in an am transmitter. The power supply has not been included in the diagram because it is the same as would be used for an am transmitter.

222. Frequency Drift

If there is difficulty in keeping the driver or power amplifier stages tuned properly, or if receiving station report carrier drift, the oscillator is probably drifting. An afc circuit is incorporated in the same transmitter (fig. 78) to keep the oscillator frequency stable; therefore, the most likely source of trouble would be in the afc section. It is possible, however, that trouble in the modulator stage or the oscillator stage could cause the oscillator frequency to drift so far that the afc section could not keep the oscillator stable.

a. Stage V5 is a crystal oscillator that is tuned to a frequency different (usually lower) from the output frequency of the transmitter. Its output, and a signal from the grid of driver V10, are fed to mixer V4, where a beat signal (an intermediate frequency, the same as produced in a superheterodyne receiver) is produced and applied to a discriminator (V3). The discriminator is tuned to a frequency equal to the difference between that of the crystal oscillator and the carrier frequency of the transmitter. When the carrier frequency is right, the frequency applied to the discriminator will produce zero output. When the carrier frequency drifts, the frequency applied to the discriminator will be different from that to which it is tuned, and V3 will produce a dc voltage of correct polarity to restore V1 to its operating frequency. This correction voltage is applied to a reactance modulator (V2), which, in turn, controls the frequency of oscillator V1.

b. In cases of frequency drift, first test tubes V1 through V5 by substitution. If trouble persists, remove V3 from its socket and check for

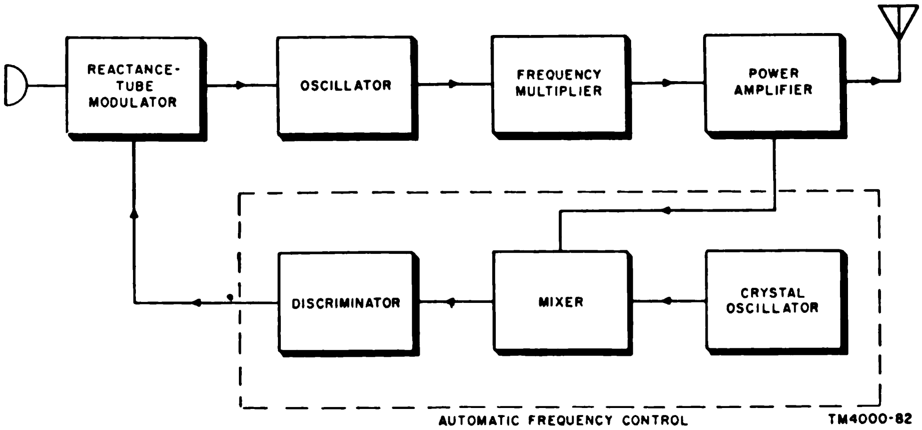


Figure 77. Fm transmitter, block diagram.

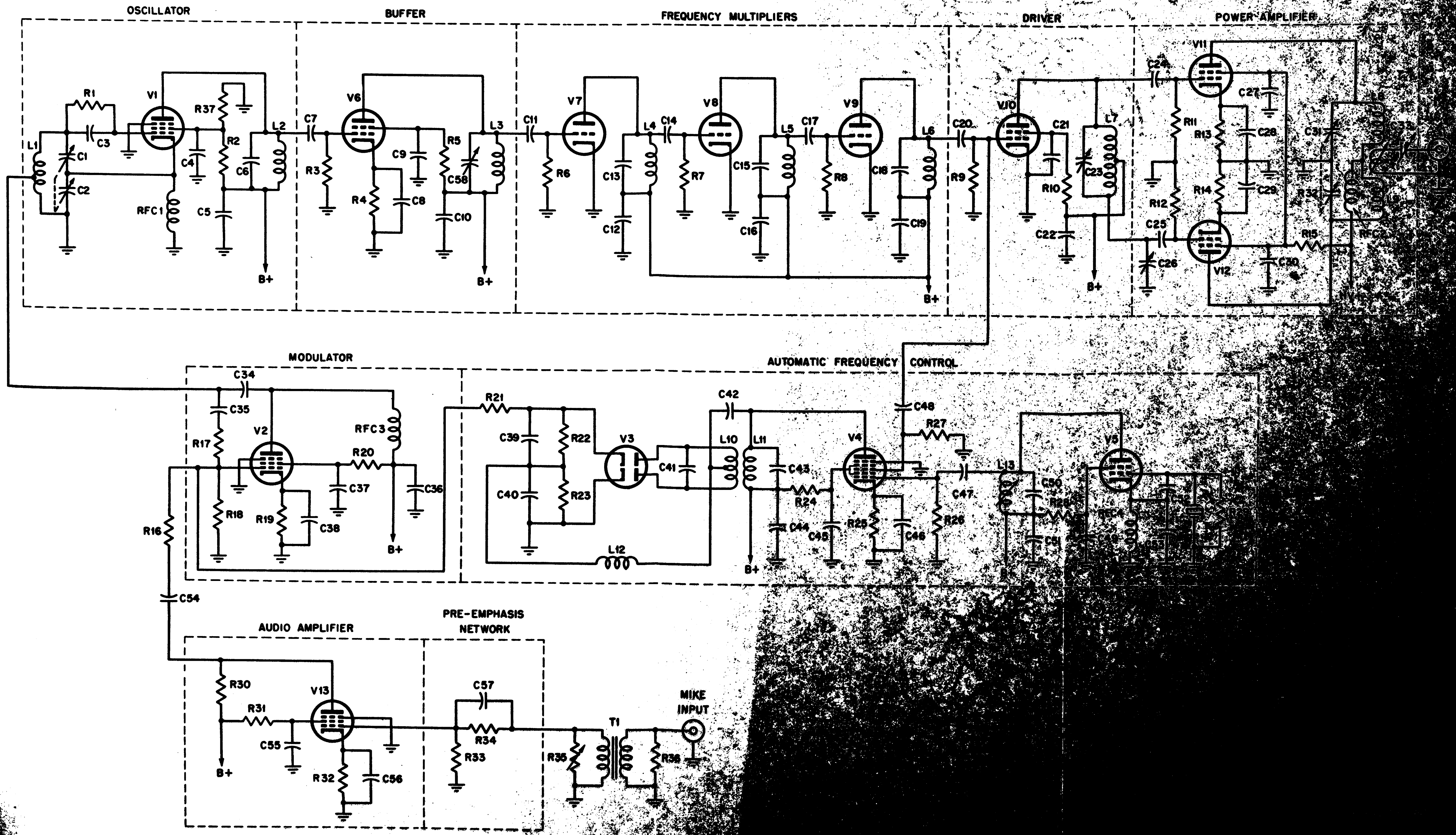


Figure 48. FM transmitter, schematic diagram.

positive voltage at the control grid of modulator V2. If such a voltage is present, it is caused by one or more leaky or shorted capacitors C54, C42, C34, and C35.

c. If tests in *b* above are negative, it is safe to assume that there is trouble in the afc section. Although the defect usually can be found by ordinary troubleshooting methods, such as voltage and resistance measurements, it would be wise to check the frequency of the crystal oscillator (V5) with a frequency meter. Any change in the frequency of the crystal will shift the frequency of V1.

223. Transmitter Troubleshooting Charts

The charts below are intended to help in locating troubles quickly. The information can be applied to any transmitter that has built-in meters. Consult the charts when trouble arises and, when the general location of the trouble is known, use the specific information appearing in the equipment technical manual to pin-point the defective circuit and component part.

a. Typical Capacitor, Resistor, and Inductor Failures in Transmitter RF Amplifier Stage.

Symptoms	Circuit meter readings	Dc voltage measurements	Resistance measurements	Defective transmitter part
1. Feedback and instability.	*a.* Erratic.	*a.* Normal.	*a.* Capacitor does not charge.[a]	Plate bypass capacitor. *a.* Open.
No output or very weak output.	*b.* Low or no grid current in next stage.	*b.* Zero or very low from plate to ground.	*b.* Partial or direct short from B+ to ground.	*b.* Shorted or leaky.
2. Decreased output.	*a.* Erratic meter readings.	*a.* Normal.	*a.* Capacitor does not charge.[a]	Screen capacitor. *a.* Open.
No output or very weak output. Hot screen resistor.	*b.* Low plate current. Low or no grid current in next stage.	*b.* Zero or very low from screen to ground.	*b.* Partial or direct short from screen to ground.	*b.* Shorted.
3. Slight reduction in output.	*a.* Slight decrease in grid current in next stage.	*a.* Normal.	*a.* Capacitor does not charge.[a]	Cathode bypass capacitor. *a.* Open.
High plate current with no grid signal.	*b.* High plate current with no grid signal.	*b.* No reading across cathode resistor.	*b.* Partial or direct short from cathode to ground.	*b.* Shorted.
4. No output or very weak output.	*a.* Low grid current in next stage.	*a.* Normal.	*a.* Capacitor does not charge.[a]	Coupling capacitor. *a.* Open.
Low output.	*b.* Erratic readings. High plate current. Grid current in next stage high.	*b.* Reduced plate voltage and positive reading from grid to ground in next stage.	*b.* Low resistance across coupling capacitor or from one terminal to ground.	*b.* Shorted.
5. No output.	*a.* High reading; no resonant dip in plate current.	*a.* Normal plate voltage.	*a.* Direct short across capacitor terminals with one end of coil detached.	Plate tuning capacitor. *a.* Short between plates.
No output.	*b.* Zero plate current for series-fed plate. No resonant dip for shunt feed.	*b.* No reading from plate to ground for series feed. Normal for shunt feed.	*b.* Direct short from hot terminal to ground. Detach coil if plate is shunt fed.	*b.* Stator plates shorted to ground.
6. No output.	*a.* No resonant rise in grid current.	*a.* Normal grid bias.	*a.* Short circuit across terminals with one end of coil detached.	Grid tuning capacitor. *a.* Short across plates.
No output.	*b.* No resonant rise in grid current.	*b.* Normal bias if applied in shunt with tuned circuit. No reading if bias is applied in series.	*b.* Short circuit from hot terminal to ground.	*b.* Stator plates shorted to ground.

7. Normal or slighly reduced output.	*a.* Meter erratic and warm.	*a.* Normal.	*a.* Capacitor does charge.[a]	Meter shunting capacitor. *a.* Open.
No meter reading; output normal.	*b.* No reading.	*b.* Normal.	*b.* Short circuit across capacitor.	*b.* Shorted.
8. No output.	*a.* Zero or low grid current.	*a.* Normal unless coil is in series with bias line.	*a.* Open circuit across coil.	Grid tuning coil. *a.* Open.
No output.	*b.* Zero or low grid current.	*b.* Dc bias normal.	*b.* Direct or partial short across coil.	*b.* Shorted.
9. Low output.	*a.* No grid current reading.	*a.* No dc bias on grid.	*a.* Open circuit across choke.	Grid choke coil. *a.* Open.
Reduced output.	*b.* Slightly lower grid current.	*b.* Normal.	*b.* Direct or partial short across choke.	*b.* Shorted.
10. No output.	*a.* Zero or very low plate and grid current.	*a.* High reading from cathode to ground.	*a.* Open circuit from cathode to ground.	Cathode resistor. *a.* Open.
High plate current with no grid signal.	*b.* High plate current with no grid signal.	*b.* No reading from cathode to ground.	*b.* Short circuit from cathode to ground.	*b.* Shorted.
11. No output or very low output.	*a.* Zero or low plate current.	*a.* No reading from screen grid to ground.	*a.* Open circuit screen to B+ line.	Screen resistor. *a.* Open.
Decreased plate current.	*b.* Low plate current.	*b.* Low reading from screen grid to ground.	*b.* Partial or direct short from screen to B+ line.	*b.* Shorted.
12. No output.	*a.* No resonant dip in plate current if plate is shunt-fed. No reading if series-fed.	*a.* Normal for shunt-fed. No reading for series-fed.	*a.* Open circuit across tuning coil.	Plate tuning coil. *a.* Open.
No output.	*b.* No resonant dip in plate current in shunt or series feed.	*b.* Normal.	*b.* Direct or partial short across tuning coil. Use low ohms scale.	*b.* Shorted.
13. No output.	*a.* No plate current reading.	*a.* No reading from plate to ground.	*a.* Open circuit across choke.	Plate rf choke. *a.* Open.
Normal or slightly reduced output.	*b.* Normal.	*b.* Normal.	*b.* Direct or partial short across choke.	*b.* Shorted.

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[a] Test to be made with one end of part detached from circuit.

b. Troubles in Transmitter Rf Amplifier Stage as Indicated by Plate Current Meter.

Plate current meter readings	Probable trouble
1. Higher than normal.	1. Plate circuit off resonance. Loss of excitation. Bias failure. Stage not neutralized. Excessive loading. Gassy tube. Defective meter.
2. Reading increases gradually.	2. Gassy tube.
3. Low.	3. Drop in plate voltage. Insufficient loading. Low filament emission.
4. Reading decreases gradually.	4. Tube losing filament emission gradually.
5. Zero.	5. Plate voltage supply failure. Open plate circuit. Defective meter.
6. High, with no resonant dip.	6. Excessive loading.
7. Resonant dip to very low value.	7. Load disconnected, detuned, or defective.
8. Reading is erratic.	8. Intermittent circuit in load; antenna defective. Intermittent circuit in plate supply or bias. Loose connection in plate or grid circuits. Meter defective.

c. Troubles in Transmitter Amplifier Stage as Indicated by Grid Current Meter.

Grid current meter readings	Probable trouble
1. High.	1. Excessive excitation. Bias failure. Plate voltage failure. Insufficient loading.
2. Low.	2. Grid circuit off resonance. Insufficient excitation. Circuit not neutralized. Excessive loading.
3. Grid current decreases gradually.	3. Tube in preceding stage failing.
4. Zero.	4. Excitation failure. Grid circuit off resonance. Open grid circuit.
5. No resonant rise in grid current.	5. Circuit not neutralized. Shorted grid tank.
6. Erratic.	6. Intermittent circuit in bias supply. Tube defective. Intermittent preceding stage.

CHAPTER 9
RECEIVER ALINEMENT

Section I. BASIC CONCEPTS

224. Definitions

The tuned circuits of a radio receiver must be accurately adjusted to work together if the set is to achieve its maximum degree of operational efficiency. When the circuits are thus correctly related to one another, they are said to be in alinement.

a. The fixed frequency difference between the RF signal carrier and the heterodyne oscillator must be maintained with a high degree of accuracy over the entire tuning range of the receiver. Simultaneous tuning of the RF and oscillator circuits is achieved by ganging the tuning capacitors and/or inductors of the separate circuits and making them responsive to a single control.

b. The several capacitors and/or inductors are said to *track* if they retain their proper frequency relationships throughout the tuning range.

c. The aging of parts, the changing of the characteristics of tubes, climatic conditions, and vibration are some of the reasons for misalinement. Also, haphazard attempts at alinement and tinkering by inexperienced personnel often do more harm than good, and may increase the time spent on relatively minor repairs.

d. Every receiver that is operating poorly requires maintenance but it *does not follow that every receiver that needs maintenance needs alinement.* Repairs which require replacement of components or the redressing of wiring especially in high-frequency circuits, often make subsequent alinement necessary.

e. The usual indication of the need for alinement is low sensitivity and volume even though everything else is *definitely* good. Alinement is also needed if the RF circuits do not track properly; that is, if the dial reading does not agree with the frequency of the incoming signal.

f. In some difficult troubleshooting problems, it may be necessary to attempt alinement to locate the trouble; for example, a shorted trimmer capacitor across a low-resistance coil. Resistance readings are difficult to interpret in a circuit such as this, but failure of the circuit to respond to peaking during alinement will show that there is something definitely wrong with the tuned circuit.

g. Another reason for alinement is the replacement of one or more tubes in critical circuits, such as high-frequency oscillators. This illustrates the point that when slightly weak tubes are replaced with new ones, the circuit characteristics can change because of the different interelectrode capacities of the original and new tubes. This can detune the grid circuits and cause low sensitivity.

225. Alinement Precautions

a. Before alinement is attempted, all available maintenance literature on the equipment at hand should be carefully read and followed. There have been many instances where a receiver has been thrown out of alinement by tampering.

b. No adjustments of any kind should be made before it has been definitely established that component part troubles are not causing the abnormal operation. Attempting alinement when other troubles are present can lead to complete realinement after finding the other fault. Alinement is at the very bottom of the list of operations performed after troubleshooting.

c. The alinement procedures and adjustments recommended in this chapter are not meant to be used for all receivers; they are general. Use them only as a guide. The specific alinement information on any receiver is contained in the technical manual that was written for that receiver. If the technical manual is not available, the general procedure in this chapter may be used. If the receiver so alined does not perform satisfactorily, it should be realined when the technical manual is available.

Section II. EQUIPMENT NEEDED

226. Signal Generator

a. An accurately calibrated signal generator is a prime necessity both for checking the alinement of a set and for alining the circuits.

b. It is possible to do a rough job of alinement without a signal generator. Thus, trimmers and padders can be tuned for maximum output from the receiver but the results obtained from this method are not likely to be accurate.

227. Output Indicators

a. For best results, an output indicator should be used. This can be the S meter or audio level meter in the receiver or an ac output meter designed for the purpose. If an output meter is not available, the ac scale of a multimeter can be used.

b. The loudspeaker of a receiving set can be used as an output indicator as a last resort. With such a device, however, the results obtained will depend on the accuracy of the repairman's ear, and the human ear is not sensitive to small changes in the level of sound. If a loudspeaker must be used, its output should be lowered as far as possible and the weakest possible input signal should also be used. The signal should be weak in order to minimize or eliminate automatic gain control action, and the output should be lowered because the ear is best able to detect changes of sound level in the low-level range.

228. Oscilloscope

The oscilloscope is a necessary item of equipment and may be used during certain alinement procedures. For instance, an if stage, especially those used in fm receivers must have a certain bandwidth characteristic and a response curve of a certain shape. The only way to observe the wave form of this response curve is on an oscilloscope.

Section III. AM RECEIVER ALINEMENT

229. General

In general, circuit alinement is best begun in the circuits that are farthest from the antenna. Adjustment then proceeds toward the antenna, with the antenna circuit proper usually being the last one adjusted.

a. In some receivers, it is necessary to disable the high-frequency oscillator so that unwanted beat frequencies cannot cause misleading signals. The oscillator tube can be removed from its socket, or the tuning capacitor can be shorted out to stop oscillations. This applies only to IF alinement.

b. The agc circuit may be used or may be cut out of service during the alinement of the set. If the agc circuit uses a separate tube, and it cannot be removed from its socket, the circuit can be disconnected at the common point to the stages that are agc controlled, or the agc bus can be grounded.

230. Output Measurements

a. The signal output level at the detector is an effective measure of circuit alinement. This output can be measured by connecting an electronic multimeter across the detector load resistor (fig. 79). An electronic multimeter is specified because a meter with a high sensitivity is required.

b. If the level at the detector is not strong enough to give a good reading on the dc scale on the multimeter, an output meter, or the multimeter connected as an output meter by using the ac scale, may be connected to the audio output circuit. The meter test leads are connected to the voice coil (fig. 80).

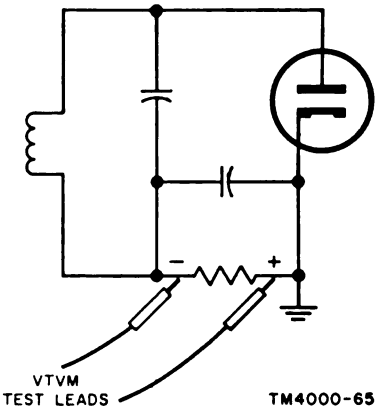


Figure 79. Signal voltage measurement at detector load.

c. The signal output may be at a low level at this point also, depending on the sensitivity of the receiver. In this case, the connection shown in figure 81 can be used at the highest point of signal voltage in the receiver. A dc blocking capacitor should be connected in the hot lead to protect the meter. If a regular output meter is available, the external capacitor need not be included because there is one connected internally.

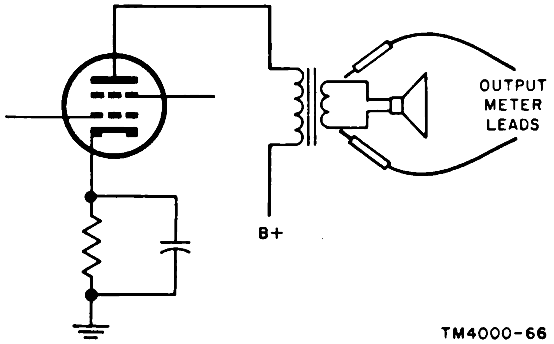


Figure 80. Signal voltage measurement at the voice coil.

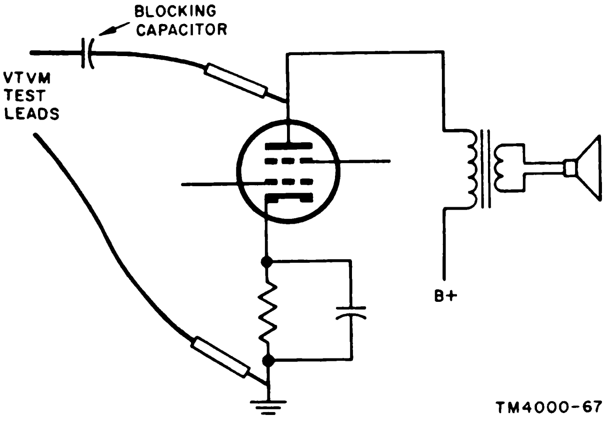


Figure 81. Signal voltage measurement in the plate circuit.

231. Location of Trimmers

Most IF stages have double-tuned transformers ; that is, the primaries and secondaries are separately tuned. Either adjustable capacitors or tuning slugs may be used as trimmers. Generally, both adjustment screws are at the top or at the bottom of the IF can. In some cases, one may be at the top and the other at the bottom of the can, both may be at the side of the can, or both may be on the chassis.

232. IF Alinement

a. Before discussing alinement procedures, it is assumed that all alinement adjustments are not in their normal positions.

b. Alinement is begun at the final IF stage. Set the signal generator to the desired frequency and turn on the modulation switch. Connect a blocking capacitor in the hot lead between the signal generator and the grid of the last IF amplifier tube and ground. Connect the output meter or multimeter (par. 230).

c. Turn the receiver gain controls on full, and set the signal generator attenuator to produce a midscale reading on the output meter. Adjust the primary and secondary trimmers in the output IF amplifier for maximum output.

d. Move the signal generator connection to the grid of the next IF tube toward the antenna, and adjust the trimmers of the stage for maximum output. The output of the signal generator must now be decreased because the signal strength has been increased by the additional amplification of this stage.

e. Other IF stages, if any, are alined in the same manner. It is very important not to change the frequency of the signal generator during the alinement.

233. Mixer Output Alinement

a. Because the frequency of the mixer output signal is the same as the IF frequency, the same signal frequency that was fed into the IF stages can be fed into it. Feed the signal into the grid of the mixer. Adjust the trimmers in the IF transformer between the mixer plate and the first IF grid for maximum indication on the output meter.

b. In some receivers, it may be very difficult to get at the underside of the mixer tube socket, especially in vhf circuits. Connect the signal generator hot lead to a metal tube shield. Push the shield down over the tube, but not so far that it touches the chassis. The signal will reach the grid by capacitive coupling. If a suitable shield is not available, wrap the signal generator lead around the mixer tube.

c. All of the circuits that are tuned to the IF frequency have now been alined. At this point, the stages that were alined previously can be touched up, with the signal generator connected to the mixer circuit. The purpose of this touching up or retuning procedure is to compensate for the slight change in frequency that often takes place because of interaction between stages during alinement.

234. RF and Local Oscillator Alinement

Alining the RF amplifier stages, local oscillator, and the mixer grid circuit of a single-conversion superheterodyne receiver, is similar to alining the IF amplifiers except that these circuits are adjusted to track with the tuning dial.

a. Set the receiver tuning dial to the highest frequency on the dial (on multi band receivers, the highest frequency of the band being alined). Connect the signal generator to the antenna input and tune it to the same frequency as the receiver. Connect an output indicator and adjust the trimmer of each circuit for a maximum output indication from the receiver.

b. Set the dial to the lowest frequency of the band being alined. Again set the signal generator to the same frequency as the receiver and this time, adjust the padders. The adjustment is for a maximum output indication as in *a* above.

c. Check the accuracy of the tracking. Set the signal generator to a freqeuncy near the middle of the tuning range of the band under alinement. Tune the receiver to this frequency. If the signal from the generator produces a maximum output indication when the receiver is tuned to exactly the same frequency as the generator then the receiver dial is tracking properly. If these results are not obtained, however, it will be necessary to repeat the procedures in *a* and *b* above. (Sometimes the adjustment of the padders will affect the alinement of the high-frequency end of the dial.)

d. Some receivers have adjustable inductors or capacitors only on the oscillator circuit for the low end of the dial. In these cases, it is still necessary to check the tracking of the dial at one or more intermediate places.

235. Double-Conversion Receivers

a. Double-conversion receivers are alined in a manner similar to that used in single-conversion. In the case of the double-conversion receiver, however, the IF amplifier, instead of being fixed-tuned, may be tunable over a wide range of frequencies.

b. If the IF frequency is tunable over a wide range of frequencies, it will be treated the same as the input signal to the RF section. Connect the signal generator to the input of the mixer. Set the signal generator and receiver to the same frequency at the low end of the frequency range. Adjust the slugs or trimmers for maximum output. Repeat these steps at the high-frequency end of the frequency range.

236. High-Frequency Oscillator Alinement

a. The main object in alining the high-frequency oscillator is to produce a signal of such a frequency that it beats with the signal at the mixer grid to produce the proper IF frequency.

b. Tune the receiver to the high-frequency end of the band. Connect the signal generator to the mixer grid circuit and tune it to the receiver frequency. Adjust the oscillator trimmer for maximum output.

c. Tune the receiver to the low-frequency end of the band, and set the signal generator to the same frequency. Adjust the low-frequency padder or coil slug for maximum output. Repeat the high-frequency adjustments. If there is no padder or slug, there is no adjustment for the low-frequency end of the band.

d. It is possible, especially in high-frequency circuits, to aline the oscillator so that its frequency is either below or above the input signal frequency. If the frequency is below when it should be above the input signal frequency, the receiver will operate normally at the high-frequency end of the band, but it will not track properly at the low-frequency end.

e. Similarly, if the oscillator frequency is above when it should be below the incoming signal frequency, the receiver will operate normally on the low-frequency end of the band, but will not track at the high-frequency end.

f. To prevent the oscillator from being alined to the wrong frequency, adjust the oscillator trimmer carefully when alining a high-frequency circuit. Turn it through its range and note that there are two points at which the output is the same. If the oscillator frequency should normally be above the incoming signal frequency, the setting of the trimmer which produces an output with the lower capacity should be used.

237. Mixer Input Alinement

a. Tune the signal generator to the high-frequency end of the band and connect it to the last RF amplifier plate; tune the receiver to the same frequency.

b. Connect the output indicator as it was connected during IF alinement. Adjust the trimmers in the mixer input circuit for maximum indication on the output meter.

238. Preselector Alinement

a. To aline the preselector, or RF stage, tune the receiver to the high-frequency end of the dial, and set the signal generator to the same frequency. Connect the signal generator to the antenna terminals.

b. Adjust the trimmers for maximum output. Set the signal generator frequency and the receiver frequency to other points desired and adjust the trimmers for maximum output. Readjust all trimmers to produce the most consistent high output over the full range of the band.

239. Alining Receivers with More than One Tuning Range

a. Receivers with more than one tuning range are alined in the same way as one-band receivers. Each band is alined beginning with the highest frequency.

b. The signal generator and receiver are set to the frequencies that are designated in the instructions. After one band is alined, the next one is alined in the same way but the frequencies involved are different.

240. Locating and Adjusting Screws

a. If there is no information on the location of the adjusting screws, they can be found by experiment. Tune the receiver to a high frequency and set the signal generator to the same frequency. Note the band in use at the time.

b. Turn the trimmers or other adjustment screws, one at a time, until that one is found that affects the output. Return all adjusting screws as closely as possible to their original positions. The fact that one affects the output means that the adjustment is in the circuit of the band in use. In some higher frequency units, the mere touching of a trimmer with an alinement tool can cause a change in the output. Because a given change in capacitance will be noticed more readily at higher frequencies, it is best to make the test at the high-frequency end of each band.

c. Trimmers in a multiband receiver are usually located in groups near the coils they tune. The trimmer associated with the band in use can be identified by the relative number of turns on the coil. Because the coil for the lowest frequency band will have the greatest number of turns, the coil in use can be identified by the number of its turns as compared with the turns on the other coils.

241. Alining Trap Circuits

a. Some receivers contain trap circuits to prevent interfering signals from entering the receiver. The trap must be tuned to the frequency of the interfering signal; signals of higher frequencies are not affected by the trap.

b. A signal that has the same frequency as the IF stages will often get into the receiver and cause interference. This is because the receiver RF section is not selective enough or the interfering signal is being fed directly into the IF section because of poor shielding or some other feature of design. If the signal is not affected by tuning the receiver through its frequency range, it is definitely feeding into the IF stages.

c. Set the signal generator to the IF frequency, turn the modulation on, and connect the generator output to the antenna terminals. Turn the IF wave trap adjustment until the signal disappears or is reduced to a minimum.

Section IV. FM ALINEMENT

242. General

Meter and visual alinement are the two methods of alinement that are in common use. The meter method makes use of a high-resistance voltmeter (20,000 ohms per volt or higher) or a vtvm and an unmodulated signal generator that covers the IF and RF tuning range of the receiver to be alined. The visual method uses an fm signal generator that covers the IF and RF ranges of the receiver and an oscilloscope. Sometimes a highly accurate crystal-controlled cw signal generator is also used with the visual method to produce marker signals on the oscilloscope. With either method, the equipment used in alinement should be turned on and allowed to warm up thoroughly before starting the alinement procedure.

243. Meter Alinement of Discriminators

a. Set the signal generator to the IF used in the receiver being alined and connect the generator output to the grid of the limiter tube immediately preceding the discriminator.

b. Connect the voltmeter across one of the discriminator load resistors. Adjust the primary of the discriminator transformer for a maximum indication on the voltmeter. (If the voltmeter indicator deflects backwards the voltmeter leads must be reversed.)

c. Without changing the signal generator, connect the voltmeter across the entire load circuit. Since the output should be zero when the secondary is tuned properly, and the polarity may be either positive or negative depending on the error of alinement, a zero-center voltmeter is very convenient. In any case, the secondary of the discriminator transformer is adjusted for zero output.

244. Meter Alinement of Ratio Detectors

a. Ratio detectors do not respond to am and therefore are not usually preceded by limiter stages. For this reason, the signal generator is connected to the grid of the last IF stage for ratio detector alinement.

b. To aline the ratio detector (fig. 82), connect the signal generator as indicated in *a* above and set the generator to the correct frequency. Connect a high-resistance meter across R1 and adjust the primary of T for a maximum indication on the meter.

c. To aline the secondary, it is necessary to divide the load circuit into two symmetrical parts. This can be done by connecting two resistors of 100,000 ohms each (R2 and R3 of figure 82) across load resistor R1. With R2 and R3 connected as in figure 82, connect the voltmeter between the junction of the two added resistors and the audio output terminal of the detector (X1 and Y of fig. 82). Tune the secondary of T for a zero indication on the voltmeter.

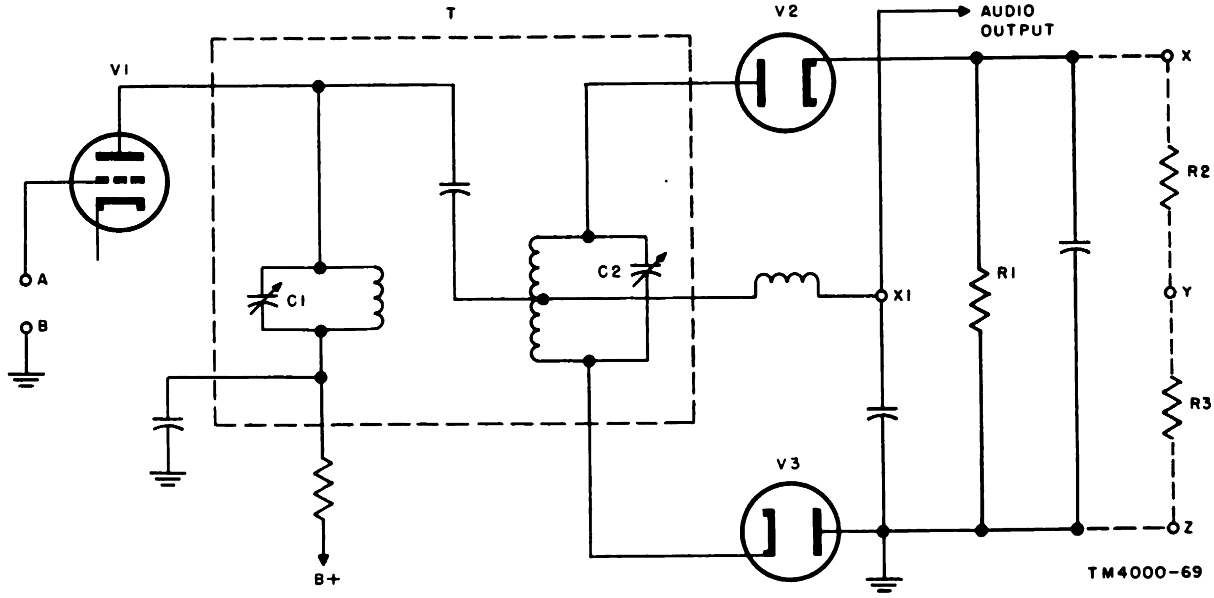


Figure 82. Ratio detector circuit, showing modification for alinement.

245. Meter Alinement of IF and Limiter Stages

a. In receivers that use a ratio detector, the IF stages are alined by measuring the detector output voltage while tuning the IF amplifiers. To do this, connect the voltmeter across the ratio detector load resistor (such as R1 of fig. 82).

b. Set the signal generator to the correct frequency and connect its output to the grid of each IF stage; work from the detector circuit toward the mixer. After generator is connected at each stage, tune the output coupling circuit of that stage for maximum indication on the voltmeter.

c. In receivers that use a discriminator circuit, the discriminator is preceded by one or more limiter stages. In these receivers, the limiters must be alined before the IF stages.

d. If two limiters are used and they are coupled by a tunable circuit, they may be alined in the following manner:

(1) Connect the signal generator (adjusted for the correct IF) to the input of the first limiter.

(2) Connect the voltmeter across the grid resistor of the second limiter. If two resistors are used in series in the limiter grid circuit, connect the voltmeter between the junction of the resistors and ground.

(3) Tune the coupling circuit between the limiters for a maximum indication on the voltmeter. The signal generator output should be kept low so that the voltage indication will rise sharply when the limiter tuning is rocked back and forth.

e. The IF stages of a receiver that uses limiters are alined in a manner very similar to that outlined in paragraphs *a* and *b* above. The only difference is that the voltmeter is connected across the first limiter grid resistor instead of across the detector load. The IF stages are still tuned for a maximum indication of voltage.

246. Meter Alinement of RF, Mixer, and Oscillator Stages

The alinement of RF, mixer, and oscillator stages in fm receivers is similar to the alinement of the same stages in am receivers (pars. 229, 233, and 234). The signal generator used for fm receiver alinement must be tunable over the same range of frequencies as the receiver and have either an fm or unmodulated output. The voltmeter used for indications of alinement is connected the same as for IF alinment (par. 245) in fm receivers.

247. IF Alinement by Use of Oscilloscope

a. A cathode-ray oscilloscope and sweep generator can be used when alining the IF stages of an fm receiver and better results can be obtained than with a meter and am signal generator. With this method, the actual tuned-circuit response curves are traced out on the oscilloscope screen. The curve shown on the oscilloscope in figure 83 is typical. The peak of the curve must be exactly at the resting frequency.

(1) To insure that the peak is at the resting frequency and that the band-pass characteristics are correct, marker signals must be used. Marker signals, properly injected into the circuit being alined, will produce pips at points on the response curve corresponding to the frequencies of the marker signals.

(2) Any signal generator that is accurately calibrated and that can be tuned to produce an unmodulated signal at the desired marker frequency may be used as a marker generator. Some special generators can supply several marker signals simultaneously.

(3) To obtain the three pips as shown in figure 83, it is necessary to inject marker signals at frequencies corresponding to the center, upper limit, and lower limit of the IF pass band.

(4) Unless the band-pass characteristics are very critical, one marker signal at the center frequency is usually sufficient.

b. To aline IF stages by this method, connect the vertical terminals of the oscilloscope across the grid resistor in the limiter stage. Connect the sweep generator to the grid of the last IF stage. Figure 83 shows the block diagram connections.

c. Adjust the primary and secondary trimmers until the desired response curve is obtained on the screen.

d. Aline the other IF stages by moving the signal-generator input to the receiver, one stage at a time, back toward the mixer stage and by repeating the above procedure.

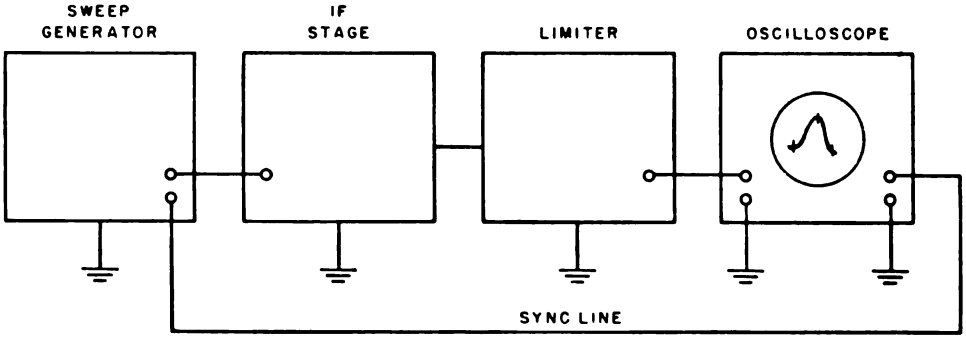


Figure 83. Connections for visual alinement of IF stages.

248. Visual Alinement of Discriminators and Ratio Detectors

a. *Discriminator Alinement.*

(1) Figure 84 shows the block diagram connections required for discriminator alinement. The two pips shown on the oscilloscope of the figure may be obtained by connecting two marker signals, at the upper- and lower-limit frequencies of the IF pass band, in parallel with the sweep-generator input.

(2) Connect the vertical input of the oscilloscope across the audio output circuit of the discriminator. Connect the fm sweep generator to the grid circuit of the last limiter stage. Connect the sweep voltage of the fm generator (sync line of fig. 84) to the horizontal input of the oscilloscope.

(3) If the discriminator is properly alined, a sharply defined S curve will appear well-centered on the oscilloscope. A further aid to determine the linearity of the discriminator is a marker signal at the center of the IF pass band. This marker will appear at the center of the S curve when the linearity is good.

(4) A raggedly shaped S curve indicates a poorly alined primary circuit. Tune the primary of the discriminator input circuit until a smooth S curve (fig. 84) of maximum amplitude is obtained.

(5) The secondary of the discriminator is tuned for maximum length of the linear portion of the S curve. If the marker signal is used ((3) above), the tuning is for centering of the S curve on the marker pip.

b. *Ratio Detector Alinement.*

(1) When alining fm receivers that use ratio detectors, connect the fm signal generator to the grid of the last IF stage. Connect the audio output of the ratio detector to the vertical input of the oscilloscope. Proper alinement is indicated by the previously mentioned S curve, the same as for the discriminator, but there the similarity ends. If the secondary of the detector input transformer is detuned, the S curve will become the familiar bell curve (fig. 83).

(2) Start the alinement by detuning the secondary of the detector input transformer. This should result in a bell-shaped curve on the oscilloscope. Tune the primary for maximum amplitude of the bell curve.

(3) Aline the remaining IF stages, one at a time, moving towards the mixer. Then adjust the secondary of the detector transformer for the S curve. A marker signal, injected with the IF signal, is helpful in centering the S curve.

249. RF Alinement by Use of Oscilloscope

a. The visual method can be used to aline the RF, mixer, and oscillator stages of an fm receiver. Connect the vertical input of the oscilloscope across the limiter grid resistor and the sweep generator output to the antenna terminals of the receiver. The test setup is the same as that in figure 83 except for the point of sweep generator connection.

b. Set the sweep generator and receiver to

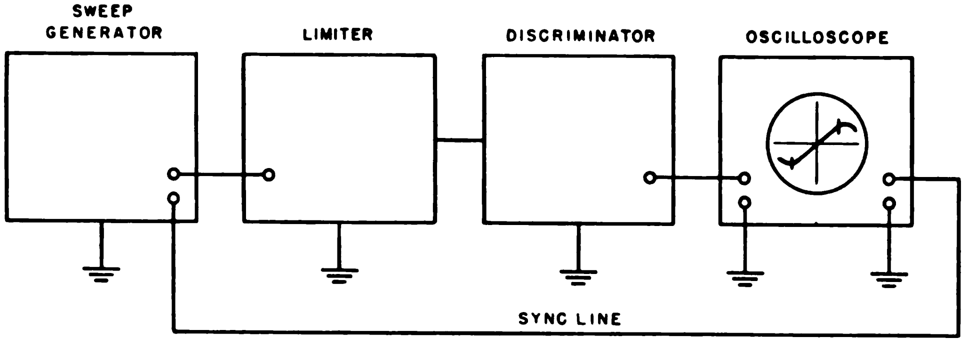


Figure 84. Connections for visual alinement of discriminators.

the same frequency near the high end of the receiver dial. This should be done with an accurately calibrated marker generator or frequency meter. The sweep generator should be adjusted to sweep at least twice the frequency width that the receiver is designed to pass to insure a display of the entire band-pass response curve.

c. Adjust the oscillator trimmer (also the RF and mixer trimmers if used) for maximum amplitude of the response curve on the oscilloscope.

d. Set the sweep generator and receiver to the same frequency near the low end of the receiver dial. Check the calibration (*b* above). Adjust the oscillator padder (also the RF and mixer padder, if used) for a maximum amplitude of the response curve on the oscilloscope.

e. Note the amplitude of the response curve in *c* and *d* above and repeat the high and low end alinement until no further increase can be obtained.

f. A final check of the receiver dial calibration and tracking should be made. This is done by checking the receiver at several frequencies throughout the tuning range of the band being alined. Set the sweep and marker generators accurately at each of these frequencies and check the receiver's output on the oscilloscope. Calibration and tracking of the receiver is checked by observing that the marker pip is in the same position on the response curve and that the curve is the same amplitude on the oscilloscope at each of the check points.

CHAPTER 10

REPAIRS AND ADJUSTMENTS

Section I. REPAIRS

250. General

a. Radio repair is the work done to restore a radio set to efficient operating condition after troubleshooting has identified and isolated the fault. It consists of realinment, the replacement of defective parts, including tubes, and all necessary disassembly and reassembly work.

b. After equipment has been repaired it should be given an operational check to insure that the over-all performance is satisfactory. The equipment performance checklist in the technical manual is for this purpose.

c. When unsoldering a connection, whether it is the pigtail lead of a resistor or capacitor, or the lead of a transformer, heat the solder joint just enough to melt the solder. When the solder is soft, use a tool to separate the lead from the lug. Twisting and pulling at the lead can splatter solder into inaccessible places and cause short circuits that are difficult to find, and can break the connecting lug. Shake excess solder from the iron to prevent the solder from dropping into the set.

d. When a part is being replaced, tag the disconnected leads or identify them in a sketch to insure proper connections to the new part. Tagging the leads enables one man to complete a job which another man has started.

e. Some equipments are so compact that it is often necessary to remove certain parts or subassemblies to reach the part to be changed. For further information, consult the equipment technical manual.

251. Installing Small Replacement Parts

a. When defective parts are replaced, exact replacement parts must be used if available. This procedure will insure normal operation of the equipment, if it operated normally before the part failed. If an exact replacement part is not available, and the original part is beyond repair, an equivalent or better part should be substituted for it. In very compact equipment there are parts that can be replaced only by identical parts because the original fitted into a very small space.

b. The new part must, if at all possible, be installed in the same place. If this is not possible, and there is room elsewhere, it can be installed where there is space. The disadvantage in changing the position of parts, especially in RF units or other high-frequency circuits, is that the change may affect the tuning and alinement. Substitute parts can be used temporarily until the exact replacement part is obtained. A tag should be attached to the set, indicating the part that was installed.

c. Before soldering any connections, carefully scrape and clean all connections on parts that will come in contact with solder. This means removing all corrosion, paint and also the enamel insulation on the wire leads. Tin the lugs and leads with solder to be sure that when the joint is made there will be a perfect bond by the solder. Make a good mechanical connection by twisting the wire lead around the lug several times before soldering. *Do not depend on the solder to form a mechanical bond.* Use only enough solder to join the wire to the lug and remove the soldering iron as soon as solder flows well into the joint. When soldering very small parts such as low-wattage resistors, ceramic capacitors or germanium diodes, hold the pigtail lead with a pair of long-nosed pliers at a point between the part and the joint you are about to solder. Thus interposed between the part and the source of heat, the pliers form a sink into which the excessive heat drains off before reaching the part. Hold the pliers in this position until after the solder has cooled. This quickens the cooling of the solder while at the same time it continues to protect the part against the heat.

d. Many equipments have been fungus-proofed with a special material to keep fungi from attacking and ruining them. When a fungus-proofed part is removed and replaced with a new one, the new part may have to be given the fungus-proof treatment. Some solder joints are also treated thus and if they are heated with a soldering iron the treatment is no longer effective. Fungus-proof all resoldered joints.

252. Repair and Replacement of Variable Capacitors

a. Variable capacitors do not normally become defective during operation. Mishandling a receiver or transmitter can ruin capacitor plates or bend them out of place; it may then be necessary to replace the capacitor or capacitor gang. If the plates are bent only slightly they can be straightened out with ordinary tools. Other troubles include poor contact at the rotor wiper springs, and loose pigtail connections.

b. Erratic operation can be caused in a receiver if there is dirt or other foreign matter between the tuning capacitor plates. The trouble will be noticed mostly while the set is being tuned. The spaces between the plates can be cleaned with an ordinary pipe cleaner.

c. Erratic operation can also be caused in a transmitter by dirt that is lodged between the capacitor plates. Arcing will occur where the foreign matter is present. A pipe cleaner or a screw driver with a cloth wrapped around the blade will remove it.

d. Some transmitter and receiver tuning capacitor plates are plated with zinc or other metallic material. The plating may peel over small areas and leave slivers that will cause arcing or erratic operation. If the plates have wide spacing between them, the plating can be removed with a pair of long-nosed pliers.

e. If the slivers cannot be removed they can be burned off by connecting a high ac voltage across the capacitor. Sometimes the line voltage will be sufficient; if not, the high voltage may be obtained from the high voltage winding of a separate power transformer. If a separate transformer is not available, it can be taken from the high voltage winding of the transformer of the set under repair. For safety, a light bulb should be connected in series with the ac line voltage. The coil connected across the capacitor must be disconnected to prevent it from burning out. To prevent any possible damage to the filter circuit, the rectifier should be removed, if the set transformer is used.

f. If the capacitor develops trouble, every effort should be made to repair, rather than replace it; for replacement would involve realinement of the RF, mixer, and local oscillator. If the capacitor cannot be repaired, the replacement work will be difficult. Follow the directions in the equipment technical manual, when alining the shafts with dials and couplings.

253. Relay Replacement and Repair

a. Relays are of different sizes and types. Some are replaced simply by unplugging the old one and plugging in a new one. This type usually is hermetically sealed in a can and cannot be repaired.

b. On some relays, certain repairs can be performed by leaving the relay in the equipment and removing a cover to gain access. Others must be removed from the equipment for repairs.

c. If the solenoid winding is open it may be repaired by the method used for repairing transformer windings.

d. The coils of certain relays are maintenance parts. If such a coil is defective, and a replacement is available, it should be used, regardless of the type of coil defect.

e. Figure 85 shows a relay assembly. If the contacts stick together they probably are pitted. If they are not too badly pitted they can be smoothed with a fine grade of crocus cloth. If they are deeply pitted they must be replaced. If the contacts are not replaceable the entire relay assembly must be replaced.

f. If the armature is not pulled down far enough to cause the contacts to touch, the energizing source may be weak. If the voltage is normal the armature-stop adjusting screw may have become loose because of vibration. If the tension on the armature-return spring is too great it will keep the armature from being pulled down as far as it should go. Correct setting of the two adjusting screws shown in the figure will

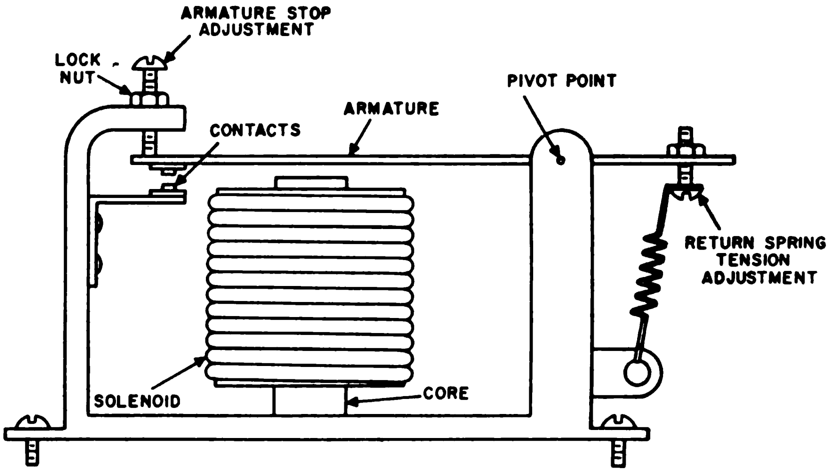


Figure 85. Relay assembly.

correct the trouble. Be sure to tighten both lock nuts securely after the adjustments have been made.

g. If the relay chatters, it may be caused by an energizing voltage that is not sufficient to hold the armature firmly in place against the pull of the armature return spring. It can also be caused by excessive tension in the return spring. Readjustment of the return spring tension adjusting screw will correct this fault.

254. Repairing and Cleaning Electrical Contacts

a. The spacing between the electrical contacts in relays and switches is often critical. If the troubleshooter finds they are touching when they should not be touching, or vice versa, the contacts must be set to their proper positions. Sometimes this involves the bending of an armature or wiper, and the equipment technical manual may specify the tools to be used for this purpose. Certain wipers and other spring contacts can be bent only a few times before they fatigue and break, and a new unit must be installed.

b. Use an abrasive, such as a fine crocus cloth, to clean the contacts when possible.

255. Tube Socket Repair

a. When the body of a socket is defective it must be replaced. The defective socket cannot be repaired. Certain types of sockets, especially octals, have replaceable contacts.

b. When a tube is removed from a socket by rocking it from side to side, one or more of the metal contact sleeves within the tube socket may become spread. This may result in poor or intermittent contact between the tube pin and the metal sleeve when a tube is reinserted in the socket. The metal sleeve of the contact may be repaired by inserting the tip of a pair of long-nosed pliers into the tube socket hole and compressing the sleeve to its original shape. If long-nosed pliers do not fit into the tube socket hole, the compression may be accomplished by inserting a pointed tool such as an awl between the sleeve and the inside wall of the hole containing it.

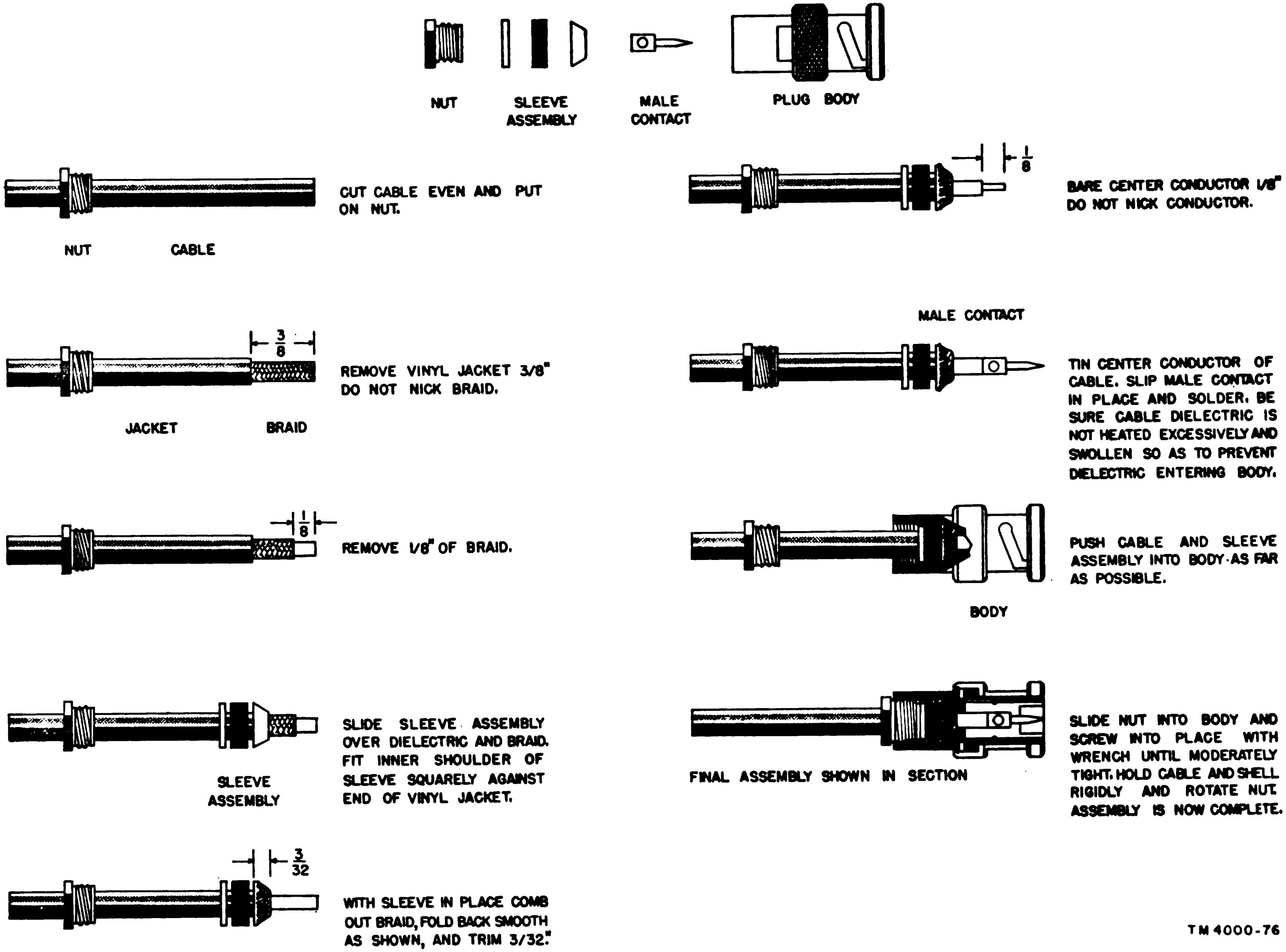
c. If the terminal is merely bent out of shape so that contact cannot be made or is intermittent, it probably can be bent back into shape with a pair of long-nosed pliers. It may be possible also to make contact by inserting a pointed tool such as an awl between the contact and socket body.

256. Cord and Cable Repairs

a. Cord trouble results from the breakage of a conductor at the connecting plug. To make the indicated repairs—

(1) Thread the cord through the hole in the plug and tie the wires in a simple knot. This procedure will keep the strain on the knot, rather than on the connection.

(2) Remove about one-half inch of the insulation from the end of each conductor and tin the ends of the wires. The tinning will form a solid mass at the ends and will eliminate loose ends and possible short circuits.



CUT CABLE EVEN AND PUT ON NUT.

REMOVE VINYL JACKET 3/8" DO NOT NICK BRAID.

REMOVE 1/8" OF BRAID.

SLIDE SLEEVE ASSEMBLY OVER DIELECTRIC AND BRAID. FIT INNER SHOULDER OF SLEEVE SQUARELY AGAINST END OF VINYL JACKET.

WITH SLEEVE IN PLACE COMB OUT BRAID, FOLD BACK SMOOTH AS SHOWN, AND TRIM 3/32."

BARE CENTER CONDUCTOR 1/8" DO NOT NICK CONDUCTOR.

TIN CENTER CONDUCTOR OF CABLE. SLIP MALE CONTACT IN PLACE AND SOLDER. BE SURE CABLE DIELECTRIC IS NOT HEATED EXCESSIVELY AND SWOLLEN SO AS TO PREVENT DIELECTRIC ENTERING BODY.

PUSH CABLE AND SLEEVE ASSEMBLY INTO BODY AS FAR AS POSSIBLE.

SLIDE NUT INTO BODY AND SCREW INTO PLACE WITH WRENCH UNTIL MODERATELY TIGHT. HOLD CABLE AND SHELL RIGIDLY AND ROTATE NUT. ASSEMBLY IS NOW COMPLETE.

Figure 86. Attaching plug to coaxial cable.

(3) Wrap each wire (in a clockwise direction) around a prong, then around a screw. When the screw is tightened, the wire will be pulled tight in the same direction.

b. In multiconductor cables the most common trouble is a broken conductor at the connector terminal. To effect repairs—

(1) Disassemble the connector and remove the broken end from the terminal while heating it with a soldering iron.

(2) Replace the connector. If the remaining wire is too short to reach the terminal, splice and solder a piece to it as an extension. Slip a piece of spaghetti tubing over the wire before the splice is made. After splicing and soldering, slide the spaghetti tubing over the joint.

(3) Solder the other end of the extension to the proper terminal. If necessary, clean out the excess solder from the terminal by heating it with a soldering iron. Shake the old solder out while it is still hot. All the conductors should be inspected, because if one is broken, others may be broken, or be near the breaking point. If others are badly worn replace the entire cable.

c. If two conductors short together inside the cable and it is impossible to open the cable, as in the case of one with a heavy rubber covering, replace the entire cable. If there are unused conductors in the cable, they can be used.

257. Repairing Shielded Cables

a. Shielded cables are repaired in the same manner as unshielded cables. The purpose of the shielding is to keep magnetic fields from causing interference in the cable and to prevent radiation from reaching the conductors. It is therefore important to reconnect the shield if it has been disconnected.

b. If the shielded cable has only one conductor in addition to the shield, the shield should always bear the strain. This is accomplished by making the shield connection shorter than any other connection, so that the shield will prevent the other conductor from breaking when any strain is put on the cable.

c. Sometimes it will be necessary to replace a plug on a coaxial cable. Follow the step-by-step procedure shown in figure 86. Take special care in cutting off the insulation. If the insulation is cut at right angles to the conductor as shown, there is danger of nicking the conductor; this will make it weak at that point and cause it to break easily. If the insulation is cut at an angle, as when sharpening a pencil with a knife, there will be less danger of nicking the wire.

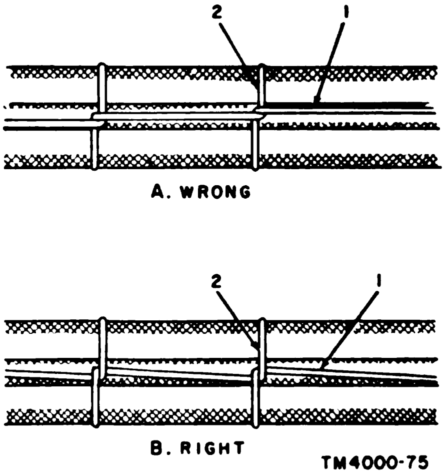


Figure 87. How to lace a cable.

258. Repairing Defective Laced Cables

a. A laced cable is made up of several single conductors laced together.

b. A conductor within a laced cable can often be repaired, but if it is damaged at more than one point it should be replaced. If the lacing is not extremely tight, the old conductor may be slipped out and a new one substituted. The lacing usually is tight, however, and it may be necessary to loosen it or remove it entirely. When replacing the cord, it should be laced tightly so that it cannot loosen again.

c. The right way to lace a cable is to make outside loops, which have a tendency to retain their tension, and hold the cable together, in the event of a break anywhere in the cord. This point is illustrated in figure 87, where an inside loop is shown in A and an outside loop in B. If the cord in A should break at point 1, the loop 2 would loosen and the entire lacing would come apart. But if the cord in B should break at point 1, the loop 2 would probably not loosen.

259. Repairing Dynamotors

a. The main source of trouble in dynamotors is caused by worn brushes. Worn brushes can cause the motor portion to become inoperative or will produce sparking. Worn brushes in the generator can result in an erratic output or no output at all. Refer to *d* below for information on replacing brushes.

b. A dirty commutator can affect the operation of the motor or the output of the generator. To clean the commutator, hold a short strip of No. 000 sandpaper against the dirty commutator while it is in operation. This will remove the corrosion. Remove the dust from between the commutator segments with a small brush.

c. If the brushes are arcing or do not make positive contact with the commutator, they probably need replacement. Arcing can also be caused by a weak or broken brush spring.

d. Some brushes have polarity markings and must be installed so that the polarity markings face away from the commutator. The commutator may become damaged if they are not installed in this manner.

260. Turning Down Commutator

a. A commutator surface can be renewed by turning it down on a lathe. The amount to be turned down usually is only a few thousandths of an inch, but a sufficient amount should be taken off to produce a smooth and round commutator surface.

b. After a smooth and round surface is obtained, the mica insulator strips between the commutator segments must be undercut until the level of the mica is below the surface of the commutator segments. A special undercutting tool usually is used, but if it is not available, the job can be done with a piece of broken hacksaw blade. Hold the blade with the teeth pointing in the opposite direction to the normal sawing position; that is, have the teeth pointing toward the body. This method can be used only when the thickness of the blade is less than the thickness of the mica.

c. Place the blade in a slot between two segments and pull it forward; then raise it and repeat the operation. Keep drawing the blade across the mica until the mica is below the surface of the commutator. Remove all foreign matter from the slots.

261. Lubrication

a. Units with bearings that are lubricated permanently when manufactured, ordinarily do not require any further attention. Occasionally, however, such bearings burn out. In such cases, exact replacements must be substituted for them.

b. Ordinary bearings may wear because dirt or other foreign matter becomes mixed with grease. If they are dirty, remove them and wash them in cleaning compound. Repack the bearings with the lubricant specified in the equipment technical manual.

Section II. FIELD EXPEDIENTS

262. General

a. An emergency repair is one that is made to keep the equipment operating until permanent repairs can be made. Any temporary expedient is an emergency repair. Sockets can be rewired to take substitute tubes, and resistor-capacitor combinations can be used to replace defective transformer windings. The workable sections of two similar receivers or transmitters can be connected together to form one complete operating unit. After an emergency repair has been accomplished the equipment should have a tag attached to it stating the nature of the temporary repairs that have been made. This is done to inform the repairman that permanent repairs are yet to be made.

b. Emergency projects that take a long time to carry out will defeat their purpose, which is to get the defective set back on the air in the shortest length of time. Army policy forbids, except as a last resort, emergency repairs that in effect produce modifications of the equipment.

263. Substitute Filament and Plate Transformers

a. If a transformer is defective and an exact replacement is not available, a similar transformer may be used if its electrical characteristics and connections are known. Such information can be found by using an ohmmeter and ac voltmeter. The ohmmeter and voltmeter may be in a multimeter or vtvm.

b. If the proposed substitute is too large to be installed in the space that was occupied by the original transformer it may, in an extreme emergency, be connected externally. It must also be determined whether the replacement transformer has the proper power rating.

c. Most transformers have terminals which usually are numbered. If a diagram of the windings and terminals appears on the transformer, the identification will be simple. If there is no diagram, the windings can be identified by their resistances and voltage tests described below.

d. Some transformers have leads instead of terminals. If the leads are color-coded, they can be identified by comparing the colors with those in the chart below. Although this code is standard, other codes may be used in some cases.

Power transformer lead color code

Leads	Colors
Primary	Black
If tapped:	
Common	Black
Tap	Black and yellow stripes
Finish	Black and red stripes
High-voltage plate	Red
Center tap	Red and yellow stripes
Rectifier filament	Yellow
Center tap	Yellow and blue stripes
Filament No. 1	Green
Center tap	Green and yellow stripes
Filament No. 2	Brown
Center tap	Brown and yellow stripes
Filament No. 3	Slate
Center tap	Slate and yellow stripes

e. The windings on the transformer with leads can be identified by visual inspection and by the thickness of the leads. The thicker leads are from the filament winding because the filaments draw more current than other circuits. In some transformers there will be two or three filament windings; one for the rectifier filaments and the others for the other filaments. The rectifier filament usually draws less than the other tube filaments combined.

f. The high-voltage winding carries the least amount of current, so the leads to it will be the thinnest of all. The primary winding is also thin; the difference can be determined by resistance measurements. Connect one ohmmeter prod to one lead and check for continuity to all other leads one at a time. The high-voltage winding will have the highest resistance, and the primary winding will have the next highest resistance.

g. A further check can be made with an ac voltmeter. When the primary winding has been found by the tests described above, connect it to the ac power line. Set the voltmeter to the highest range and measure the voltage across the thinnest leads. There probably will be three wires; the third one is the center tap, in the case of a full-wave rectifier circuit. The highest voltage will appear across the ends of the winding. If one half of this value is measured between either one of the end leads and another lead, the other lead is the center tap. The filament windings will show about 5 or 6 volts, depending on whether the winding being measured is the rectifier filament or the other filament winding.

h. There are some rectifier filaments that require 6.3 volts rather than 5 volts. In this instance the winding with the thinner wire usually is the rectifier filament winding. If they are about the same size, and a low-reading ohmmeter does not show any difference, the leads with the heavier insulation feed the rectifier filaments. This is because this winding is usually at a high potential with respect to the chassis.

i. Some power transformers have thin leads in addition to the leads described above. They are probably taps on the primary winding. Such taps are provided so that the proper secondary voltages will be produced regardless of the line voltage. Continuity checks will show whether they are connected to the primary end leads. The highest resistance will be indicated between the extreme ends of the primary winding; the next highest reading will be indicated between the next highest voltage tap and the other end. If in doubt about which taps to use, connect the lead that indicates a high resistance to all the other taps to one side of the line, and one of the taps to the other side of the line. Measure the filament voltage under load. If it reads too high or too low, select another tap until the reading is about right. As long as the line voltage remains fixed around the same value, the connections can be made permanent.

j. Filament and plate transformers are treated the same as power transformers. There are only two windings, the primary and secondary. Some transformers of this type may have center-tapped secondaries. The filament leads will be much heavier than the primary leads. In a plate transformer, the high-voltage winding will have a greater resistance than the primary winding.

264. Repairing Transformer Windings

a. If a primary or secondary winding is open, repair is impossible except in a relatively few cases. Such cases occur when the open winding is on the outside (that is, when it appears on top of the other windings) and when the break is on the surface layer and not buried under one or more turns of wire.

b. Repairable breaks are those that occur where a lead is soldered to the thin wire of a winding. The cause of the break, most often, is corrosion. Repair is effected by resoldering.

c. In a few instances it may be possible to repair a break inside a winding (below the surface layer) by fusion. Such a repair, however, would be only temporary. It is effected by applying a high-voltage momentarily across the ends of the winding; the power used should be of several hundred volts taken from the B-plus line. If the separation is not too great, the applied voltage may cause an arc that will fuse the separated ends of the wire.

265. Tube Reactivation

a. If a tube checker test indicates that a tube has low emission, it may be possible to reactivate the tube. Apply a voltage of 2 to 3 times the normal voltage to the filaments for a few seconds with the plate voltage removed. This will force to the surface some of the electrons that are well within the cathode. This procedure is a temporary one and applies only to tubes with certain types of cathode material. However, it can be tried on any tube if the tube cannot be used otherwise.

b. If the tube does not respond to this treatment, the filament can be subjected to a voltage about one and one-half times the normal value for several hours with the plate voltage removed.

c. If the tube is in a transmitter, and there is a filament rheostat in the circuit, the rheostat can be set to increase the filament voltage gradually until the correct value of plate current flows.

266. Tube Substitution

a. If a tube is not available to replace one that is defective a substitute must be used. Substituting one type of tube for another should be attempted only as an emergency measure because the equipment probably will not operate as well as it did with the original tube and considerable labor may be involved. Do not put a substitute tube into a socket unless the substitute tube characteristics and socket connections have been compared with those of the original tube. If this procedure is not followed the filaments may burn out or the power supply may be short-circuited.

b. A tube of similar electrical characteristics may prove a more or less effective substitute depending upon the purpose for which it would be used. A power tube would not be used to replace a voltage amplifier because the filament and plate current drain would probably be excessive. If the tubes are wired in parallel a slight difference in filament current rating will not matter. If the filaments are in series, the filament drain must be the same for all tubes.

c. A tube of similar electrical characteristics may be physically different from the original tube. If it is considerably larger, it may not be usable. If it has a different type of base, the socket will have to be changed to make it available for use.

d. Tube substitution in critical RF amplifier and oscillator circuits may necessitate the realinement of the circuits.

267. Repairing Vibrators

A defective vibrator should be replaced. If no replacement is available and if the defect is traceable to the contacts, it may be possible to make temporary repairs.

a. If there is no mechanical hum when the power is turned on, the contacts probably are stuck in the open position. Strike the vibrator can or housing several sharp blows. The vibrator may start operating again.

b. If the fuse blows immediately when the power is turned on, there is a probability that the contacts are stuck in the closed position. Open the vibrator can, or housing, by unsoldering or by removing the screws. Force the contacts apart and make repairs as in any defective contact.

Section III. ADJUSTMENTS

268. General

a. The controls of a radio set are divided, conventionally, into two categories: adjustments and operating controls. Adjustments are those controls that are used by the repairman to bring the set to its peak of operating efficiency and keep it there. In many instances the adjustment is equipped with a locking device that must be tightened to prevent the adjustment from changing after it has been set. Operating controls are those that are used by the operator in the normal use of the set.

b. The replacement of any part, or even the making of repairs, may necessitate a resetting of one or more adjustments.

c. Adjustments are always necessary after the replacement of a variable component or of a fixed component that influences the operation of a variable. Such influence can result if the fixed component is either in series or in parallel with the variable.

d. Even when exact replacements are used, differences must be accommodated. These differences lie within the limits of the manufacturer's tolerances, but in critical circuits they acquire considerable importance.

e. The adjustments made necessary by replacements and repairs may amount, in some instances, to a complete realinement of the set.

f. After all replacements and repairs, the technician should check the set for proper operation and follow through on the adjustments that are revealed to be necessary.

269. Transmitter RF Amplifier Neutralizing Procedure

a. When a tube, especially a triode, is used as an RF amplifier, it is usually necessary to neutralize the stage to prevent it from breaking into oscillation. In addition to following the instructions in *b* through *g* below, an oscillating RF amplifier can sometimes be detected by noting RF output from the transmitter when the oscillator tube is removed from its socket.

b. Remove the plate voltage from the stage that is being neutralized and apply excitation to the circuit. Couple an RF indicator to the plate tank coil. The indicator can be a simple one, such as a dial lamp connected to the ends of a single-turn loop of wire.

c. Rotate the plate tank capacitor through its range. If the lamp glows at resonance, the stage is not neutralized. To neutralize the stage, adjust the neutralizing capacitor or other neutralizing device until the glow in the lamp disappears.

d. A stage with tubes in a push-pull circuit has two neutralizing capacitors. Adjust them to get the same results as above. If possible, keep them at about the same capacitance.

e. If the neutralizing device knobs are set to the approximate correct positions before neutralizing is begun, the adjustments can be performed quickly.

f. If a transmitter has a milliammeter in the grid circuit of the final RF amplifier, remove the plate voltage from the stage being neutralized. Apply sufficient excitation to the stage to produce a grid current indication on the meter, and then tune the grid circuit to resonance (indicated by maximum grid current).

g. Tune the plate capacitor through its range. If there is a change in grid current, the stage is not neutralized. Slowly adjust the neutralizing capacitor to a point where there is no change in grid current when the plate tank capacitor is tuned through resonance.

270. Modulator Adjustments with Wave-Envelope Patterns

a. When a transmitter is being used for voice operation, the carrier must be modulated properly. Undermodulation will cause a low output, and overmodulation will cause distortion and interference with adjacent channels.

b. To check modulation characteristics while the modulator gain control is being adjusted, observe the results on an oscilloscope screen. Figure 88 shows the connections to the oscilloscope that will cause the modulation-envelope pattern to appear on the screen. Coil L1 is the antenna coupling coil, and L2 is the final tank coil. Coil L3, the third winding, can be wound with a few turns of insulated wire and coupled to the tank. The connections are made directly to the vertical plates and not through the vertical amplifiers. Connections can be made through the vertical amplifiers only when its positive response is wide enough to handle RF. Note that the sweep circuit switch is turned on.

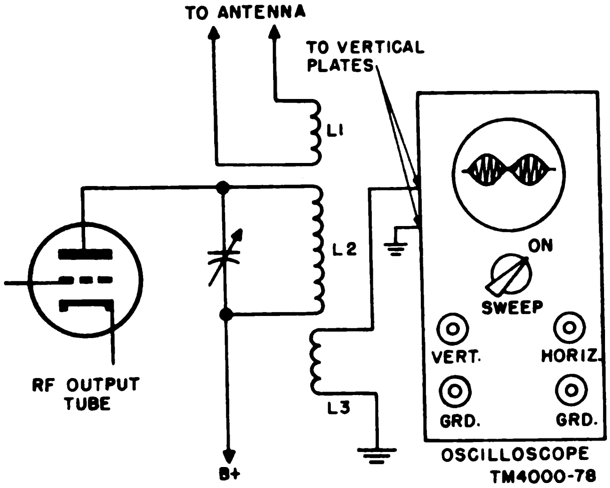


Figure 88. Oscilloscope connections for checking modulation-envelope pattern.

c. Refer to figure 89. Before the modulating signal is applied, pick-up coil L3 should be oriented with respect to tank coil L2 until a suitable height is obtained. The horizontal sweep voltage should be adjusted until the pattern is wide enough to fill more than half of the oscilloscope screen.

d. Feed an audio sine-wave signal into the modulator. Adjust the modulator gain control until the wave form resembles that in B, figure 89. Note that the peak voltages are twice the unmodulated carrier amplitude.

e. If the modulator output is insufficient for complete modulation, the wave envelope may appear as that in C, figure 89. It the gain control is advanced too far, overmodulation will take place and the wave form will separate completely as at point X in B, figure 89.

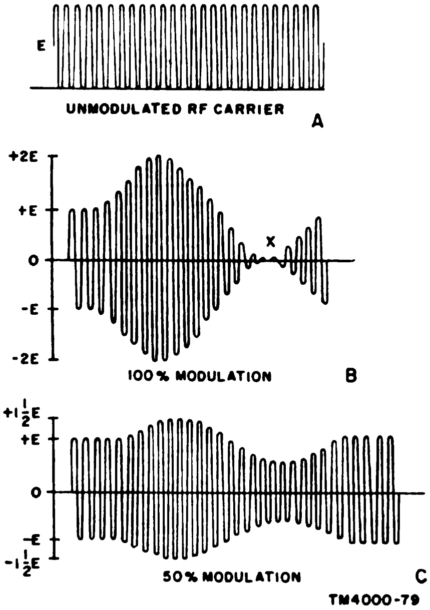


Figure 89. Modulation-envelope patterns.

271. Modulation Adjustments with Trapezoidal Patterns

a. When the oscilloscope is connected as shown in figure 90, the wave form shows the modulated carrier amplitude plotted as a function of the modulating voltage, rather than as a function of time, as in figure 89.

b. In this case, the connections are made to the horizontal and vertical amplifier terminals, and not directly to the deflection plate terminals. Coil L3 is a pick-up coil that can be wound with a few turns of insulated wire and coupled to L2, the output tank coil. Note that the sweep control is turned off. The value of R should be between .25 and 1 megohm, and will vary with the size of the oscilloscope screen. The value of C should be about .005 μ.

c. To adjust the modulator gain control for the desired output, proceed as follows:

(1) Turn the transmitter on but leave the modulator gain control turned off. A vertical trace as shown in A, figure 91 will appear on the screen. The trace represents the RF carrier voltage. It can be set to the desired height with the oscilloscope vertical control.

(2) Turn up the modulator gain control;

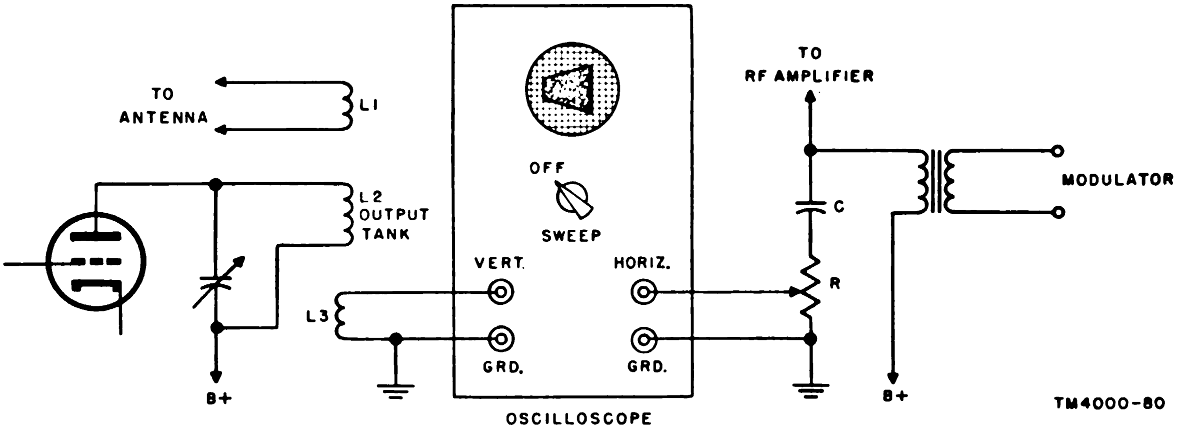


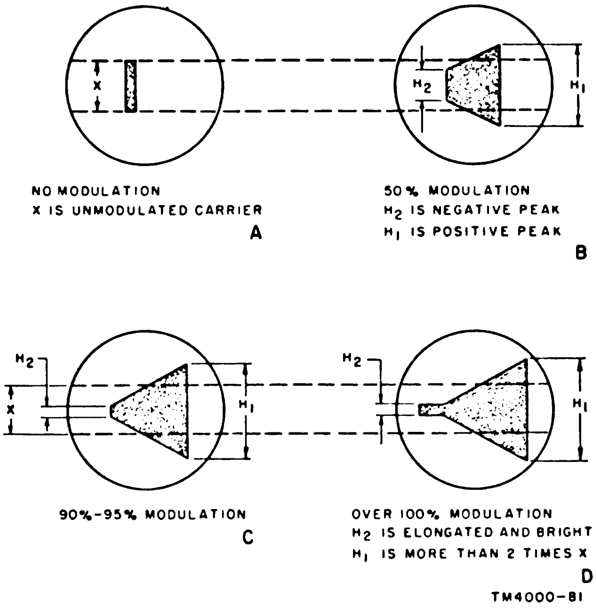
Figure 90. Oscilloscope connections for checking trapezoidal wave forms.

the trapezoidal pattern will now be visible. The width of the pattern can be adjusted by varying the resistance of R in figure 90.

272. Modulation Percentage

Count the number of divisions that the modulating voltage causes the carrier amplitude to increase or decrease from its former level X. This is indicated by H_1 and H_2, respectively, in figure 91. Substitute that value in the formula below and calculate the percentage of modulation.

$$\text{Modulation percentage} = \frac{H_1 - H_2}{H_1 + H_2} \times 100$$



NO MODULATION
X IS UNMODULATED CARRIER
A

50% MODULATION
H2 IS NEGATIVE PEAK
H1 IS POSITIVE PEAK
B

90%-95% MODULATION
C

OVER 100% MODULATION
H2 IS ELONGATED AND BRIGHT
H1 IS MORE THAN 2 TIMES X
D

Figure 91. Trapezoidal modulation patterns.

273. Adjusting Preset Circuits in Receivers

a. Some receivers have tuned circuits that can be tuned through a wide range of frequencies. Other receivers have separate adjustable tuned circuits for each channel, that are set to the desired frequencies and can be selected with a switch.

b. To adjust a preset tuned circuit, proceed as follows:

(1) Connect a modulated signal generator, tuned to the desired frequency, to the input of the tuned circuit.

(2) Connect an audio output meter or headset to the audio output stage and adjust the tuning capacitor for the greatest output in the headset or on the meter.

c. When adjusting a receiver local oscillator, set the oscillator frequency to the point where there will be maximum output from the receiver when it is tuned to the desired frequency. If the local oscillator is crystal-controlled, adjust the input tuned circuits to produce maximum output when a signal of the proper frequency is fed into the circuit.

d. Other channels are set up in a similar manner (*b* and *c* above), and are connected to a multicontact selector switch. The desired preset channel is connected into the circuit by throwing the switch.

e. These circuits usually have a coil with a shunt adjustable capacitor that can be set to resonate the circuit to the desired frequency. The procedure is the same as that in tuning a receiver, but the circuit is tuned to one frequency and the adjustment is left at that point. The adjustment is not disturbed until it is necessary to adjust the circuit to another preset frequency.

274. Adjusting Preset Circuits in Transmitters

a. In communication networks where certain prearranged frequencies are used and must be changed often and quickly, transmitters are usually provided with facilities for the operator to preset the frequency channels to be used.

b. The oscillator stage must be set to the proper frequency before any other stages can be tuned. The procedures for adjusting the stages in a transmitter using preset circuits is described in *c* through *f* below. The stages should be adjusted in the order given.

c. When possible set an accurate frequency meter to the frequency at which the oscillator is to operate. Couple the frequency meter loosely to the oscillator. Adjust the oscillator so that the frequency will be the same as that of the frequency meter. Adjust the buffer and final amplifier tuned circuits to resonate to the oscillator frequency.

d. The procedure for a frequency multiplier is slightly different. Set the frequency meter to the desired oscillator frequency, couple it to the oscillator, and set the oscillator to the same frequency. This frequency may be two, three, or even four times the oscillator fundamental frequency. Set the frequency meter to the frequency to which the multiplier is to be tuned, and couple it to the multiplier. Adjust the multiplier tuned circuit to that frequency. Adjusting the frequency of the multiplier is a more critical operation than tuning to the fundamental frequency; therefore more care and skill must be used.

e. Adjust all other similar preset tuned circuits to the proper frequency in the same manner. Each tuned circuit forms a different operation that can be connected into the rest of the circuit by throwing a switch.

f. If the oscillator frequency is controlled by a quartz crystal, tune the plate circuit to resonance with the crystal. If the oscillator output produces harmonics of the crystal, tune the plate circuit to the proper multiple of the crystal frequency. It will be necessary to set the frequency meter to the correct harmonic, and adjust the tuned circuit to resonate at that frequency.

CHAPTER 11

FINAL CHECKUP

Section I. TRANSMITTERS

275. General

Final checkup determines whether a transmitter meets certain performance standards. It is a duty that should be assigned to a repairman other than the one who made the repairs, and its purpose is to insure that the repaired equipment meets the standards of performance called for in the equipment technical manual. The test equipment required and the procedures to be followed are found in the equipment technical manual. A record is made of the results of the final checkup.

276. Measuring Am Power Output

a. The power output of a transmitter or, the RF power delivered to the final amplifier plate load is an absolute measure of the transmitter's operating efficiency. If the power input is normal and there is no output, the set's efficiency is 0 percent. If the input is normal and the output is at the peak level, the set's efficiency is 100 percent. Between these extremes, for every loss or gain of efficiency, there is a corresponding and proportionate loss or gain in output. The efficiency of a set can be measured by calculating the power output and comparing this with the output specified for the set.

b. To calculate the efficiency of a particular am transmitter, first consult the equipment technical manual and see what the power output should be. Assume that the am power output should be 470 watts on the low-frequency band and 400 watts on the high-frequency band. To measure the actual output proceed as follows:

(1) Construct an RF dummy load by connecting a number of available resistors in series-parallel to obtain a resistance equal to the output impedance of the transmitter. This value will probably be about 50 ohms. Be sure that the total wattage of the resistors used is at least 500.

(2) Connect an audio oscillator to the input of the first speech amplifier. Set the audio oscillator to 1,000 cycles with 1 milliwatt output across 600 ohms. This is equivalent to .75 volt.

(3) Connect an RF ammeter with a maximum range of 5 amperes between the antenna terminal and the RF dummy load.

(4) Couple the transmitter RF output to the vertical deflection terminals of an oscilloscope with a pick-up coil. The pick-up coil can be made by winding 2 to 4 turns of insulated wire (about No. 14) over a space of 3 inches. Couple it loosely to the final tank coil L2 (fig. 88).

(5) Set the transmitter function switch to the am position and turn on the power switch. Adjust the coupling coil so that the pattern covers a large portion of the oscilloscope screen.

(6) Adjust the audio gain control for 100 percent modulation indication on the oscilloscope. Refer to figures 88 and 89. The grid excitation meter should now indicate a maximum current of 8 ma.

(7) The power output is calculated from the formula $P = I^2R$, where I is the current reading on the RF meter and R is the dummy load resistance.

277. Modulation Capability Measurements

a. Amplitude-modulation measurements are necessary to determine whether the transmitter is being modulated properly. Modulation capabilities are measured by determining the minimum audio signal into the audio speech amplifier that is necessary to vary the carrier amplitude a certain amount. (Assume that the audio signal fed into the speech amplifier is to be not more than .7 volt to produce 100 percent modulation.) Then, to measure the amplitude capabilities proceed as follows:

(1) Set up the test equipment (par. 276 and fig. 88). Set the audio oscillator output to zero and the audio gain control on the transmitter for maximum output. Set the oscillator output to the point where 100 percent modulation is shown on the oscilloscope.

(2) Measure the voltage at the output of the audio oscillator. A voltage higher than the value specified indicates that troubleshooting is necessary.

b. Another method is to set the audio oscillator to a specified value. The percentage of modulation should be not less than that specified for the input given.

278. Overload Relay Adjustment
(fig. 73)

a. If there is a change in the value of current required to operate the cw overload relay, the transmitter may suffer damage. Such a condition may arise after repairs have been made, and especially if a substitute relay requires more current to operate than the original relay did.

b. A method of testing the adjustment of the relay is to measure the amount of current required to cause it to open. The example for adjusting the relay given below assumes that the cw overload relay must operate and open the power circuits when the current flowing through the relay reaches 450 ma during cw operation.

(1) Turn off the power switch. Remove the back panel to gain access to the high-voltage circuits. Bypass the interlock switches; they were opened when the panel was removed.

(2) Remove power amplifier tube V1 and clamper tube V2 from their sockets so that the only current drawn will be that passing through the resistor described below.

Caution: Be sure that the disconnected plate caps are insulated from ground to prevent the high-voltage power supply from being short-circuited. Although the power is turned off at this point, use a shorting stick or other insulated device as a safety precaution.

(3) Connect an adjustable-resistance dummy load with an adequate power rating and resistance (about 1,100 watts and 5,900 ohms) to high-voltage contact E4 behind the RF deck. Connect the other end of the dummy load to the positive terminal of a milliammeter that has a full-scale deflection of 1,000 milliamperes. Connect the negative terminal of the meter to the chassis. This places the meter and the dummy load in series across the power supply.

(4) Turn overload relay adjustment control R57 on the power supply deck fully clockwise (minimum resistance). Turn the power switch to the ON position and the function switch to the cw position.

(5) Adjust the dummy load resistance to a point where a current of 450 ma is indicated on the meter. Adjust R57 until the relay operates and opens the power supply circuits. At the same time, the plate power pilot light should go out and the current reading on the meter will drop to zero. Test the operation by reducing the dummy load resistance. Reset the relay and increase the load. Note the current at which the relay opens.

279. Am Overload Relay Adjustments
(fig. 73)

a. During voice operation, the equipment should also be protected. The procedure is the same as that described in the preceding paragraph with the exception of the value of the current that will operate the relay.

b. Set up the transmitter and test equipment as described in paragraph 278, but change the value of the resistor. There is more current drawn during am operation than during cw operation; therefore the relay will operate at a different value of current.

c. To draw the required current of 550 ma, the adjustable resistor should have a power rating of 1,400 watts and a resistance of about 4,500 ohms.

d. Turn the power switch on and set the function switch to the am position. Turn the am overload relay adjustment R56 on the power supply deck to the maximum clockwise position.

e. Adjust the resistance value until a current of 550 ma is indicated on the meter. Turn the am overload relay adjustment control until the overload relay operates. The plate power indicating pilot light should go out and the meter reading will drop to zero.

280. Am and Fm Frequency Indication Accuracy Tests

a. Frequency accuracy is important, especially in transmitters that have dials that are calibrated directly in frequency.

b. The frequency accuracy of a transmitter can be measured by picking up the transmitted signal on a calibrated instrument such as a highly accurate receiver or frequency meter.

c. An example of a frequency accuracy check is given below. The frequency in this example must be accurate to within .01 percent.

(1) Set the transmitter to the lowest operating frequency. Tune a very accurate receiver or frequency meter to the modulated transmitter signal.

(2) Read the frequency indicated on the receiver or frequency meter and compare it with the transmitter frequency. Calculate the percentage of error by using the following formula:

$$\text{Percent of error} = \frac{Ed}{Fn} \times 100,$$

where Ed is the difference between the measured frequency and what the frequency should be, and Fn is what the frequency should be.

Example: $\text{Percent of error} = \frac{50 \text{ kc}}{1{,}950 \text{ kc}} \times 100 = 2.5 \text{ percent error.}$

d. This test procedure should be made at several frequencies within the operating range of the transmitter because the output may be accurate at only certain frequencies.

281. Am and Fm Frequency Range Tests

a. The range of frequencies which the transmitter covers must be as specified.

b. The frequency range can be checked by a method similar to that used in paragraph 280. It is only necessary to determine whether the transmitter covers the correct frequencies.

c. An example of testing frequency coverage follows:

(1) Set an accurate receiver or frequency meter to the lowest frequency to be transmitted.

(2) Vary the transmitter frequency until the signal is picked up on the receiver or frequency meter.

(3) Use the same procedure for the highest frequency to be covered.

282. Frequency-Modulation Measurements

a. Many final tests apply to both am and fm transmitters. The method of modulation and the method of modulation measurements, however, are different in fm transmitters. Therefore make the fm tests separately.

b. The modulation capabilities of an fm transmitter determine the quality of the signal received in a distant receiver. It is therefore important to be sure that it is in proper operating condition.

c. Because the frequency deviation is directly proportional to the strength of the audio signal, the deviation must be measured as a modulation test.

d. A method of measuring frequency deviation in an fm transmitter is given in *e*(1) through (8) below.

e. The frequency deviation of an fm transmitter can be determined by measuring the amount of audio output produced in a calibrated fm receiver. The following procedure will indicate whether the transmitter meets the required deviation specifications. Any fm receiver that can handle the transmitter deviation and is capable of covering the frequency range of the transmitter, can be used. Calibrate the receiver as follows:

(1) Connect the output of an fm signal generator through an impedance-matching network to the antenna terminals of the receiver to be calibrated.

(2) Adjust the frequency of the signal generator and the receiver to the transmitter center frequency. Set the output of the signal generator to 1,000 microvolts.
(3) Set the frequency deviation of the signal generator to 1 kc.
(4) Measure the audio output of the receiver discriminator and record it. Refer to paragraph 182*c* for connecting the ac vtvm to the discriminator.
(5) Change the frequency deviation of the signal generator to 25 kc.
(6) Measure the discriminator output and record it.
(7) The receiver is now calibrated.
(8) Remove the signal generator connections and connect an antenna to the receiver.
(9) Measure the transmitter frequency deviation as follows: Connect an audio signal generator, set to 1 kc, to the input of the modulator speech amplifier.
(10) Turn on the transmitter. The receiver discriminator output voltage should be the value obtained in (4) above.
(11) The audio output will be of a different value depending on the frequency of the modulating signal. The chart below shows some arbitrary values of discriminator voltages obtained with certain frequency deviation values.

Discriminator output (volts)	Deviation (kc)
2	1
5	6
10	15
15	20

Section II. RECEIVERS

283. General

The information in paragraph 275 applies to receivers as well as transmitters. Therefore it will not be repeated here.

284. Am Receiver Sensitivity

The am sensitivity of a receiver is the value of the modulated input signal necessary to produce a specified (usually 10 to 1) signal-plus-noise to noise ratio. The sensitivity for a signal-plus-noise to noise ratio of 10 may be obtained as follows:

a. Connect a signal generator, whose output is calibrated, to the receiver antenna terminals. Connect a 600-ohm resistor across the receiver audio output and connect an ac vtvm across the resistor.

b. Tune the receiver and the signal generator to the same frequency and set the signal generator for 30 percent modulation at 400 cycles per second.

c. Turn the signal generator modulation off and adjust the receiver AF gain control until the vtvm indicates .8 volt (1 milliwatt). This is the noise output.

d. Turn on the signal generator modulation and adjust the signal generator output until a signal-plus-noise reading of 2.5 volts (10 milliwatts) is obtained on the vtvm. At this point the signal from the signal generator produces a signal-plus-noise to noise ratio of 10 to 1. Note the value of the signal generator output. This is the am sensitivity.

285. Cw Sensitivity

The cw sensitivity is expressed in the same manner as the am sensitivity defined in paragraph 284. The cw sensitivity for a signal-plus-noise to noise ratio of 10 may be obtained as follows:

a. Connect a signal generator, whose output is calibrated, to the receiver antenna terminals. Connect a 600-ohm resistor across the receiver audio output and connect an ac vtvm across the resistor.

b. Tune the receiver and unmodulated signal generator to the same frequency. Turn on the receiver bfo and set it to produce a 1,000-cycle beat note.

c. Turn off the signal generator and adjust the receiver AF gain control until the vtvm indicates .8 volt (1 milliwatt).

d. Turn on the signal generator and adjust its output until a reading of 2.5 volts (10 milliwatts) is obtained on the vtvm. Note the value of the signal generator output. This is the cw sensitivity.

286. Fm Receiver Quieting Sensitivity

Fm receiver quieting sensitivity is the smallest unmodulated carrier voltage that when applied to the receiver through a standard 300-ohm dummy antenna reduces the noise output of the receiver to a value of 30 db below the receiver output obtained when the standard test modulation is applied to the same signal input. It is expressed either in microvolts, or in decibels below 1 watt. For some military equipments the test is modified and is performed as described in the paragraphs that follow. All values used are arbitrary figures.

a. Connect an fm signal generator to the receiver antenna input terminals through a dummy load.

b. Connect an output meter and a 600-ohm resistor in parallel across the receiver audio output terminals. Turn the receiver squelch control to the OFF position.

c. Connect a dc vtvm across the grid resistor in the limiter circuit (fig. 92).

d. Set the signal generator to produce a 1.5-microvolt unmodulated signal at 40 mc.

e. Tune the receiver to 40 mc. Adjust the signal generator frequency for a maximum indication on the vtvm and minimum indication on the output meter.

f. Reduce the signal generator output to .7 microvolt. This will be considered the standard RF input to the receiver. Turn the modulation on at 1,000 cycles and set the deviation to 15 kc.

g. Adjust the receiver volume control for a 1-mw indication on the output meter. This is the standard output.

h. Reduce the signal generator output to zero and note the db reading on the output meter.

i. Turn the signal generator modulation off and set the output to 1.5 microvolts of unmodulated carrier output. The db drop from that previously obtained (*h* above) should be at least 17 db. These values will vary with different receivers.

287. Fm Receiver Squelch Sensitivity

The squelch sensitivity test measures the output of the receiver under two conditions. One is the modulated signal input needed to produce an output signal when the squelch control is at maximum. The other is the modulated input signal needed to produce an output signal when the squelch control is at minimum. The ratio of these outputs is the squelch sensitivity.

a. Connect the equipment as instructed in paragraph 286.

b. Turn the signal generator modulation on and decrease the output to zero.

c. Turn the squelch control clockwise until the noise output cuts off.

d. Increase the signal generator output until the audio returns. This should occur before the signal generator output reaches 2 microvolts.

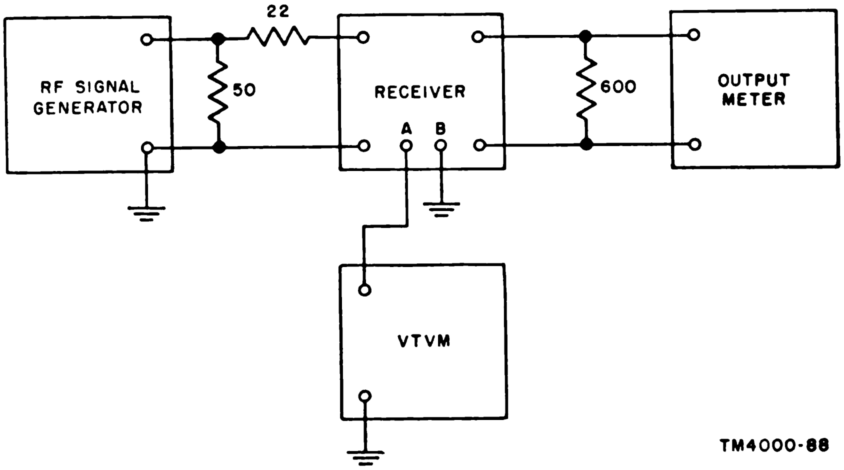


Figure 92. Quieting sensitivity test setup.

e. Turn the squelch control to the maximum clockwise position.

f. Increase the signal generator output until the audio output returns. The signal generator output should be less than 100 microvolts. This value should be at least four times as great as that mentioned in *d* above. This is a measure of the squelch sensitivity.

288. Fm Receiver Selectivity

a. This test determines the bandwidth of the RF and IF stages. If the selectivity is poor, the receiver may pick up unwanted signals that will interfere with the desired signals. This test, therefore, is important.

b. Connect the test equipment to the receiver as shown in figure 92 but omit the output meter connections. Terminals A and B are connections to the limiter grid and ground within the receiver. The 50- and 22-ohm resistors are for matching the signal generator output impedance of 50 ohms to the receiver input impedance of 72 ohms.

c. Set the signal generator to supply an unmodulated signal at 50 mc. Tune the receiver to 50 mc and adjust the signal generator for maximum limiter grid voltage as indicated on the vtvm. Adjust the receiver fine tuning control for maximum indication on the vtvm.

d. Adjust the signal generator output until a reading of —5 volts of limiter grid voltage is indicated on the vtvm. Note the value of the signal generator output voltage.

e. Vary the frequency of the signal generator on both sides of 50 mc until the same reading (—5 volts) is obtained on the vtvm. Note the frequency of the signal generator on each side of 50 mc when a value of —5 volts is produced. It must be the value that is specified for the receiver being tested.

f. The same procedure is used for checking the bandwidth of am receivers, except that the vtvm and load are connected to the audio output.

289. Am and Fm Frequency Coverage Tests

a. This test determines whether the receiver is capable of tuning to the same frequencies after it has been repaired. Any repair that could detune the RF, mixer, or oscillator circuits should be followed by this test.

b. A sensitivity test may be considered an RF coverage test within the limits of the frequencies covered. The frequency coverage test differs from a sensitivity test in that the object is to test the frequency coverage rather than the value of the signal produced in the receiver output.

c. A typical RF frequency coverage test is given below.

(1) Connect a signal generator to the antenna terminals through a dummy load. Use a headset or loudspeaker as an output indicator.

(2) Set the signal generator to the lowest frequency to which the receiver will respond, and tune the receiver to that signal. The signal should be received clearly, and the receiver should tune to a slightly lower frequency to insure that all modulation frequencies can be received.

(3) Repeat the procedure in (2) above, but set the signal generator and tune the receiver to the *highest* frequency to which the receiver will respond.

290. Fm Receiver Audio Output Test

a. In the sensitivity test on an fm receiver the indicating meter is in the limiter circuit. Because this test does not include the audio amplifiers, an audio test must be made separately.

b. The audio output test determines whether the gain of the audio amplifiers meets the specified standards.

c. The audio system must be capable of a voltage gain of at least 10,000 for the receiver in this example. A typical audio test is given below.

(1) Connect an audio signal generator to the input of the first audio amplifier, and set the signal generator to any frequency between 400 and 1,000 cycles.

(2) Connect a 100-ohm resistor across the output of the last audio stage, and connect an output meter across the resistor.

(3) With the aid of an ac vtvm, set the output of the audio oscillator to produce 1 millivolt. The reading on the output

meter should be at least 10 volts. This is a gain of 10,000.

291. Agc Tests

a. The agc circuit tests insure that strong signals are reduced in intensity by the time they reach the output of the receiver. If the agc circuit is completely inoperative, extra strong signals will produce strong blasts above the normal signal level when the receiver is tuned from one frequency to another. The values listed are arbitrary figures.

b. One method of checking the operation of the agc circuit is given below. The results to be expected are listed in the chart at the end of the test.

(1) Connect a signal generator, through a dummy load, to the antenna terminals of the receiver. Set the signal generator to a frequency that is approximately in the middle of the receiver tuning range.

(2) Connect a 600-ohm resistor across the audio output terminals of the receiver, and connect an ac vtvm across the resistor.

(3) Adjust the signal generator for an output of 5 microvolts and set the modulation frequency to 400 cycles at 30 percent modulation.

(4) Tune the receiver to the signal generator frequency, and adjust the receiver gain control to produce a 5-milliwatt output (1.73 volts across 600 ohms) on the vtvm.

(5) Increase the output of the signal generator and note the rise in the audio output. Compare the results with the figures in the chart below.

Input level in microvolts	Audio output not to exceed (volts)
5	1.7
1,000	2.4
1,000,000	4.3

292. Beat-Frequency Oscillator Test

a. The beat-frequency oscillator output usually is injected into the detector circuit to be mixed with the IF signal. If the bfo frequency becomes changed so that the beat note produced cannot be varied over a considerable range, it is not serving its purpose.

b. To determine whether the bfo is producing the proper frequency, proceed as follows:

(1) Tune the receiver to any convenient frequency and set the bfo control to the zero setting.

(2) Connect a signal generator to the antenna terminals through a dummy antenna. Adjust the signal generator, with no modulation, to the receiver frequency.

(3) Vary the bfo control to the maximum counterclockwise position, and then to the maximum clockwise position. Zero beat should occur halfway between the clockwise and counterclockwise positions. The extreme positions should produce a beat note of at least 1,000 cycles.

(4) To determine the frequency of the beat note, compare it with the signal from a calibrated audio oscillator.

CHAPTER 12

RADIAC PROCEDURES

Section I. INTRODUCTION TO RADIOACTIVITY

293. General

a. The development of nuclear reactors and nuclear weapons (fission and fusion) and the use of radioactive isotopes have introduced new and unseen dangers to humanity, namely radiation and radioactivity. Unfortunately, the human senses are unable to detect the presence of dangerous radiations. Special equipments are required to detect, indicate, and measure radiation in areas suspected of contamination. These equipments are called radiac detectors. The word radiac is coined from radio activity detection, identification and computation.

b. Before the functioning of radiac equipment can be understood, some knowledge of the nature of radioactivity is required.

294. Radioactivity

a. Disintegration. Radioactivity is the spontaneous emission of particles or rays caused by the disintegration or breaking up of an element. The result of this disintegration is another element. The disintegration and accompanying radioactivity may be natural or artificially induced.

(1) *Natural radioactivity.* A few chemical elements have natural radioactive properties. These elements break up into a series of other elements and in the process always emit radiations; the end product is usually lead. For instance, uranium breaks up into radon and radium in a sequence of many steps and finally ends up as stable lead. Thorium is radioactive while breaking up into other elements until it finally becomes stable lead.

(2) *Artificial radioactivity.* It is possible to bombard certain stable elements (aluminum, boron, cobalt, etc.) with radiation to produce a different element; these artificially produced elements are radioactive and in time disintegrate to form another stable element. Aluminum, upon bombardment by radiation, yields radioactive phosphorus which in time disintegrates into stable silicon.

b. Types of Radiation. Radiation, whether natural or artificially induced, is classified into three types—alpha particles, beta particles, and gamma rays. Elements that are disintegrating will produce one or more of these types of radiations at one time.

(1) *Alpha particles.* Alpha particles are helium nuclei (helium nuclei with a double positive charge), traveling at high speeds (up to 7 percent of the speed of light). These particles are positively charged and are relatively heavy; they have very strong ionizing power (power to dissociate stable molecules into electrically charged parts or ions) and poor penetrating power; they can be stopped by a sheet of paper (A, fig. 93).

(2) *Beta particles.* Beta particles are electrons moving at high speed. Therefore, the charge of the beta particle is negative; it travels at speeds up to 95 percent of the speed of light. Though beta particles have strong ionizing power, it is only approximately 1/100 that of the alpha particle. The penetrating power of these particles is stronger; a sheet of aluminum of a few millimeters in thickness is required to stop them (B, fig. 93).

(3) *Gamma rays.* Gamma rays are electromagnetic radiations just like radio

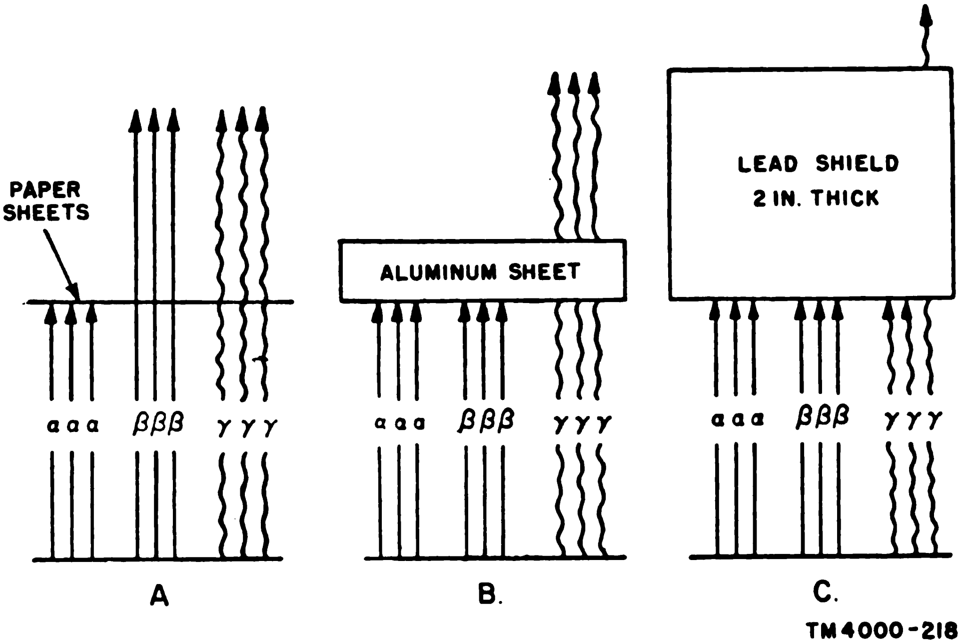


Figure 93. Penetration powers of alpha, beta and gamma radiations.

waves, light, or X-rays, but they have a much higher frequency of operation. *Gamma rays are not particles and carry no charge.* They are considered photons or bundles of electromagnetic energy. Compared to alpha and beta particles, gamma rays have a mild ionization power (about 1/10,000 that of the alpha particle) but have intense penetrating power; in fact, the rays can be detected after passing through 2 inches of lead (C, fig. 93).

295. Half-Life

In any radioactive element, the amount of radioactivity is proportional to the quantity of the element present. The time required for the strength of the radioactivity of an element to drop to one-half its initial value is called the half-life of that element. The rate of decay of radioactivity varies with each element. Radium, for example, loses one-half of its original radioactivity in approximately 1,600 years; the half-life of radium is therefore said to be 1,600 years. Cobalt 60, in contrast, has a half-life of approximately 5 years. Thus, 1 pound of cobalt 60 will have disintegrated to ½ pound in 5 years; in 10 years from the start, the amount of cobalt 60 in the sample will have dwindled to ¼ pound. The radioactivity of the sample of cobalt 60 will have dropped in the same manner (fig. 94). Starting with 100 percent, the radioactivity will have dropped to 50 percent in 5 years, to ½ of 50 percent or 25 percent in another 5 years (age 10), and to ½ of 25 percent or 12.5 percent in another 5 years (age 15).

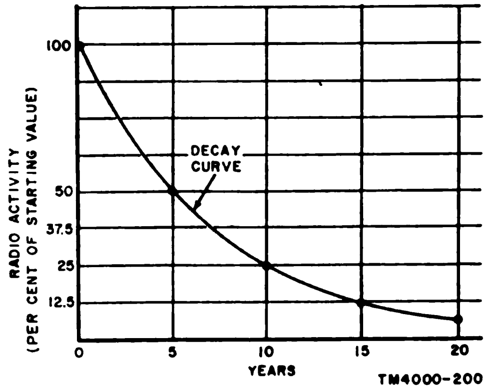


Figure 94. Decay curve of cobalt 60.

296. Decay and Distance Correction

Radioactive elements are used for medical purposes, in manufacturing processes, and in calibration procedures for radiac sets. In any use, the actual strength of radioactivity of the element must be known. This radiation strength decreases with time as well as with the distance between the source and the measuring device. To compensate for this characteristic, charts

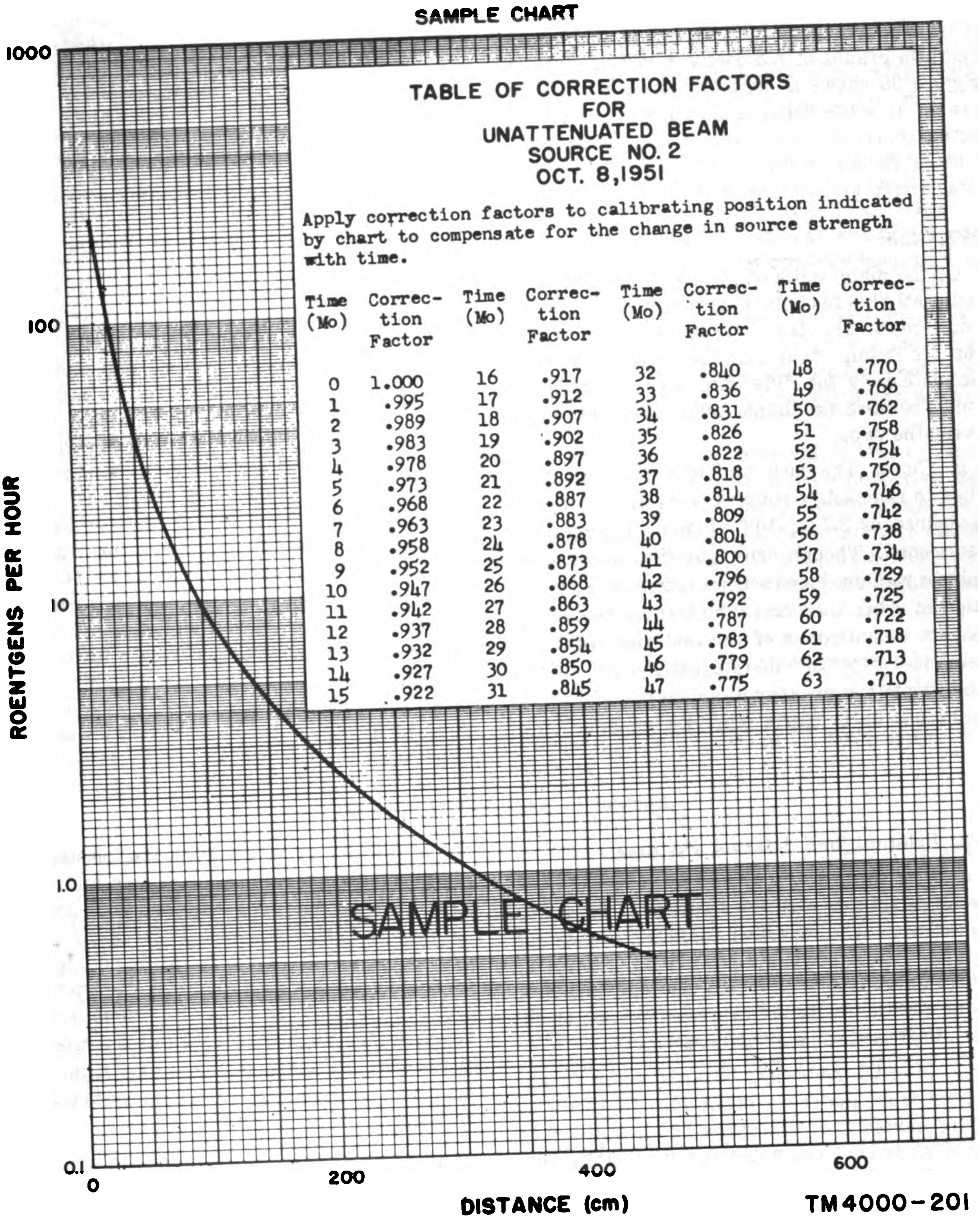


TABLE OF CORRECTION FACTORS
FOR
UNATTENUATED BEAM
SOURCE NO. 2
OCT. 8, 1951

Apply correction factors to calibrating position indicated by chart to compensate for the change in source strength with time.

Time (Mo)	Correction Factor	Time (Mo)	Correction Factor	Time (Mo)	Correction Factor	Time (Mo)	Correction Factor
0	1.000	16	.917	32	.840	48	.770
1	.995	17	.912	33	.836	49	.766
2	.989	18	.907	34	.831	50	.762
3	.983	19	.902	35	.826	51	.758
4	.978	20	.897	36	.822	52	.754
5	.973	21	.892	37	.818	53	.750
6	.968	22	.887	38	.814	54	.746
7	.963	23	.883	39	.809	55	.742
8	.958	24	.878	40	.804	56	.738
9	.952	25	.873	41	.800	57	.734
10	.947	26	.868	42	.796	58	.729
11	.942	27	.863	43	.792	59	.725
12	.937	28	.859	44	.787	60	.722
13	.932	29	.854	45	.783	61	.718
14	.927	30	.850	46	.779	62	.713
15	.922	31	.845	47	.775	63	.710

Figure 95. Sample correction chart.

usually accompany the radioactive sources listing correction factors for the age of the element and also graphs of radioactivity versus distance. Figure 95 shows a sample of such a chart and graph. In some radiac calibrating sets the radioactive source is fixed at certain distances to produce a certain radiation strength and only a time correction chart is needed.

297. Units

Of the many units of measurement applied to radioactivity, two main ones are generally encountered in the field—the curie and the roentgen. It is important that the repairman understands clearly the difference between these two units, because no simple relationship exists between the two.

a. Curie. The basic unit of measurement applied to radioactive sources is the curie. A curie is defined as 3.7×10^{10} atomic disintegrations per second. Though originally the curie applied only to radium, by extension it is now being applied to other radioactive materials, and it represents that amount of the materials that also develops 3.7×10^{10} disintegrations per second. The disintegrations may be accompanied by alpha radiations or by alpha plus any combination of beta and gamma radiations. Unless many more data are known about the radioactive material, one cannot determine the radiation level if its radioactivity is expressed in curies.

b. Roentgen. The second important unit of measurement in radioactivity is the roentgen, which technically is that quantity of gamma radiation or X-ray radiation that will produce ions carrying 1 electrostatic unit (esu) of either polarity in 1 cubic centimeter of dry air at 0°C. and 760 millimeters of mercury. One volt is equal to 3×10^9 esu. The roentgen is therefore a direct representation of the strength of gamma radiations present; it does not show the actual energy of beta or alpha radiations present because the ionization powers of the three rays are not equal (par. 294). The unit *roentgen* is a good measure of damage done to human bodies; the greater the exposure in roentgens, or milliroentgens, the greater is the damage to human tissue. Many radiac equipments are calibrated in milliroentgens per hour (mr/hr); the reading in mr/hr multiplied by the number of hours of the presence of radiations will result in the total amount of exposure suffered in milliroentgens. One milliroentgen is equal to 1/1000 roentgen. The standard maximum limit of exposure for humans is placed at 0.3 roentgen per week.

Section II. RADIATION HAZARDS

298. External and Internal Hazards

a. The hazards from radiation usually are classified according to the location of the radiation source. The source of radiation of external hazards is located outside the human body, and the radiation must pass into the skin and deep tissue. If the radiation source is outside of the body, it presents an external hazard.

b. Internal radiation hazards refer to the danger from materials taken into the body by eating, inhaling, or through a break in the skin. When such emitters enter the body, they continue to eject high energy alpha and beta particles that have the ability to produce intense ionization inside the body. The result is that blood cells are destroyed and the blood-forming mechanism of the body is injured. Local irritations often occur and may become malignant. The radiations from an internal source also affect the bones, liver, and kidneys. Radioisotopes are absorbed from the digestive system and become a part of the body and are thus not eliminated for a long period of time. It is difficult, if not impossible, for the body to throw off the radioactive materials within the body. No known process can destroy or neutralize these radiation sources other than the normal decay rate of the radioactive material; nor can the rate of discharge of such materials from the system be controlled.

299. Personnel Precautions

a. For those who must work with radioactive equipment and materials, a strict system of personnel inspection is necessary. Such a program insures that no one receives an exposure greater than the maximum safe tolerance of 300 milliroentgens (millirads) in 1 week. This is equivalent to 7.5 mr/hr for a 40-hour week or 6.25 mr/hr for a 48-hour week. The figures above apply for external gamma radiations of a relatively uniform intensity. Short exposures slightly in excess of these rates are permissible if the weekly tolerance is not exceeded. In any unusual situation, or in case of overexposure, notify the Radiological Safety Officer. Personnel who have been overexposed must be relieved from work involving radioactivity until their average dose, beginning with the time of the overexposure, is less than .3 roentgen per week. Acute gross overexposure (greater than 25 roentgens) must immediately be brought to the attention of the Radiological Safety Officer and a medical officer.

b. Strict personal cleanliness is essential as part of the daily work routine. Radioactive materials must be treated like other poisonous substances. At the end of each work day, the hands should be thoroughly washed.

c. When entering an area which is radioactive, care must be used to avoid taking radioactive dusts into the body through the nose, mouth, or through lesions or cuts in the skin. The standard gas mask offers considerable protection against breathing radioactive dusts, and should be worn in a radioactive area. Smoking, eating, drinking, or chewing gum in a radioactive area should be avoided, and every possible caution should be taken to avoid stirring up clouds of dust.

300. Monitoring Procedure

a. If any radioactivity can be detected on the hands or other body surfaces of personnel, decontamination is necessary. Usually washing thoroughly with soap and water is sufficient to remove all radioactive materials so that the detection equipment indicates only background level. To monitor the dose rate of the individual, an ion chamber survey meter such as the radiac set shown in figure 99 is recommended. This instrument should be calibrated against cobalt 60 or radium periodically.

b. Personnel exposed to noncombat radiations must wear a suitable dosimeter (film badge or quartz-fibre type dosimeter) to measure total exposure to gamma radiations. The record of all film badge exposures for each individual should be made a part of the individual's permanent personnel file.

c. In areas where both beta and gamma radiations are present, it is difficult to obtain an accurate measure of the radiation level. For most conditions, a beta-gamma survey meter (fig. 99), calibrated for gamma measurements may be used.

d. The probability that an external beta source will prove hazardous is very remote and no special monitoring system is required. Where a special beta radiation problem exists, special beta measuring rings or wrist badges may be obtained.

e. Alpha radiations may be monitored with special calibrated survey meters, but no record of total external exposure is usually kept since alpha radiations have very limited penetrating powers.

f. Special precautions should be taken in handling equipment that contains radioactive material as an integral part, or that has been contaminated with radioactive material during use. Such equipment, if unpacked, should be stored with a few feet of free space around each set to prevent the radiation level from increasing. Normally packed new equipment can be stored one on top of the other because the packing material acts as a shield, but any label on the package should be carefully checked for information on the radiation level around the package.

301. Radioactive Tube Dangers

It is important for the technician to be aware of the poisonous substances inside radioactive tubes. The danger is greatest when a radioactive tube breaks and the radioactive particles enter the body by breathing, eating, or through cuts in the skin. The utmost caution must be used when handling broken tubes containing radioactive materials. The types of materials used in radioactive tubes and their characteristics are discussed below.

a. Glow lamps or cold-cathode tubes and transmit-receive (TR) tubes contain from .01 to 1 microgram of equivalent radium per tube. Spark gap tubes contain from 1 to 2 micrograms of equivalent radium per tube.

b. Radium bromide is used in sparkgap, glow lamp, and cold-cathode tubes. Like other radium compounds, it is a cumulative poison and an extremely dangerous source of radioactive infection if absorbed in the human system. Radium bromide causes the formation of radon gas within the tube envelope. This gas is tasteless, colorless, and odorless. Should the tube break, inhaling this gas could cause serious injuries or be fatal.

c. Radioactive cobalt is used in transmit-receive (TR) tubes. This radioactive material is generally applied to the glass wall, the dome, or in some other convenient place in the envelope. Radioactive cobalt has a relatively short life of several years, and does not give off any gas. However, there is danger of serious injury from the harmful invisible radiations if they enter the human system.

d. Some electronic equipments use special-purpose electron tubes that contain minute amounts of radioactive materials. These tubes are normally harmless to personnel, because the quantity of radioactive material is almost negligible.

302. Handling Radioactive Tubes

Inexperienced personnel without survey instruments may be called upon to handle radioactive tubes; the proper procedure is described below.

a. Storage and Handling. There is little or no danger to personnel from radiation when handling radioactive tubes that are properly stored in cartons, nor is there any danger when handling individual radioactive tubes for normal removal and installation in equipment. However, if 100 radioactive tubes were piled together without cartons, a radiation hazard would exist that could result in harmful injury to personnel. Concentrated storage of radioactive tubes in quantity should be avoided. If some supplies of radioactive tubes are not properly marked, refer to TB SIG 225, Radioactive Electron Tube Handling, which lists tubes used by services that are known to be radioactive, and are a hazard to personnel.

b. Breakage. A broken radioactive tube presents a hazard because the possibility exists that radioactive materials will enter the body. This may occur by breathing poisonous gases and dust, by absorption of contaminated material through cuts in the skin, or eating, drinking, or smoking contaminated substances, and by radiation. There are two accepted methods for cleaning an area where radioactive tubes may have been accidentally broken. The two methods are:

(1) First, pick up large fragments with forceps. Then wipe across the area with a wet cloth. Fold the cloth in half after each stroke, keeping the clean side out at all times. When the cloth becomes too small, place it in a suitable container and start again with a clean one. Do not rub the cloth back and forth, as this tends to grind the radioactive material into the surface being cleaned. All debris and cloths used for cleaning should be sealed in a container such as a plastic bag, heavy waxed paper, ice cream carton, or glass jar and buried (*c* below).

(2) The second method for cleaning the contaminated area when breakage occurs is to pick up large pieces with forceps, and clean the entire area with a vacuum cleaner. The collecting bag in the vacuum cleaner should be discarded (*c* below).

c. Disposal. Broken or useless radioactive tubes should be disposed of in accordance with instructions from the Radiological Safety Section or the Health Physics Section at the installation. Where there are no qualified radiological safety personnel, the tubes to be discarded should be sent to the nearest installation having waste disposal facilities. The waste material should be packed in a carton and labeled: "Danger: Radioactive; do not touch or handle broken tubes. Do not remove from carton." Disposal of replaced and defective tubes should be by, or in accordance with instructions from, the nearest Radiological Safety Officer. In the event that no authorized disposal facilities are available, waste material may be buried, provided the plot is adequately posted and supervised. The plot selected should be located as far as possible from other facilities, because the buried material may be exposed by land excavation at a future date.

Section III. RADIATION DETECTORS

303. Detection of Radiations

Radioactivity produces many visible results that are used in the design of detection devices. Some devices use chemical reactions that result in changes in color to show the user the presence of radiations. Others use crystals that give off flashes of light when in the presence of radioactivity. Still others use chambers filled with gases that ionize in radiation fields. The detecting equipment can be divided into two general categories: The cumulative detector, which indicates the total amount of exposure to radiation; and the instantaneous field-strength indicator which indicates intensity at any instant.

304. Film Badges

Whenever photographic film is left in a radiation field, the film becomes exposed just as if it had been left open in direct light making the film a cumulative detector of radiations. This effect is put to use in the radiac detecting element shown in figure 96 The holder, a sheet steel box narrow enough to fit in a coat pocket, is loaded with a special photographic film element This film element consists of two strips of photographic emulsion next to two reference strips of different shadings of gray Each gray block on the reference strip represents a definite amount of exposure To determine the amount of exposure

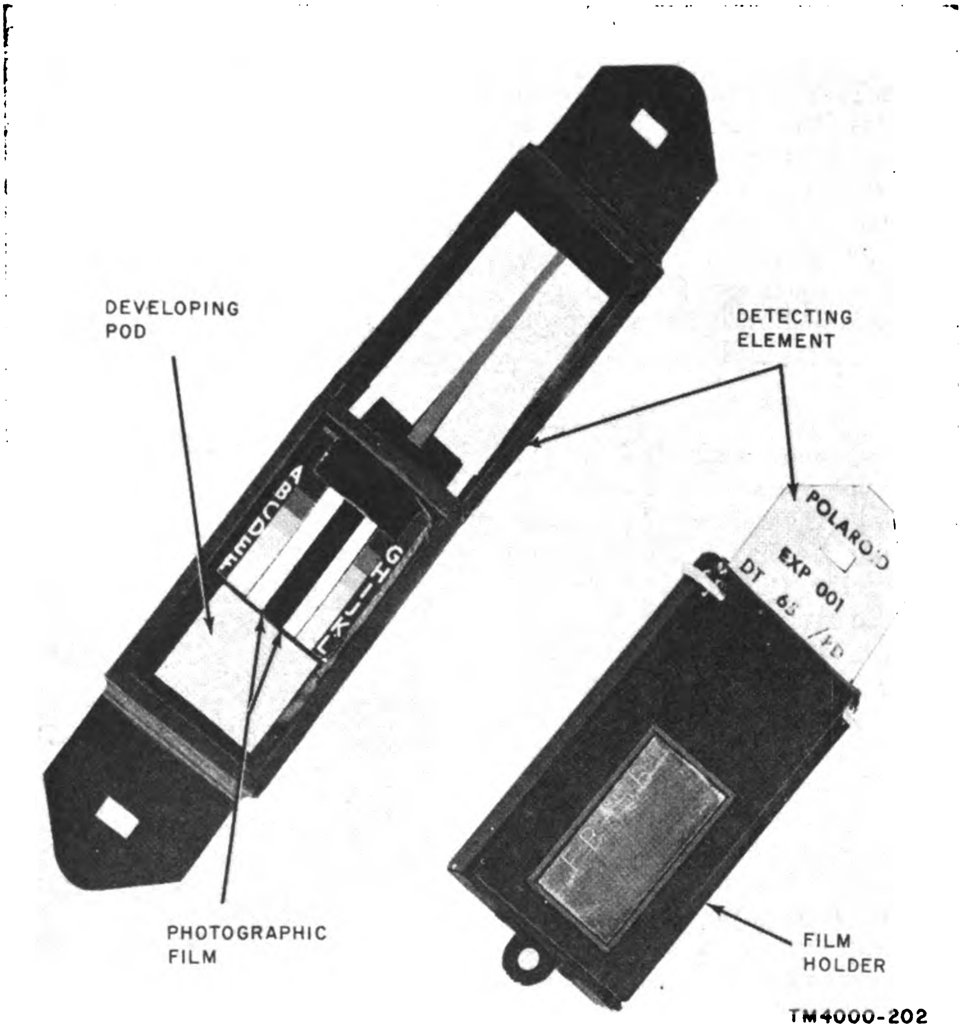


Figure 96. Film badge.

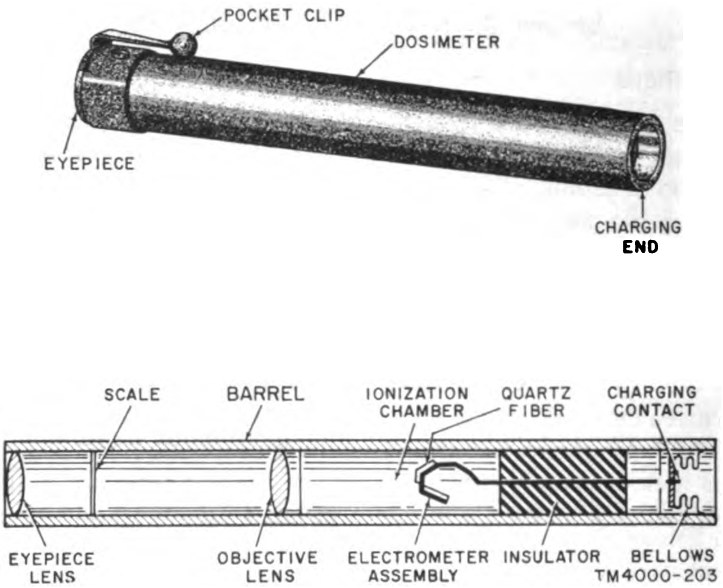
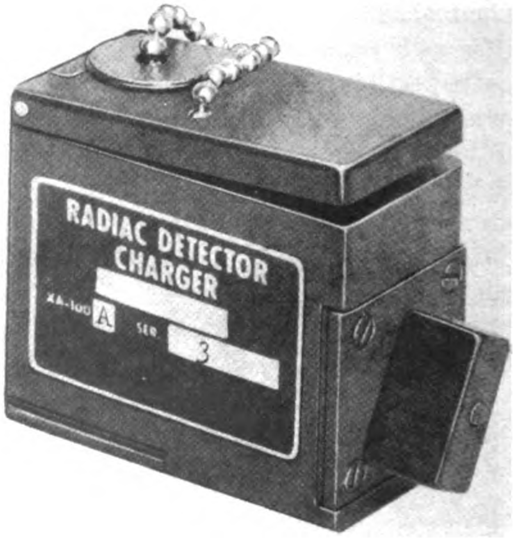


Figure 97. Quartz-fiber dosimeter.

received, the developing chemicals are spread across the film strips The detecting element is then opened and the film strip color is then compared with the reference strips. The whole operation for reading the film strip takes approximately one minute After one use, throw the film strip away, and insert a new strip in the holder. No electronic repair is performed on this type of radiation detector.

305. Dosimeters

Electrometers have been manufactured as cumulative radiation indicators called dosimeters. They work as follows: The electroscope is essentially a capacitor in a gas-filled jar, connected to a quartz-fiber assembly (fig. 97). When the capacitor is fully charged, the quartz fiber is completely extended, and the fiber indicates 0 when viewed through the eyepiece. As soon as the electroscope is exposed to radiations, the inclosed gas becomes ionized and stays ionized until the unit is taken out of the field. While the gas is ionized, the ionized gas discharges the capacitor and the quartz moves toward the assembly. The movement of the quartz fiber is proportional to the total radiation; it is proportional to the strength of the ionization of the radiation and the length of time of exposure. The scale for the quartz-fiber movement can be directly marked in roentgens. The only maintenance involved in this equipment is keeping it clean and checking its calibration periodically. Cleanliness of the electrometer is an absolute necessity since radioactive dirt would slowly discharge the unit and ordinary dirt would possibly produce such a large leakage current during the charging procedure that the unit would not charge correctly. The charger (fig. 98) is a power supply that produces the necessary dc voltage (approx. 165 volts) to charge the dosimeter.



TM4000-204

Figure 98. Radiac detector charger.

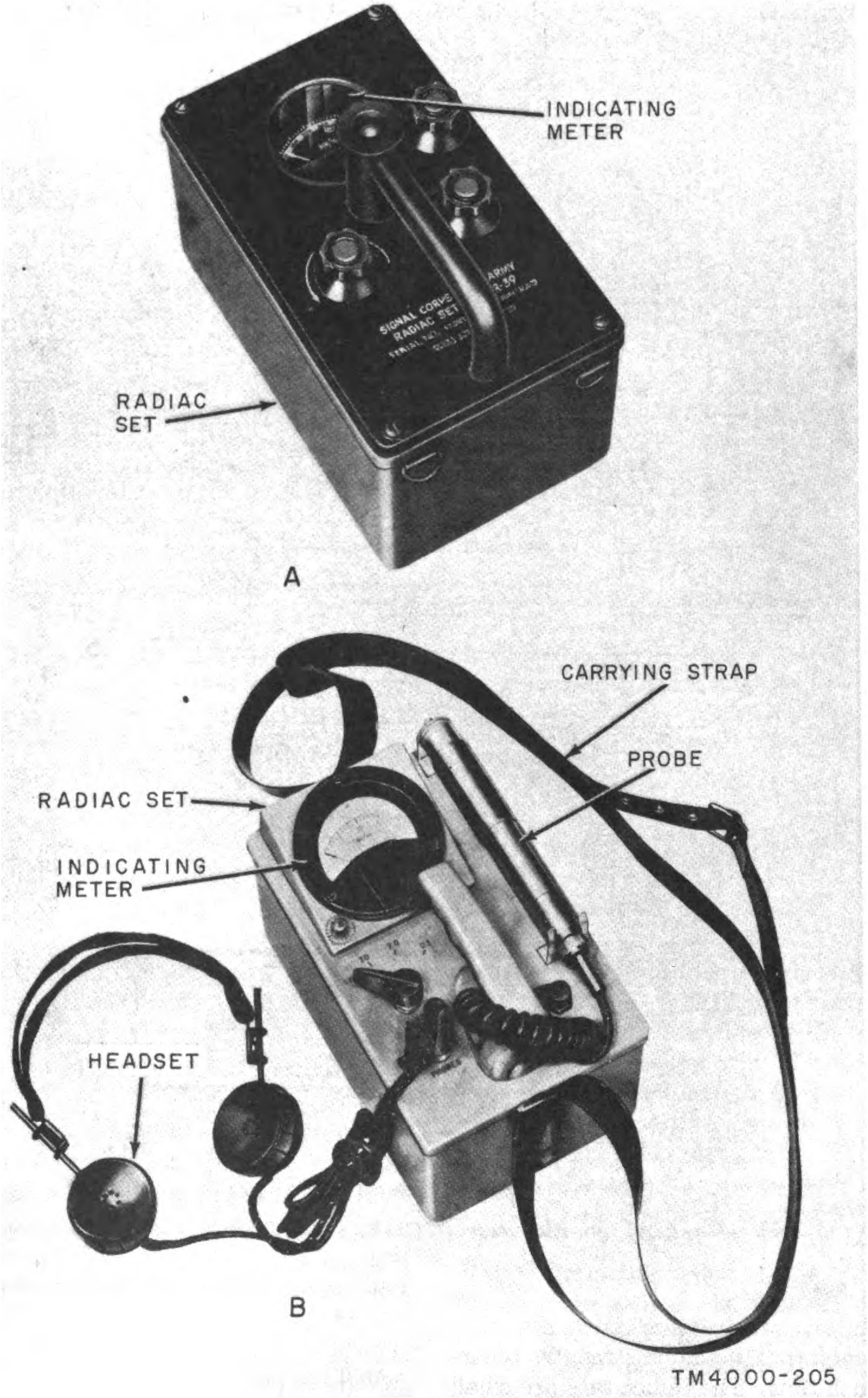
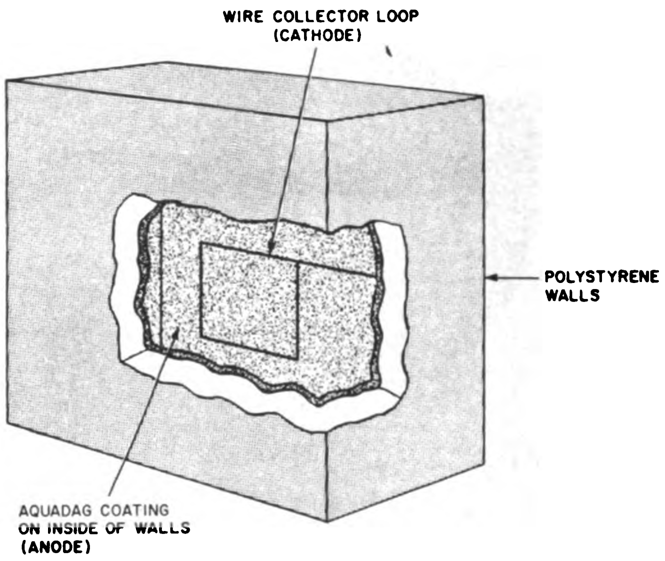
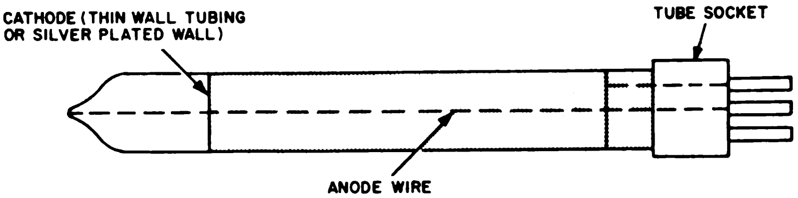


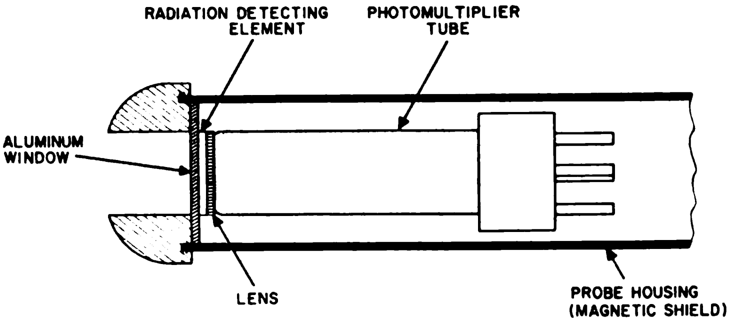
Figure 99. Typical self-contained radiac sets.



A. AIR-FILLED IONIZATION CHAMBER



B. GEIGER-MÜLLER TUBE



C. SCINTILLATION DETECTOR TM4000-206

Figure 100. Cut-away views of (A) ionization chamber, (B) Geiger-Muller tube, and (C) scintillation detector.

306. Radiac Sets

Radiac sets are radiation detection sets that indicate instantaneous radiation strengths occurring at any one time. The radiac sets are small self-contained units in a single case (A, fig. 99). They may contain a probe (B, fig. 99) to permit checking in corners or other small places, or they may be large and elaborate (fig. 101) containing, besides the detecting unit, sensitive amplifiers and accurate pulse counters. Special repair procedures and cautions applicable to radiac sets are described in paragraphs 307 through 319. The actual radiation detecting elements used in radiac sets are described in *a* and *b* below.

a. Ionization Element. The ionization elements used in radiac sets are closed containers, filled with air or gas, and contain two electrodes. The air or gas ionizes when exposed to radiation, and

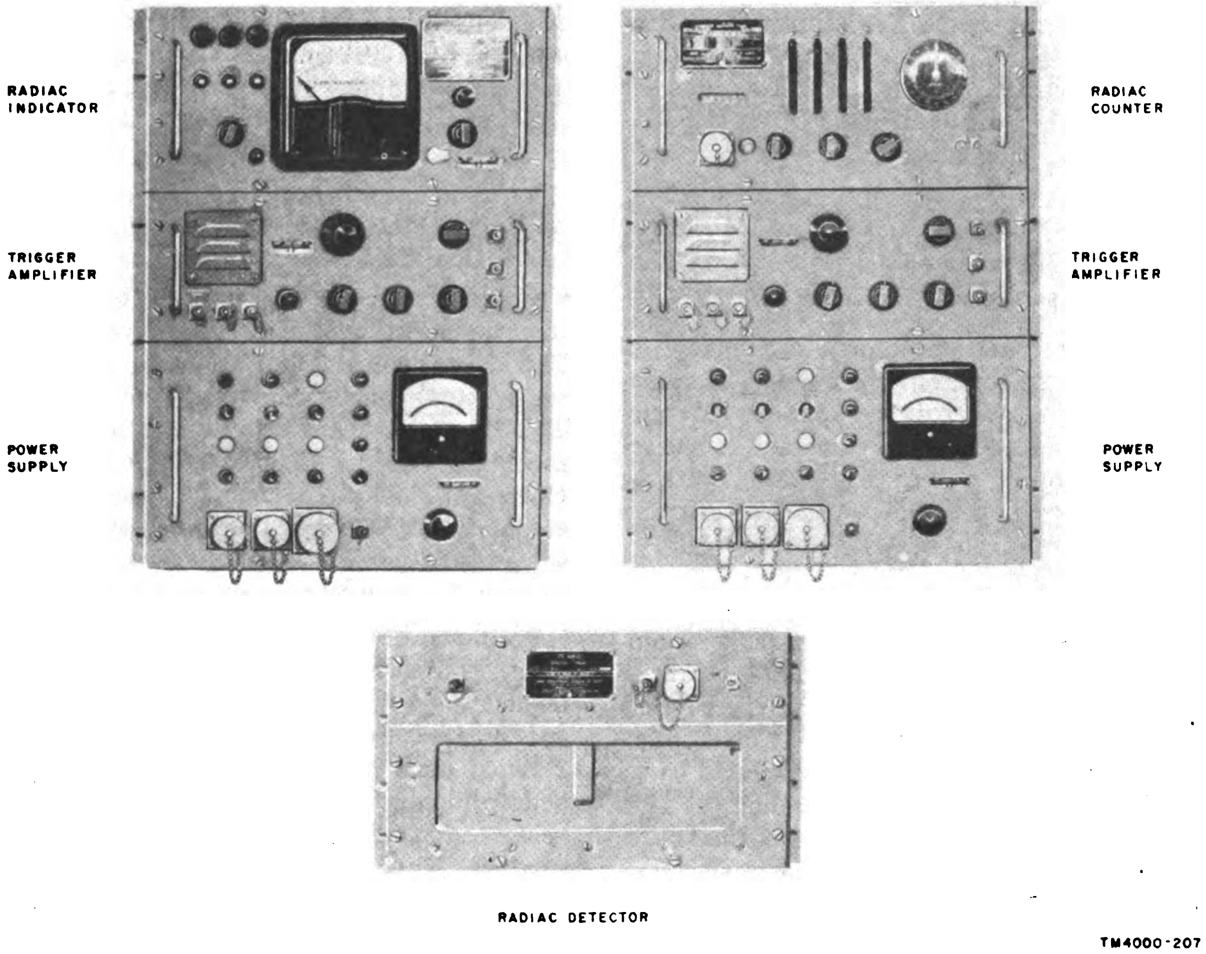


Figure 101. Elaborate radiac set with pulse counter.

current flows through the container. Two types are used, the ionization chamber, and the Geiger-Muller (G–M) tube.

(1) The ionization chamber, usually used in the less sensitive radiac sets, consists of a closed rectangular polystyrene box (A, fig. 100) filled with dry air at the pressure of one atmosphere. A wire as the cathode, and an aquadag coating on the walls as the anode, form the elements necessary to complete the electrical circuit. In this type of ionization element, the amount of steady current flow is directly proportional to the strength of radiations entering the chamber. The voltage necessary for the correct operation is low, about 135 volts.

(2) The G–M tube (B, fig. 100) consists of a thin-walled metal tube or a metal-coated glass filled with a halogen gas and a center wire electrode. When the radiac set using a G–M tube is placed in a radioactive area, the gas in the tube will ionize and a large current will flow. Because of the circuit arrangement, and the halogen gas used, the current in the G–M tube is quenched (stops) and then starts again. The amplitude as well as the number of pulses per second of this current depends upon the strength of radioactivity present. The voltages used with the G–M tube may be 700 volts or higher.

b. Scintillation Counters. Early in this century, physicists found that a certain material, such as Zinc-Sulfide (ZnS), gave off flashes of light whenever it was exposed to radiations. The number of light flashes, or scintillations, depended upon the strength of the radiations present. This particular property is utilized in some radiac sets which often are also called *scintillation counters.* The detecting element is covered with an aluminum sheet as a light cover; a lens couples the element optically to a photomultiplier tube (C, fig. 100). In more elaborate equipment, the photomultiplier tube may take the physical shape of a large cathode-ray tube. A more elaborate radiac set is shown in figure 101.

Section IV. GENERAL REPAIR PROCEDURES

307. General

The proper operation of radiac equipment, in the hands of personnel being exposed to radiations, may be a matter of life or death. Maintenance personnel should not return any radiac set to the user unless the set is in perfect working condition. Repair personnel must protect themselves from overexposure to radiations.

308. Troubleshooting Techniques

The techniques used in repairing radiac equipment are similar to those used in the repair of any other electronic equipment. Whether the equipment is small, such as a G–M radiation detector (fig. 99), or whether it includes large pieces of equipment, such as a radiac set (fig. 101) with separate power supplies, counting circuits, and indicators, three logical steps should be followed: *Sectionalize, Localize,* and *Isolate.*

a. Sectionalization. Careful observation of the performance of the set during "turn on" and operating procedures may sectionalize the fault to a particular circuit.

b. Localization. To localize the fault to a particular stage, one can use the troubleshooting chart to advantage, as a guide in locating the faulty stage. In small equipments sectionalization and localization are often done at the same time.

c. Isolation. Final checks, such as voltage and resistance measurements, are necessary to isolate the faulty part so that it can be replaced.

309. Personnel Safety

Radiation damage to personnel and property may occur, but the effects of the damage are not felt or seen until it is too late. Therefore, caution must be exercised in the handling of radiac equipment.

a. Personnel handling, storing, and repairing such equipment should be monitored. They should wear film badges or carry pocket dosimeters if the equipment contains radioactive materials. The exact amount of radiations that can be absorbed continuously, every day, without serious damage, is specified in existing regulations which should be obtained through command channels. Until exact data can be had, the value of .3 roentgen per week should be used as a maximum dosage of radiation that a person can stand continuously without serious damage.

b. In addition, disassembly and reassembly of radiac equipment that contains radioactive elements should not be attempted without the presence of a health physicist; damage can easily be inflicted upon hands and isolated parts of the body while the dosimeter in the pocket still reads below the maximum permissible radiation exposure rate. Dosimeters or film badges should be on those parts of the body that will come closest to the radioactive sources.

c. When exposure to radiations cannot be avoided, as during calibration, prepare everything in advance so that handling of, or exposure to, the radioactive material can be kept down to the shortest possible time. Do not handle any radioactive sample with bare hands no matter how feeble the source; always use forceps or thick rubber gloves. Keep the greatest possible distance between the body and the radioactive source.

310. Shop Considerations

Plans for the shop layout and facilities should be coordinated with the chemical, medical, and engineer officer at the installation concerned. Consider the following points.

a. Radiac equipment requiring calibration or repair may have become contaminated with radioactive material during use. Such equipment should never enter the shop area. A separate receiving point should be set up where all incoming equipment can be carefully checked and when necessary, rerouted to a decontamination center.

b. The repair area must be as dust-free as possible because of the critical values of circuit components and operating voltages used in radiac sets. All measures possible should be taken to control and eliminate dust. Except for this one condition, no specialized requirements exist. Benches, shelves, and racks, usually found in a radio repair shop, may be used.

c. A separate area, adjacent to the repair shop, should be provided to house the calibration facilities. The calibration area should be restricted to personnel performing calibration. The actual amount of space required will depend upon the calibration equipment used. The area should be marked off, possibly into concentric circles, with the source of radiation at the center. These lines can then be used for rapid calibration of large numbers of equipments. At very high levels, such as 100 roentgens per hour or higher, remote control devices will have to be used to move instruments and make adjustments.

311. Nature of Radiac Test Equipment

a. The test equipment required to troubleshoot radiac equipment is essentially the same as that used to troubleshoot other electronic equipment. However, there are certain additional items of test equipment which are peculiar to radiac detection equipment. Such items as electrometer tubes and high-megohm resistors require that special equipment be used for testing. In addition, a radioactive source of known intensity is required for calibrating and checking the radiac equipment. A device of this type is called a radiac calibrator.

b. The calibration equipment is nothing more than a radioactive source with a mechanical arrangement for controlling the amount of radiation permitted to escape from the unit. There are no electronic circuits involved. Some radiac calibrators are very simple, consisting of only a minute bit of radioactive material in the end of a metal rod. With the simple calibrators, sometimes called test samples, the intensity or radiation can be determined only approximately. Its primary purpose is to produce some indication on the radiac detector. More complex calibration equipment has provisions for selecting radiations of different intensities.

c. Regardless of the radiac calibration equipment used, the technician must use care to avoid contact with the radioactive parts of the test equipment and to avoid exposure beyond the maximum levels allowed. Appropriate signs should be posted (fig. 102). Information on safety rules to follow in connection with radioactivity are given in paragraphs 298 through 302.

312. Radiac Test Samples

a. The simplest type of radiac calibrator is a radioactive sample like the one shown in figure 103. Test samples contain small amounts of radioactive material, such as radium or cobalt 60. The sample shown contains cobalt 60, a source of beta and gamma rays. The sample is imbedded in a metal rod which stops all beta rays. To prevent any dangerous radiation levels during the time the sample is stored, the metal rod with the sample is placed inside a large lead container. The radiation strength of the area surrounding the sample depends upon the age of the sample as well as the distance between the area and the sample. To make calibration setup calculations easy, the samples are accompanied by charts that plot age-versus-radioactivity and also distance-versus-radiation strength. Some radiac detector sets contain small radio-

TM4000-219

Figure 102. Sample caution form.

active test samples (fig. 104) that can be used for quick overall operational (go, no-go tests) checks. These test samples cannot be used for calibration checking because the correct radiation strength is seldom known.

b. For accurate calibration, radiac detection sets must be placed at a definite distance from the calibration source to produce a known indication on the detector. If a radiac set with a full-scale reading of 5 mr/hr is to be checked, the distance D (fig. 105) from the source should be found, where the radiation is exactly 4 mr/hr, or four-fifths of full-scale deflection. This distance D can then be marked off on the floor or a table; the radioactive test sample is then placed at one end of the distance, and the radiac set at the other end (A, fig. 105). Adjust the radiac set calibration control until the meter indicates correctly, in this case 4 mr/hr.

c. Dosimeters are checked for calibration by being exposed to a known amount of radiation for a fixed length of time. A jig, as shown in B, figure 105, will permit a number of dosimeters to be tested at one time. With the test sample at the center, the radiation level at the circumference of a circle with radius D should be determined from the accompanying charts. Assume that the radiation level at the dosimeters is 100 mr/hr, and the dosimeter to be checked has a scale reading up to 5,000 mr/hr (5 roentgens per hour). If the dosimeter is exposed for 20 hours, the reading should be 2 roentgens; if it is more than 10 percent off, the dosimeter is defective and should be discarded.

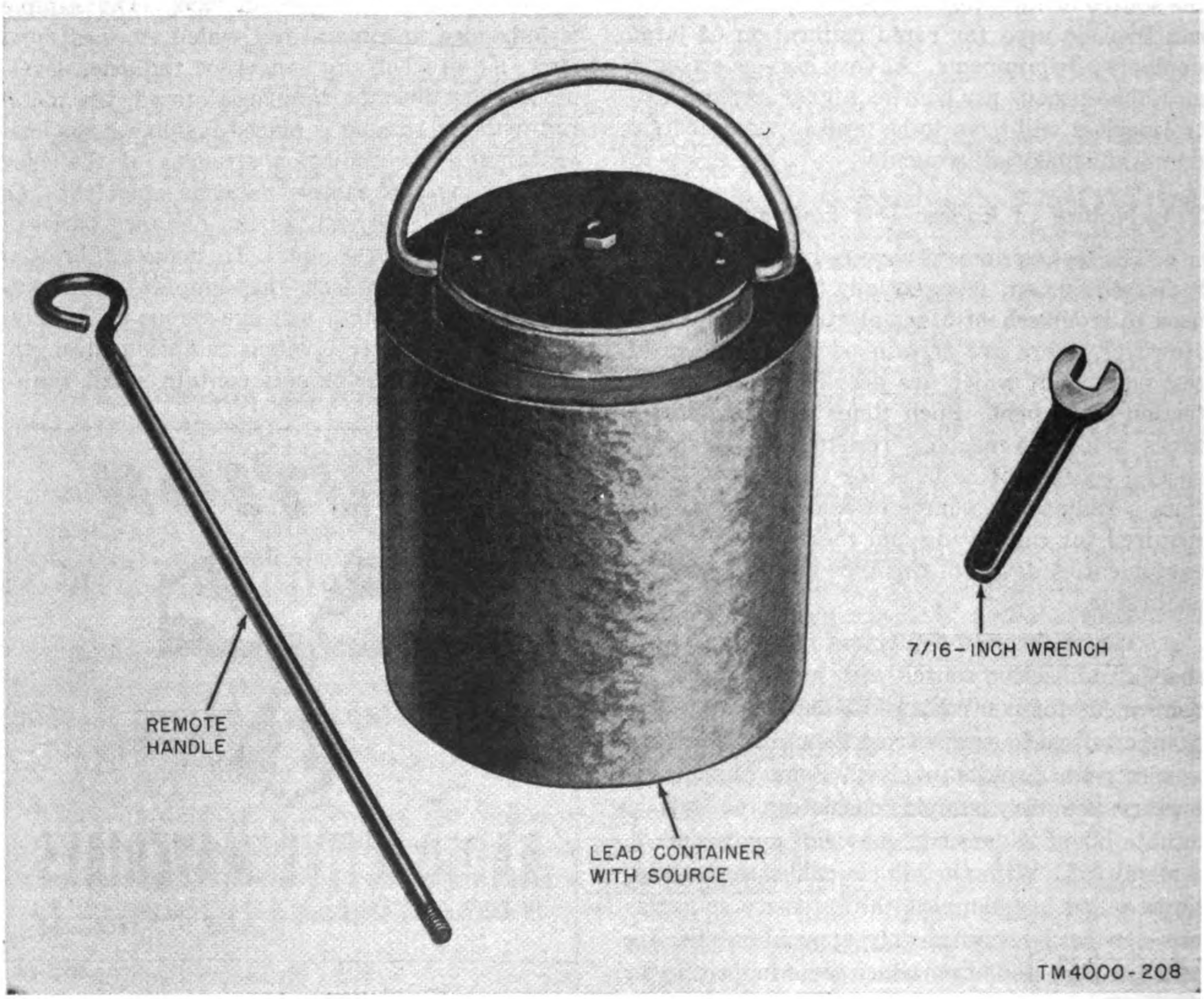


Figure 103. Radioactive test sample.

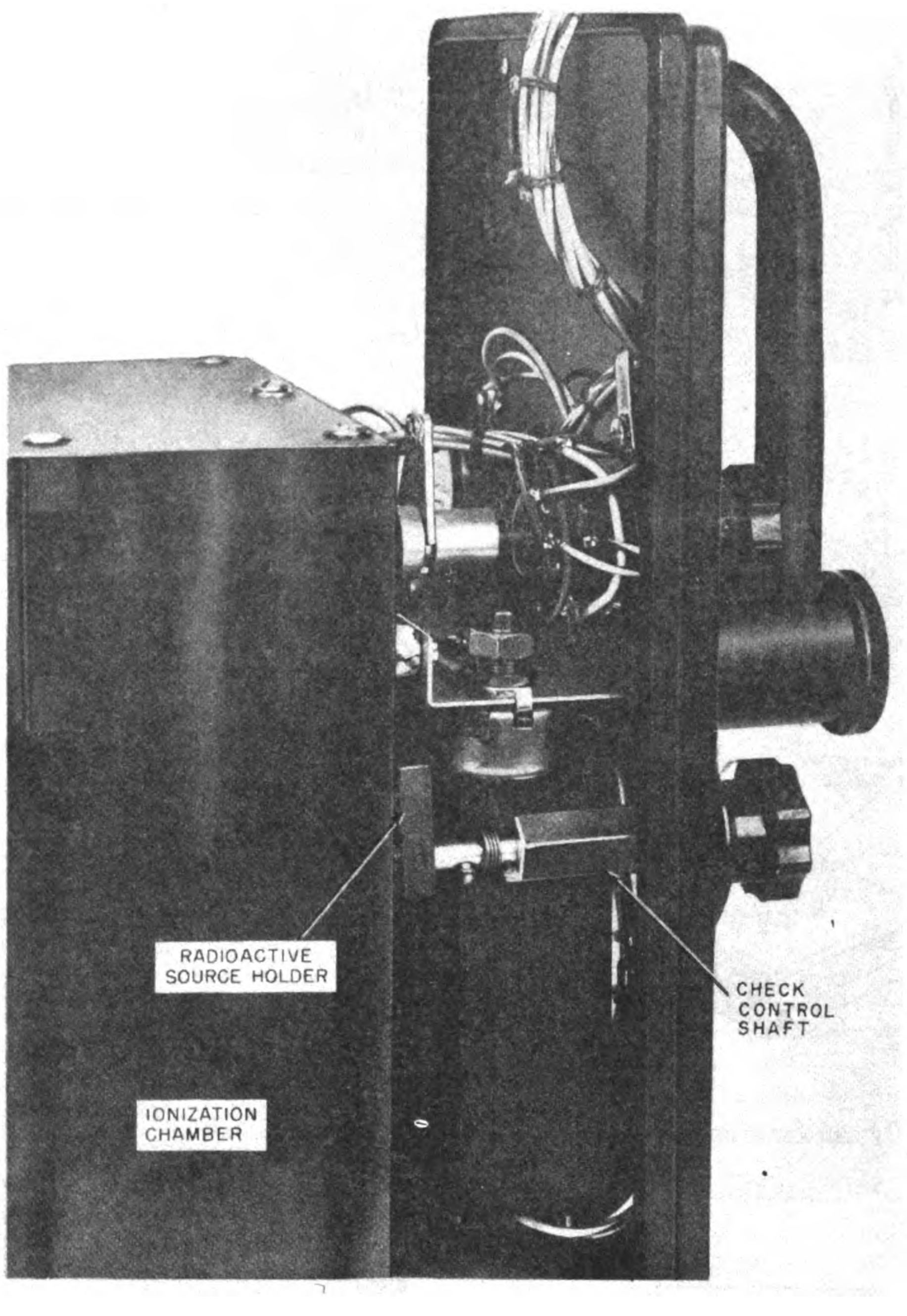


Figure 104. Test sample built into a radiac set.

313. Radiac Calibrators

a. Figure 106 shows a field-type radiac calibrator that was specially designed for one type of radiac set. When using the calibrator, remove the steel cover and place the radiac set to be calibrated inside the case. Therefore, the distance between the ionization chamber of the radiac set and the radioactive source in the calibrator is accurately controlled. The calibrator output is variable so that every range of the radiac set can be calibrated with the least amount of trouble. The radiation level at one foot from any outer surface of such a calibrator is very low, around 45 mr/hr; personnel operating the calibrator are therefore safe even though the radioactivity inside the case is very high.

Warning: Do not attempt to repair a radiac calibrator except under the supervision of a health physicist.

b. A depot-type radiac calibrator is shown in figure 107. A radioactive source of very high activity is mounted on a frame with special attenuation controls. The radiac set to be checked is placed on a carriage which rides on a track that contains a scale. Correct setting for the radiac set is shown by the X, Y, and H setting on the carriage. Charts that come with the calibrator are then checked to find the distance to place the carriage for a desired radiation level. The calibration set comes complete with a telescope and mirror, so that all readings can be made from a safe location behind the radioactive source.

314. Tube Testers

Special tubes used in radiac sets require special test equipment. The low grid-current electrometer tubes, or the Geiger-Muller tubes cannot be tested on ordinary tube test sets; particular equipments have been designed for that purpose. Figure 108 shows a tube tester that can test not only the characteristics of electrometer tubes but also their leakage resistance between the leads as well as the actual value of

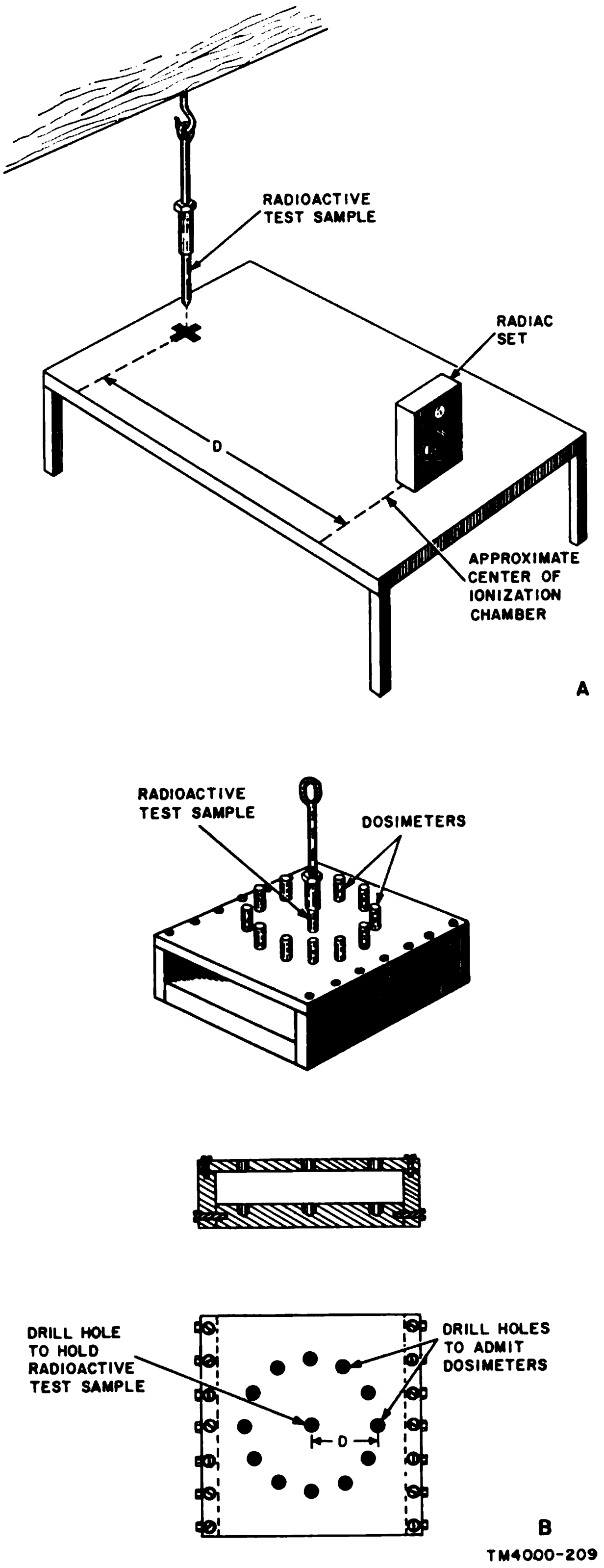


Figure 105. Calibration setups.

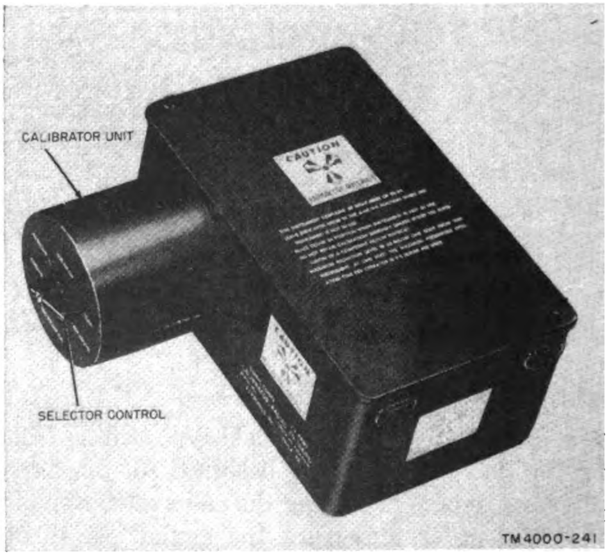


Figure 106. Field-type radiac calibrator.

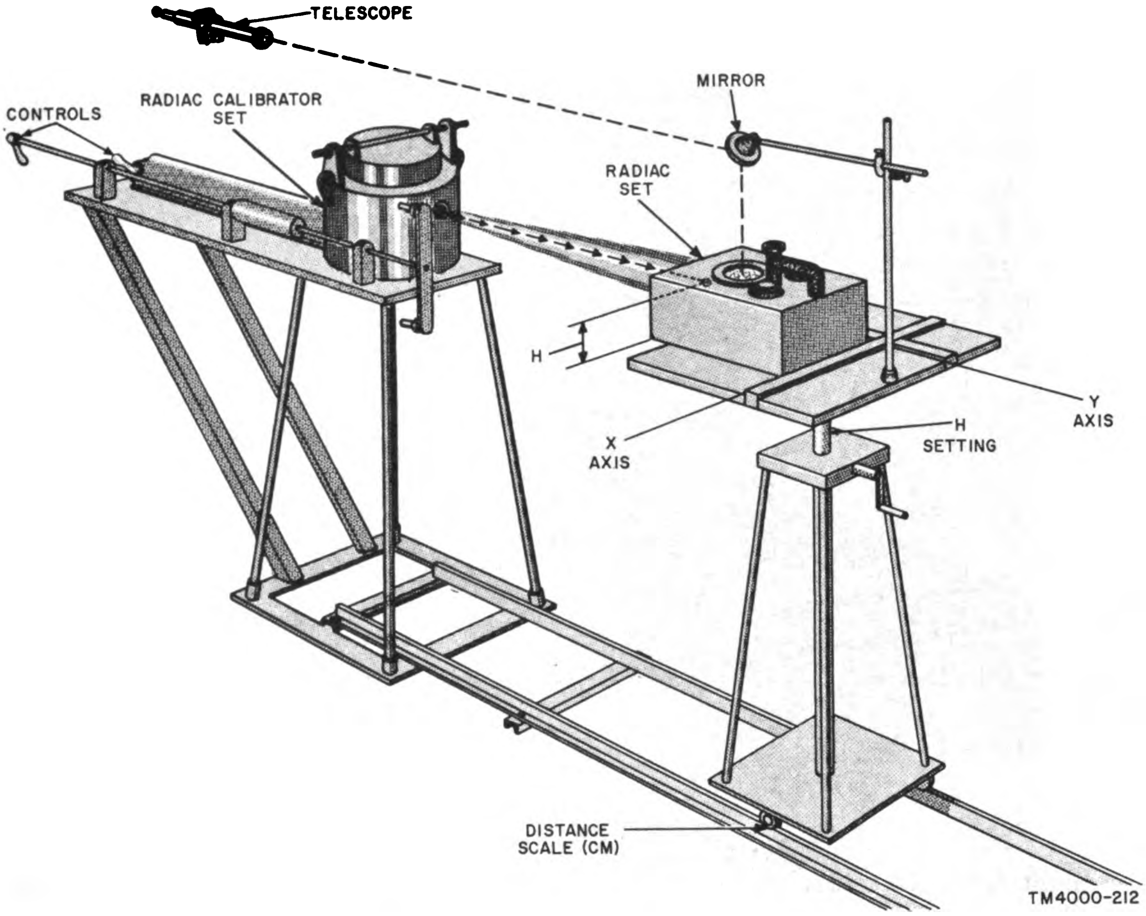


Figure 107. Depot-type radiac calibrator.

resistance of the high-megohm resistors that are used in radiac sets. Figure 109 shows a tester for G–M tubes and corona-discharge voltage-regulator tubes. Special handling procedures for the tubes to be tested are described in the paragraph that follows.

315. Special Handling

Some items are specifically designed for use in radiac sets; these items should be handled according to the procedures below.

a. Geiger-Muller Tubes. Geiger-Muller tubes must be handled very carefully because of the extremely thin tube or window. Some Geiger-Muller tubes have mica windows that are only .0005 inch thick; a blow by any hard object will rupture the window and leave the tube useless. Electrically, these tubes are sturdy.

b. Scintillation Counters. The radiation detector in scintillation counters is a chemical element covered with a lightproof aluminum window. As in the G–M tube, this window is very thin and care must be taken not to break it; a break in this cover would allow the chemical element to combine with air and therefore change its chemical composition. The radiation detector may or may not be directly attached to the photomultiplier tube.

c. Photomultiplier Tubes. Photomultiplier tubes are amplifiers of minute electric currents that are started by exposure of the cathode to light. Any exposure to bright sunlight, or occasionally even to ordinary daylight, can damage the cathode and render the tube useless. Keep the photomultiplier tube in its carton until it is to be installed; do not let bright light fall on the tube during installation.

d. Electrometer Tubes.

(1) Electrometer tubes are special low grid-current triodes or tetrodes. Under normal conditions almost no grid current flows. If the tubes are exposed to

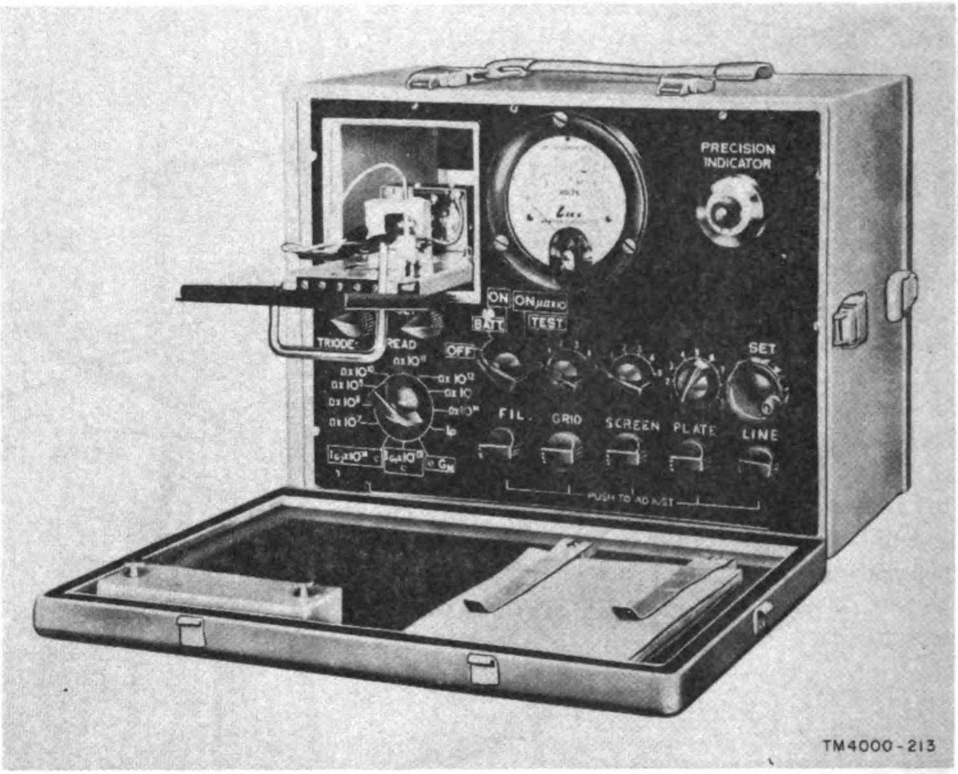


Figure 108. Electrometer tube tester.

light from either the sun or a lamp, the grid current increases enough so that the radiac set in which the electrometer tubes are used is thrown completely out of calibration. In a normally operating radiac set, the meter could show full-scale deflection if the electrometer tube is exposed to sunlight, even though no radiations are present. During tests, keep a lightproof cover over the electrometer tube compartment; use a heavy piece of canvas or thick wrapping paper.

(2) The electrometer tubes are specially processed to keep the leakage current between the leads to a minimum. Any dirt or salt on the envelope where the leads enter the glass, lowers the resistance between the leads and increases the leakage current. Therefore, never touch the lower part of the tube (fig. 110); hold the tube by the leads. To clean the tube, dip a clean cotton swab into denatured alcohol, then wipe the glass surface. DO NOT dip the swab into the alcohol again after it has been used once; discard it and use a new swab. Allow the tube to air-dry.

e. High-Megohm Resistors. High-megohm resistors are used in the grid circuits of electrometer tubes and may have values up to 200,000,000 megohms (2×10^{14} ohms). The glass body of these resistors should not be touched with bare hands; always use forceps or hold the resistors by the wire ends (fig. 110). If the resistors become dirty, use the procedure in *d*(2) above.

f. Indicating Meters. The indicating meters used in radiac sets are usually microammeters with 20 to 50 microampere (μa) full-scale deflection. Because of the low permissible current, the continuity of these meters cannot be tested with an ohmmeter; the meter movement would be burned out. Refer to the circuit shown in figure 111. Find the value of resistor *R* by dividing 1.5 volts by ½ the full-scale deflection current of the meter to be tested. For example, for a 20-μa meter the value of $R = 1.5/10 \times 10^{-6} = 1.5 \times 10^5$ or 150,000 ohms. For a 50-μa meter the value of *R* should be 60,000 ohms. When used in such a circuit, a good meter will

Figure 109. Geiger-Muller tube tester.

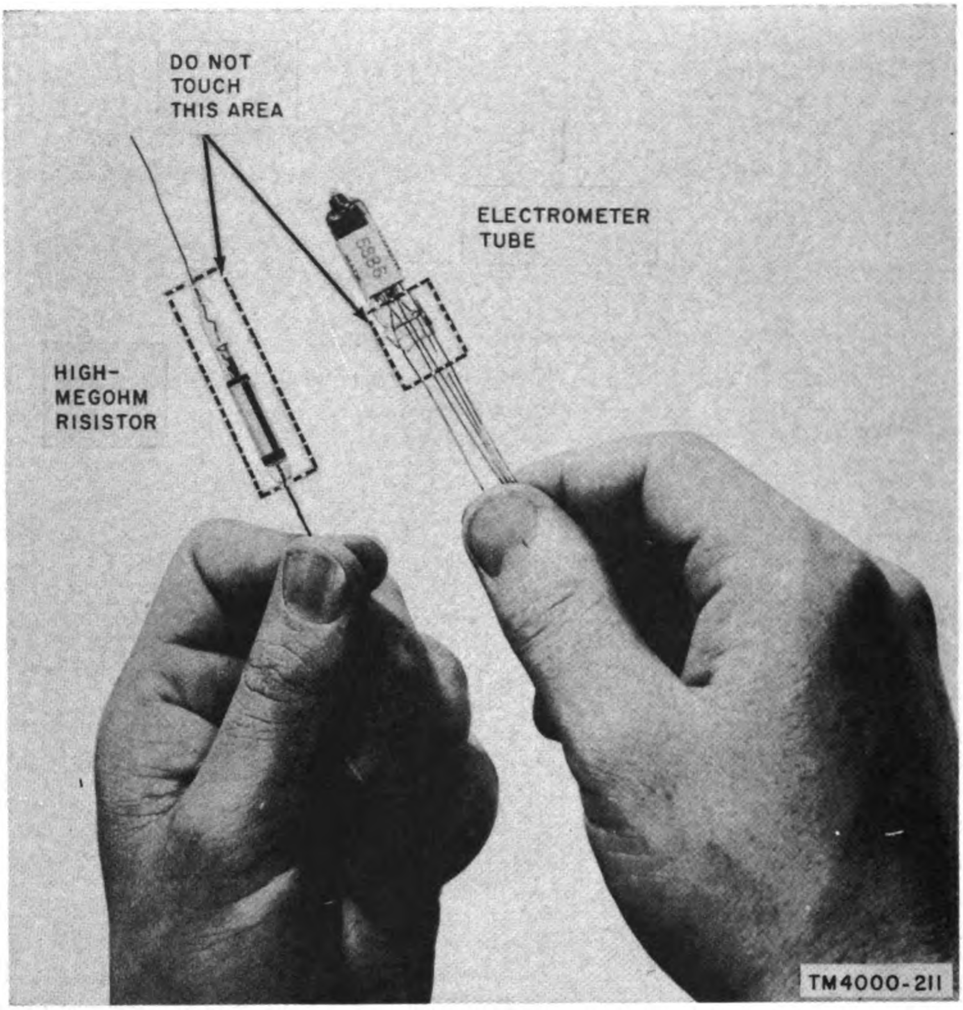


Figure 110. Handling electrometer tubes and high-megohm resistors.

show ½-scale deflection ±20 percent, because the value of the resistor used also may vary by 20 percent.

Caution: Do not measure voltages with a 1,000-ohms-per-volt or 20,000 ohms-per-volt meter indiscriminately in a radiac set. If the relatively low resistance of these meters is connected from some test points to ground, enough current may flow on the indicating meter circuit to burn out the meter movement.

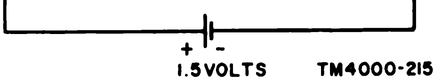


Figure 111. Meter test setup.

Section V. REPAIR OF TYPICAL RADIAC SET

316. Introduction

A possible approach in troubleshooting small radiac sets is covered in this section. Two simplified circuit diagrams (figs. 112 and 113) are used for reference throughout the discussion. The small radiac sets were chosen as a guide in this section because they represent troubleshooting techniques that differ from those encountered in radio work. In contrast large radiac sets, such as the one shown in figure 101 can be checked and repaired by standard repair procedures.

317. Battery Check

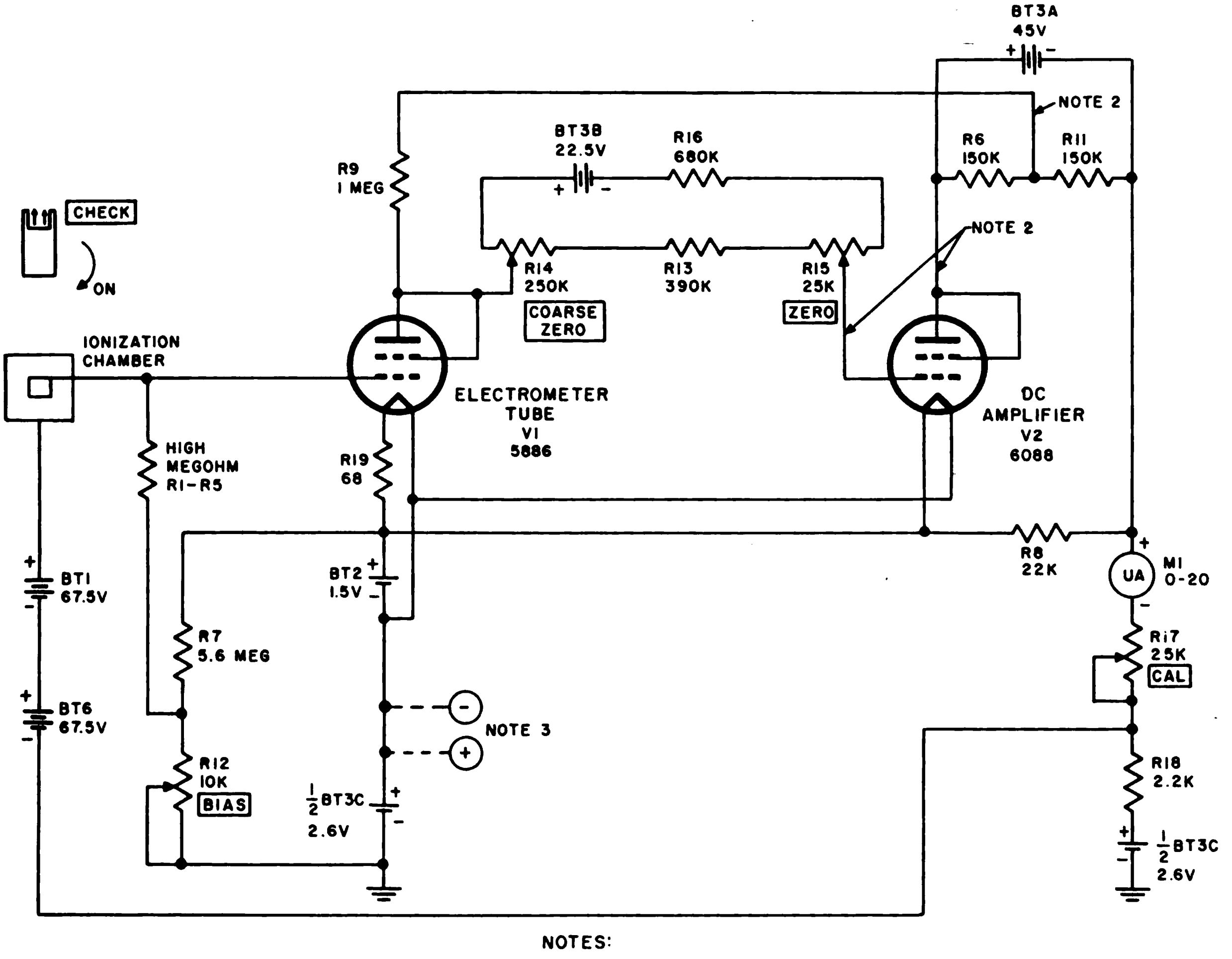
a. Most radiac sets are self-contained, using three or four batteries as sources of power. These batteries cause most of the troubles, because cells age, or wear drops the battery voltages below the acceptable limit. Whenever possible, replace the complete complement of batteries of the radiac set with a fresh set before starting to troubleshoot.

b. Most radiac sets include a circuit for checking the filament battery (BT 2, fig. 112 and BT 104, fig. 113) under load. Make this check, whether the filament battery has been replaced or not. Besides testing the battery, this check is a fast test for the meter. If no meter deflection is obtained, test the battery with a voltmeter, if the battery tests good, test the meter as described in paragraph 315*f*.

Caution: Do not check the meter continuity with an ohmmeter.

318. Operational Test

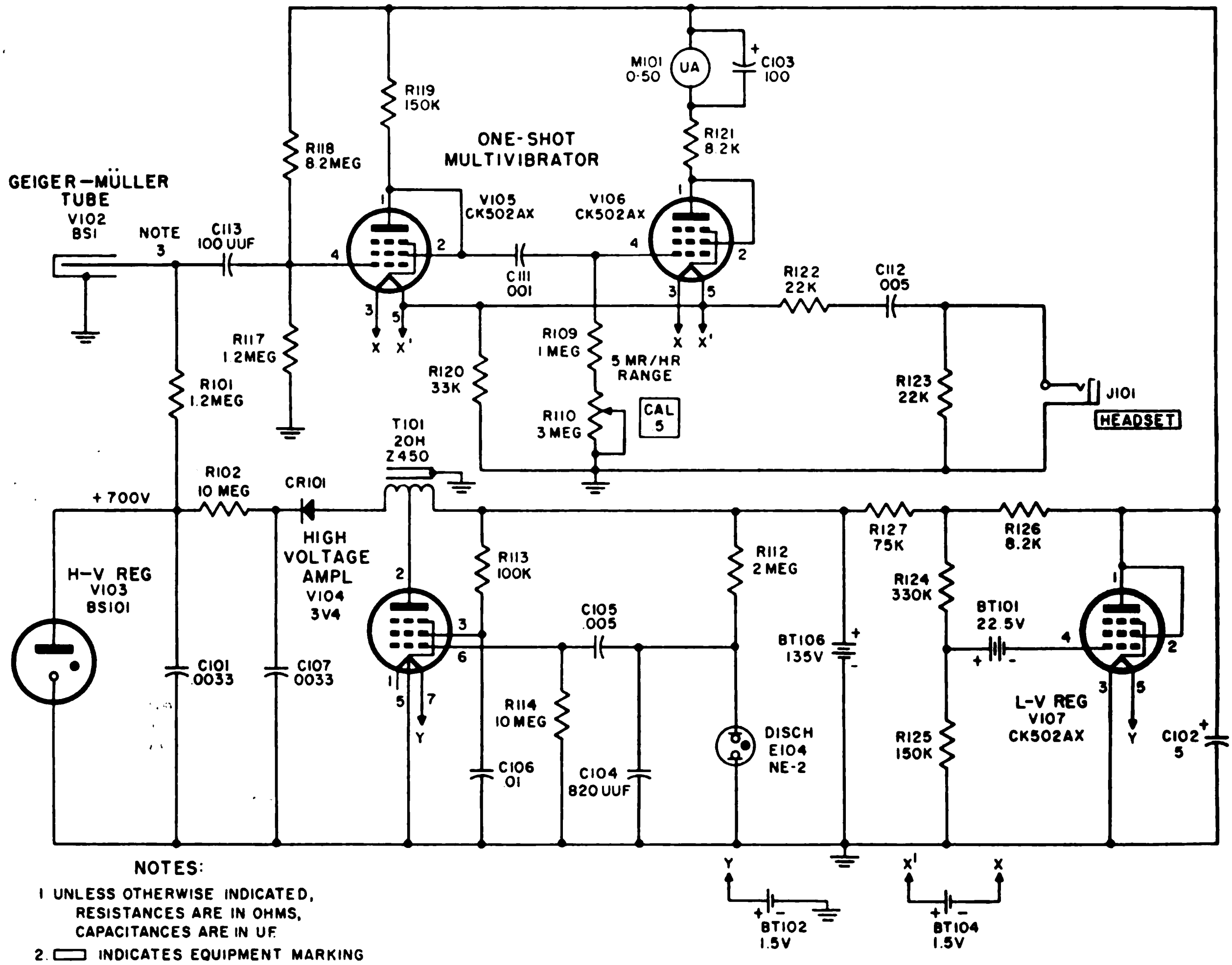
a. In many radiac tests, the first step before operation is the zeroing procedure. In the circuit shown in figure 112 resistor R15 must be adjusted. If the COARSE ZERO and ZERO adjustments (R14 and R15) do not permit zeroing



NOTES:
1. ▭ INDICATES EQUIPMENT MARKING.
2. DO NOT PLACE 1,000 OHMS-PER-VOLT OR 20,000 OHMS-PER-VOLT VOLTMETER BETWEEN THIS POINT AND GROUND.
3. INSERT TEST SIGNAL AT THIS POINT.
4. UNLESS OTHERWISE INDICATED, RESISTANCES ARE IN OHMS.

TM4000-216

Figure 112. Radiac set with ionization chamber, simplified schematic diagram.



NOTES:

1 UNLESS OTHERWISE INDICATED,
RESISTANCES ARE IN OHMS,
CAPACITANCES ARE IN UF.

2. ▭ INDICATES EQUIPMENT MARKING

3 INSERT TEST SIGNAL AT THIS POINT

TM4000-217

Figure 113. Radiac set with Geiger-Muller tube, simplified schematic diagram.

the meter, check the voltages of all batteries in the metering circuit, such as BT3A, BT3B, and BT3C. If the battery voltages check correctly, check the voltage and resistance measurements against the values given in the manual covering the radiac set involved. The radiac detecting element need not be tested at this point because it usually is shorted when the range switch is in the ZERO position and therefore cannot add any trouble.

b. After zeroing the set, switch it to the lowest operating range. The background radiation noise on the earth usually will produce a very slight meter movement in all but very insensitive radiac sets. If no indication is obtained, even when a radioactive test sample is brought close to the set, check the remaining batteries. In the circuit of figure 112 check BT1 and BT6. In the circuit of figure 113 check BT101 and BT102. BT2 and BT104 were checked during the filament battery test. If the trouble still persists with good batteries in the radiac set, determine whether the detecting element or the remainder of the circuit is at fault as described in paragraph 319.

319. Test Signal and Tube Check

Final localization of the trouble to either the detecting element circuit, high-voltage circuit, or the amplifier circuit is necessary before the trouble can be isolated to a part.

a. In the circuit of figure 112, the trouble could be isolated to either the ionization chamber or the remaining circuit by the test signal check. Construct the test signal circuit (fig. 114) and apply the signal to the grid circuit of the first stage. The point between batteries BT2 and

BT3C was chosen because the battery leads are the most easily reached points in the radiac set. If the meter shows full deflection, the trouble is in the ionization chamber. Replace the ionization chamber. If the meter does not indicate any deflection, make voltage and resistance measurements, but take note of any cautions listed in the equipment manual. Failure to observe them may damage the meter movement. Test the tubes as instructed in paragraph 407*d*.

Note. If no test signal voltage is listed in the equipment manual, apply the test signal circuit (fig. 114) to a radiac set known to be operating properly and vary the 2,500-ohm potentiometer until the meter on the radiac set indicates full-scale deflection. Without changing the setting of the potentiometer, apply this test signal to the radiac set under repair.

b. After the battery and meter checks have been completed, continue trouble shooting by checking the high-voltage circuit, all the tubes including the G-M tube, and by measuring the voltages and resistances of the whole set (fig. 113).

(1) A high-voltage circuit of the type shown can be checked with an oscilloscope. The wave shapes are found in the technical manual covering the radiac set. Occasionally good tubes placed in such circuits will not operate properly. If all component parts test good but the high-voltage output is still too low, replace the high-voltage amplifier tube V104.

(2) Test the Geiger-Muller tubes and all the remaining vacuum tubes on the appropriate tube test sets. If all tubes check good, perform voltage and resistance measurements on the set. Abide by all cautions listed in the manual accompanying the radiac set to avoid damaging the meter.

(3) If a test signal check is desired for troubleshooting or calibration purposes, use a pulse generator and proceed as follows: Disable the high-voltage circuit by removing the high-voltage batteries, or as in the sample circuit (fig. 113) the high-voltage amplifier (V104). Adjust the pulse generator repetition rate, pulse width, and amplitude to the values specified in the radiac set repair literature. Apply the pulse generator output to the grid coupling capacitor (C113) of the input stage (V105).

Note. If the test signal data are not listed in the equipment repair literature, perform the test on a good radiac set of the same nomenclature, adjusting the pulse generator repetition rate, pulse width, and amplitude until full-scale deflection is reached on the radiac set. Without changing the pulse generator control settings, apply the output to the radiac set under repair. The pulse generator should be capable of developing a pulse of 2 microseconds width, and 50-volt amplitude at a rate of at least 3,000 pulses per second for every milliroentgen per second of the radiac set scale.

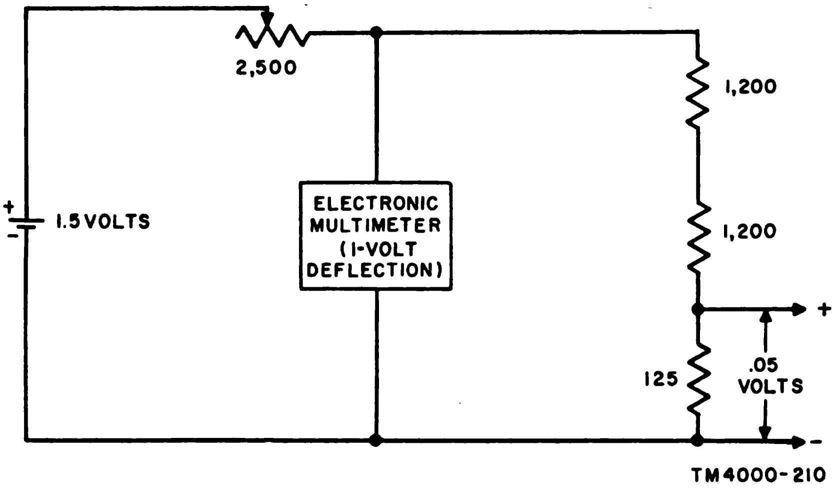


Figure 114. Test signal circuit diagram.

CHAPTER 13

TROUBLESHOOTING TRANSISTORIZED EQUIPMENT

320. General

a. The overall plan for troubleshooting transistorized equipment is essentially the same as that used for vacuum-tube equipment. The standard procedures of sectionalization, localization, and isolation used for vacuum tube circuits apply also to transistorized circuits. In many cases the methods used to accomplish these procedures will be the same. Determining the fault or defective part in a system or set containing transistors still requires using the senses to examine the equipment. Voltage and resistance measurements are still essential. However, because of the nature of conduction through a transistor, certain troubleshooting methods are more important and specific techniques are necessary to prevent damage to the transistors.

b. The various types of test equipment for servicing conventional vacuum-tube circuits will also prove satisfactory for troubleshooting transistorized circuits. However, because of the internal circuitry of many pieces of test equipment, a voltage will exist between the equipment and earth ground when the equipment is connected to a source of line voltage. This voltage is present at the test prod or at the connecting cable of the test equipment and may be applied across the transistors when the test equipment is used. Transistors are designed for use with very small voltages; therefore they can become damaged permanently by the application of a high voltage. As a general rule for protection against such an occurrence, the chassis of all test equipment in use and the chassis of the equipment under test should be connected together by jumper leads to form a common chassis ground.

c. Momentary short circuits in transistorized equipments can damage transistors severely because the magnitude and polarity of the operating bias applied to transistors depends upon the voltage drops across the various circuit resistors. The magnitude of these bias voltages may be increased greatly and their polarities may be reversed if any given resistor is short circuited. An excessive voltage or reversed polarity, even though only momentary, may damage a transistor. For this reason, the conventional method of troubleshooting by short circuiting certain points to chassis and listening for clicks is impracticable. Short circuits must be avoided at all times. When testing a piece of transistorized equipment take care not to cause short circuits with test prods. The momentary short circuit caused by the slip of a test prod, while not serious in vacuum tube circuitry, can cause serious damage to transistors. It is advisable therefore, to insulate the conductive end of test prods with tape, except for a very short tip that is necessary for contacting the circuit under test.

d. In general, transistorized circuits should be less troublesome than vacuum tube circuits. The useful life of a transistor operated under normal conditions is far greater than that of any vacuum tube. The devices are nonmicrophonic, mechanically rugged, and will operate in any position. They need not be mounted horizontally or vertically as is necessary with many vacuum tubes. These qualities, naturally, remove many potential sources of trouble.

321. Localizing and Isolating Trouble

The methods discussed in *b* through *e* below are presented in the logical order in which they should be performed. The checking of bias voltages, discussed in *a* below, may, at times, be accomplished after the trouble has been localized. However, because of its importance this material precedes the methods of localization. Do not replace defective transistors with new ones until you understand the information in *a* below.

a. Checking Source and Bias Voltages.

(1) The polarity of the source and bias (operating) voltages takes on added

importance in transistorized circuitry. If the polarity of the voltage applied to an operating vacuum tube becomes reversed the circuit may not operate properly but no permanent damage to the tube will be incurred. If a new tube is plugged into a socket with reversed polarity, it *probably* will not be *damaged.* Reversed polarity, however, *can* completely destroy a transistor and the one subsequently inserted in the socket for test purposes. Therefore, check the polarity of the bias voltages applied to a transistor that may be defective before replacing it with a new one.

(2) The polarity of the voltages between the leads of a transistor (termed the *emitter, base,* and *collector* leads) is not the same for all transistors. The *collector* (comparable to the plate of a vacuum tube) is not always positive with respect to the other elements of the device as in a vacuum tube. The polarity of the operating (bias) voltages depends on which of the two types of transistor is used. The two types are known as *NPN* and *PNP* and require opposite polarities for proper operation. The following chart shows the voltage polarity to be expected on each electrode with respect to each of the other electrodes for the two types of transistor.

	Voltage polarity with respect to:					
	Emitter		Base		Collector	
	NPN	PNP	NPN	PNP	NPN	PNP
Emitter	0	0	—	+	—	+
Base	+	—	0	0	—	+
Collector	+	—	+	—	0	0

(3) When checking the bias voltages on any transistor, two facts must be determined. First, the leads must be identified. Second, it must be determined whether the transistor is of the *NPN or PNP* type. If these facts are not apparent from labeling they can usually be determined by the following means: To identify the leads examine their spacing at the point where they enter the transistor. If they are unequally spaced (A, fig. 115), the closer leads are the emitter and base with the emitter being at the outside. The third lead, widely spaced from the other two, is the collector. If the leads are equally spaced, look for a red dot on one edge of the transistor (B, fig. 115). The lead closest to the dot is the collector while the base and emitter leads follow in order. If the transistor is cylindrical in shape, look for a red dot on the side at the lower edge. The pin adjacent to this dot is the collector. The base and emitter follow in a clockwise direction, when the transistor is viewed from the bottom (C, fig. 115). To determine whether a transistor is of the *NPN* or *PNP* type connect a switch, 5,600-ohm resistor, 4½-volt battery, meter, and the transistor to be tested as shown in figure 116. (Before removing a transistor from a circuit, refer to par. 324.) Set the meter to a scale capable of indicating a dc current of 1 milliampere and close the switch. If the transistor is of the *NPN* type, the diode section composed of the base and collector regions will be biased in the forward direction. With forward bias the diode can pass a comparatively large current. The meter will indicate approxmiately 1 milliampere. If the transistor is of the *PNP* type the diode section will have a reverse bias applied. In this case only a small leakage cur-

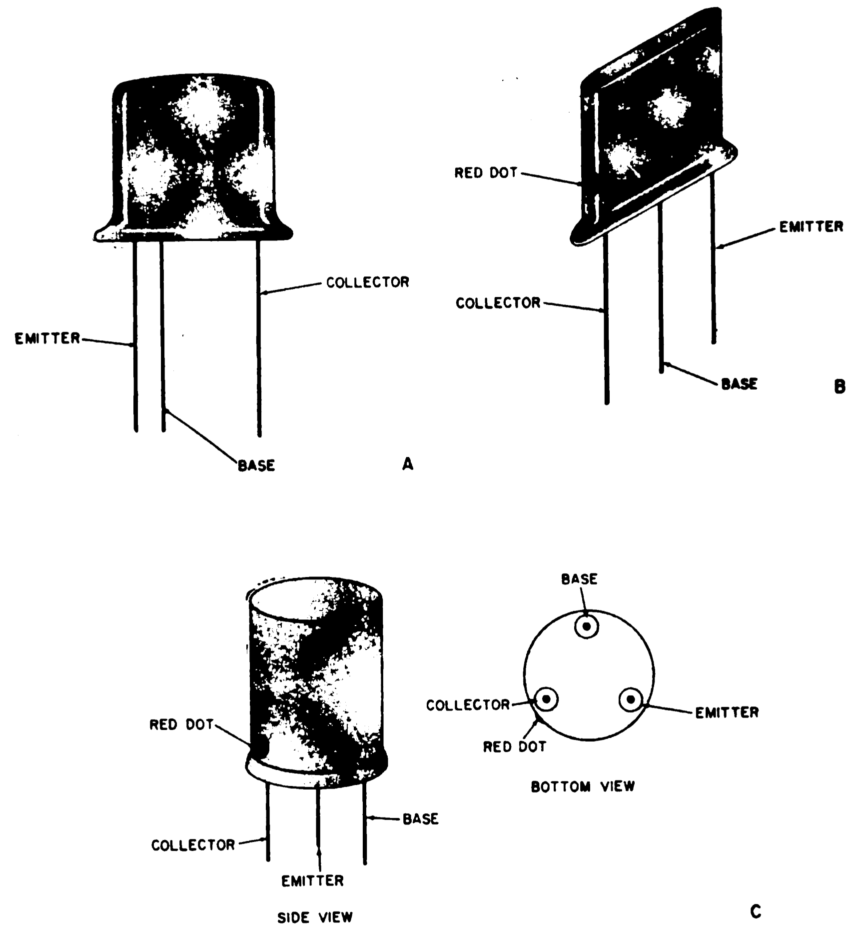


Figure 115. Identifying transistor leads.

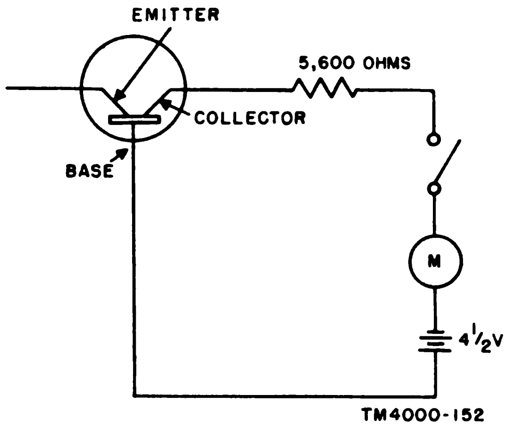


Figure 116. Test circuit to determine transistor type.

rent known as the *reverse saturation current* can flow. The indication on the meter will be almost neglible (on the order of microamperes).

Note. A reversed polarity of a high voltage *can* damage a transistor, but the voltage in the test set is too low to cause damage.

(4) The source voltage usually is a battery with a keyed socket for compartment which allows the battery to be installed only in the proper position. However, it is important to examine the battery to be sure it is inserted properly. The polarity of the bias voltages can be checked at the transistor terminals. If the transistor is mounted in a socket, remove the transistor from the circuit and use a dc voltmeter to check the polarities of the voltage between the emitter, base, and collector terminals of the socket. The polarities should be as indicated in the chart in (2) above. In some cases the transistors are soldered in the circuit, thereby making it impracticable to remove them. In such cases the check may be made with the transistors in the circuit. The emitter-base junction represents a very

low resistance during normal operation; therefore a proper operating bias will give a very low voltage indication on the meter when it is properly connected to the circuit. If the meter leads are reversed the meter will read off scale in the reverse direction. If the polarity of the operating bias is incorrect, the proper connection of the meter leads will give a reversed meter reading and when the meter leads are reversed a substantial voltage reading will be obtained. The collector-base junction represents a high resistance; therefore a proper operating bias will produce a voltage indication on a properly connected meter. A zero or reversed reading, or a very low reading with the meter leads reversed, indicates that the polarity of the bias voltage is incorrect.

b. Overheated Transistor. One of the simplest methods of detecting a defective transistor in a piece of equipment is to check each transistor for heat. Transistors do not produce a current flow by thermionic emission (emission of electrons from a heated cathode) and therefore do not require filaments. Under normal operating conditions they should be cool. Exceptions to this general rule are power transistors. These may generate considerable heat during operation; therefore to check for a defective transistor, lightly touch each one in the equipment. If one or more is found to be hot, determine whether they are used in power stages. If they are not, the transistors are defective and should be replaced. Refer to paragraph 324 before replacing any transistors.

Caution: Be sure to touch each transistor lightly. If one is defective it can become extremely hot and cause an uncomfortable finger burn when pressed firmly.

c. Transient Method. The procedure described in *b* above detects only completely defective transistors or circuit defects that cause overheating of transistors. It does not give any indication of the worth of the associated circuitry. If the results of the *overheated transistor* method prove negative and the transistors are mounted in sockets, the *transient method* of trouble shooting should be employed. This method consists of developing transient current in each stage of the equipment by momentarily interrupting the circuit and looking for an indication of the proper passage and amplification of the transient signal through the set. The *transient method* may be used as follows:

(1) Starting with the audio stage immediately preceding the speaker (fig. 117), pull the transistor out of its socket just far enough to break its connection in the circuit. Immediately reinsert the transistor. A click should be heard from the speaker.

(2) Repeat the procedure for each stage in succession, working back from the indicating device.

(3) A click should be heard each time a transistor is pulled out and reinserted and the click should get progressively louder with each stage tested.

(4) If at any point in the test a click is not heard when the circuit is interrupted or a gain in amplification is not evident, the stage last tested is probably defective (fig. 117).

d. Transistor Substitution.

(1) If the above tests do not provide positive results, substitute a transistor known to be new or in good operating condition for each transistor in the set.

(2) It is advisable, if possible, to try several of the proper types of transistors in each stage if satisfactory results are not obtained with the initial substitution. Manufacturing inadequacies can cause one transistor to operate in a given circuit while another of the same type will not.

e. Signal Tracing and Injection. When the more simple methods of locating a defective stage fail, signal tracing or injection may be used. The procedure for signal tracing or injection is the same as that used for vacuum tube circuitry. However, when injecting a signal into transistorized stages, keep the signal as low as possible. Transistors operate at very low levels of signal voltage and can be very easily overloaded. Severe overloading can damage a transistor.

322. Isolating Trouble

a. The methods used to isolate a trouble to a specific component in a defective transistor stage are the same as those used for vacuum tube circuits. The multimeter is the prime troubleshooting instrument. Use it to check the voltages and resistances throughout the stage. However, when checking resistances, remember that transistors do not require heated cathodes to pass current. They will conduct whenever a voltage is applied across their terminals even when the main power switch of the equipment is off. The internal voltage of an ohmmeter (which is present at the leads) is enough to cause conduction in a transistor. If the polarity of the ohmmeter voltage is incorrect it can act as a reversed bias on the transistor and damage it. To prevent damage and obtain accurate readings when measuring resistances in a transistor circuit, remove the transistor from the circuit.

b. If resistance measurements must be made and the transistors cannot be removed from the equipment, the indications may not compare with those expected. This is because the current also passes through the transistors and other parts that form a parallel circuit, and it may be necessary to disconnect parts before measuring its resistance.

c. Another unusual effect will be noted. The reversing of the test leads and the use of different ranges of the ohmmeter will cause different indications at the same points. Depending on the polarity and the range used, the indicated resistance between two points may vary over a range of 300 to 50,000 ohms.

323. Testing Transistors

a. For troubleshooting and repair purposes, only two transistor characteristics need be checked to obtain a fairly accurate indication of a transistor's condition. These are the reverse saturation current (I_{co}) of the base-collector circuit and the approximate current gain of the device. Both characteristics may be checked with a meter and a 4½-volt battery. The expected meter readings given below are typical readings to be used if specification data are not available. When such data are available, however, consult them for the proper I_{co} and gain readings.

(1) To obtain an indication of the I_{co} of a PNP transistor, connect the meter and battery to the collector-base circuit with the emitter circuit open (A, fig. 118). The meter will indicate the I_{co} which should be as stated in *b*(2) below.

(2) To obtain an indication of the current gain of a PNP transistor, connect the battery and meter to the emitter-collector circuit with the base circuit open (B, fig. 118). The meter should indicate a current from 20 to 40 times greater than I_{co} obtained in (1) above.

(3) To obtain these readings for NPN transistors, reconnect the battery so as to reverse its polarity in the circuit.

b. If parts listed below are available or obtainable, the circuit shown in figure 111 can be used to perform both tests outlined in *a* above plus the test used to determine the type of transistor outlined in paragraph 321*a*(3). After constructing the tester, label the switches and switch positions as shown in figure 119.

1 multimeter.
1 5,600-ohm resistor.
1 4½-volt battery.
1 dpdt switch.
1 spdt switch.
1 transistor socket or terminal board.

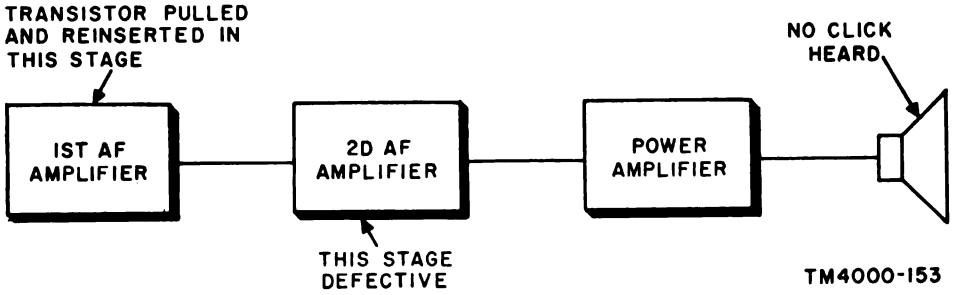


Figure 117. Transient method of troubleshooting.

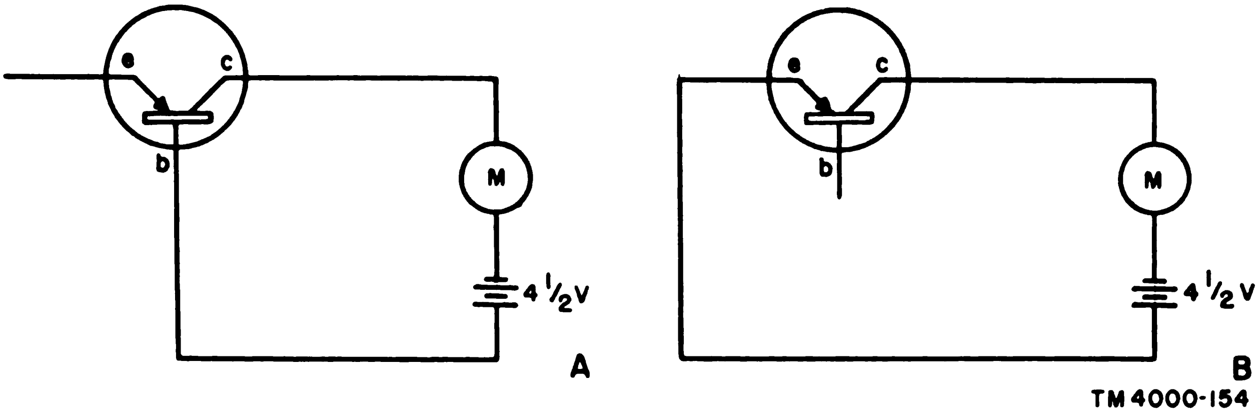


Figure 118. Testing transistor characteristics.

To operate the tester proceed as follows:

(1) Set the meter to the 2.5 ma current scale. Set test switch, S2, to the I_{co} position and insert the transistor into the socket (or connect the transistor leads to the proper terminals as shown in (fig. 119).

(2) Set type switch, S1, to the position (NPN or PNP) that correspond to the type of transistor under test and note the reading on the meter. If the meter reading is above .250 ma (except for power transistors), the transistor is considered defective. If the meter indicates a current of less than .250 ma, set the meter to the 250 microampere current scale and note the reading. This reading is the I_{co} and will be in microamperes. For low-powered transistors (50 milliwatts and generally used in RF, IF, oscillator, or 1st audio stages), it should be from 1 to 5 microamperes. For medium-powered devices (from 100 to 150 milliwatts and often used in audio output stages), it should be from 2 to 10 microamperes. Power transistors (2 watts) may have an I_{co} as great as 300 microamperes. If the transistor type is not known, set the type switch in each of its two positions. The position that produces the smaller meter reading indicates the type of transistor under test. Leave the type switch in that position, reduce the meter scale to 250 microamperes, and note the meter reading. This reading is the I_{co} and should be as stated above.

(3) Set the test switch to the gain position. The meter should indicate from 20 to 40 times the I_{co} reading noted in (2) above.

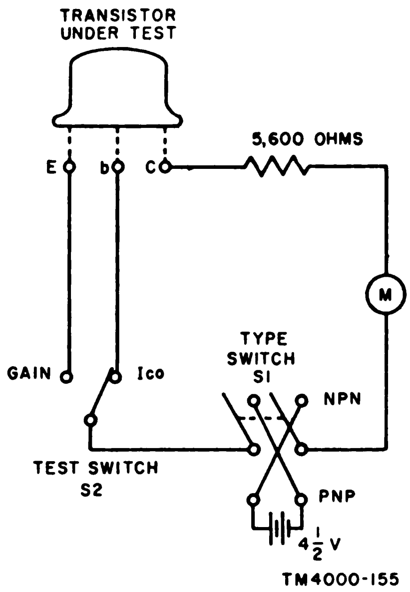


Figure 119. Field test circuit.

c. If the equipment required to construct the field test circuit described above is not available, some indication of the condition of a transistor may be obtained with an ohmmeter. The ohmmeter test will not definitely indicate that a transistor is serviceable. This is because it gives no indication of the gain or current handling ability of the device. However, if a transistor fails to produce the required results of an ohmmeter test the device may be considered unserviceable. To perform the ohmmeter test, proceed as follows:

(1) For a PNP transistor, connect the positive lead of the ohmmeter to the base terminal of the transistor.

(2) Connect the common, or negative, lead of the ohmmeter to the transistor emitter terminal and observe the indication on the meter. Because of the polarity of the small ohmmeter voltage applied, the emitter-base junction is biased in the reverse direction and the indication on the meter should be .5 megohm or greater.

(3) Remove the negative lead from the emitter terminal and connect it to the collector lead. Observe the indication on the meter. The ohmmeter voltage biases the base-collector junction in the reverse direction and the indication on the ohmmeter should be .5 megohm or greater.

(4) By connecting the negative lead on the base terminal and placing the positive lead, in turn, on the emitter and collector terminals, the two junctions will be biased in the forward direction. The meter reading in each case should be below 500 ohms.

(5) For an NPN transistor, reverse the ohmmeter lead connections described in (1) through (4) above. The high resistance readings should be obtained with the negative lead connected to the base; the low resistance readings with the positive lead connected to the base.

324. Repairs and Replacements

a. Transistors are extremely sensitive to heat and will be destroyed if subjected to excessive temperatures for even short periods of time. For this reason the soldering techniques used in transistor circuits are very important. Whenever possible use a low-powered soldering iron, preferably from 25 to 50 watts. In addition a heat sink of some sort should be provided between the point of contact of the soldering iron and the transistor. This is best accomplished by grasping the transistor lead being soldered with long-nosed pliers just above the point of soldering iron contact (fig. 120). The pliers then dissipate any excess heat before it is conducted to the transistor. The application of a heat sink is essential and should be employed whenever a soldering iron contacts a transistor lead, regardless of how short the period of contact time. Apply the soldering iron to the transistor lead only long enough to melt the solder to a workable state. Never bring the soldering iron into contact with the body of the transistor or any metal surface in direct contact with the body of the transistor. Do not use large, high-wattage irons. The heat radiated from the body of such an iron can be enough to damage any transistor in the vicinity. If a large iron is all that is available it can be used by wrapping a piece of heavy-gage wire around the iron tip as shown in figure 121. The extension of wire, when used as the iron tip, allows the body of the soldering iron to be held away from the transistors in the set. Also, some excess heat is lost through the loose wrapping of the wire around the iron tip.

b. Certain transistors, such as power transistors, generate considerable heat during normal operation. It is essential that this heat be adequately dissipated. The method most commonly used to accomplish this is to bolt the transistor to the chassis of the equipment. The chassis then acts as a heat sink. The heat is dissipated by a lug built on the body of the transistor or by a metal sleeve that fits over the body of the transistor and then bolts to the chassis. When such transistors are replaced, it is essential that the replacement transistor be bolted to the chassis before the equipment is operated, even for test purposes.

c. Transistor sockets generally are not keyed. It is possible, therefore, when replacing a transistor, to insert the substitute backwards, thereby reversing the pin connections to the emitter and collector leads. For this reason, before a transistor is removed from its socket, or unsoldered from a circuit, some means must be employed to identify the terminal, or pin, to which the collector lead will be connected when the transistor is replaced. This can be done by marking the emitter terminal of a socket with a pencil, chalk, or crayon before removing a transistor.

d. Many soldering irons, when plugged into an ac line, have a voltage existing between the metal of the soldering iron and earth ground.

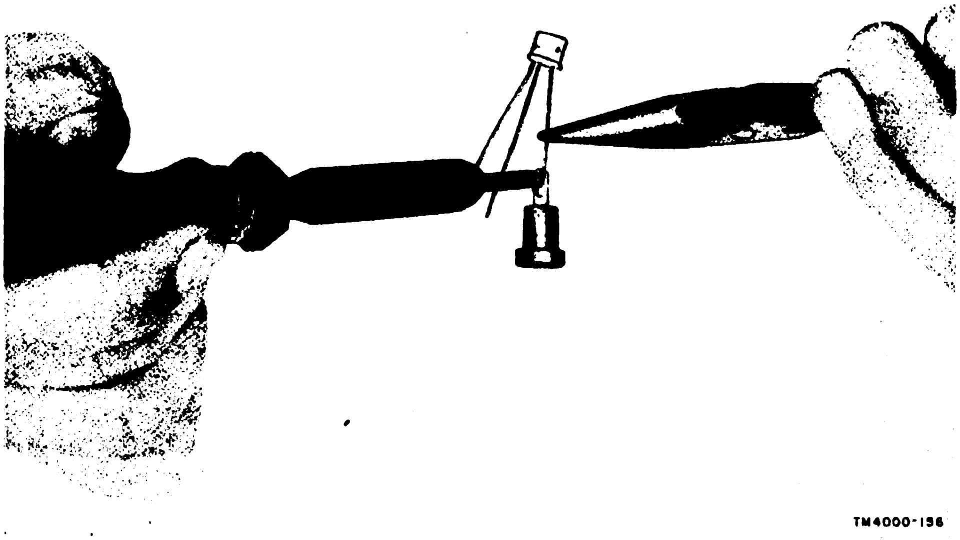

TM4000-156

Figure 120. *Use of pliers as a heat sink.*

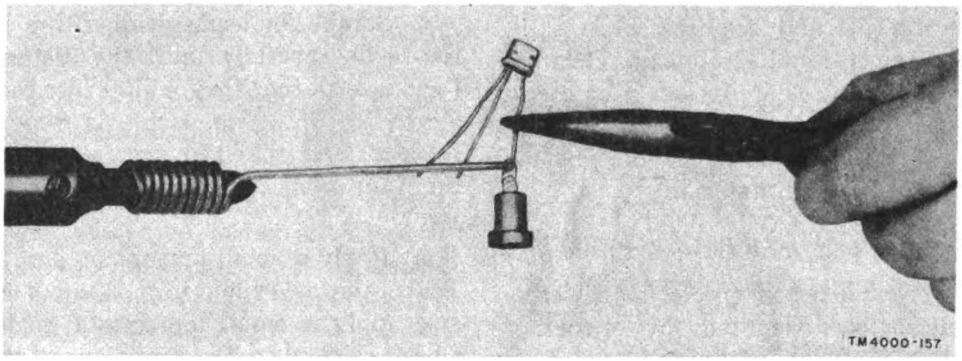

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Figure 121. *Use of high-wattage soldering iron in transistor circuits.*

This voltage causes leakage currents that can seriously damage a transistor when the iron is brought into contact with the transistor lead. These effects can be nullified by connecting a jumper lead from the metal body of the iron to the chassis of the equipment under test.

325. Alinement

The alinement of transistorized sets follows the same general procedures used for vacuum-tube sets. Perhaps some additional importance should be placed on the technique of keeping the level of an input signal low during alinement. Transistors are designed to work primarily with small signals and can easily be overloaded. The practice of peaking individual stages should not be employed. To peak any one stage, the entire set should be realined according to the accepted procedure for the equipment. Transistors have extremely low-impedance input circuits and because of the physical nature of transistors, their input and output circuits are not isolated from each other. An adjustment to one stage, therefore, not only affects the loading and the tuning of the previous stage but will also affect the tuning of all the following stages. Individual stages, therefore, should not be readjusted.

CHAPTER 14

REPAIRING PRINTED WIRING ASSEMBLIES

326. General

a. Printed wiring is a comparatively new method of assembling and connecting parts in electronic equipment in an affort to reduce the size and weight of the equipment. Printed wiring also lends itself to the design of modularized units. These modules are compact and can be replaced quickly by plugging in another unit.

b. Troubleshooting printed wiring is identical with troubleshooting conventional circuits, therefore, it will not be repeated here.

c. Repairing printed circuit wiring assemblies is more difficult and requires more skill than repairing conventional equipment. Printed wiring can be damaged easily by heat; be careful when soldering. Prolonged heat will destroy the adhesive qualities of the agent that bonds the copper foil to the base material.

327. Special Tools and Materials Required

a. Special Tools. A list of special tools, some of them small in size, required for repairing printed circuit assemblies follows:

Pencil-type soldering iron, 25 watts.
Small twist drills, No. 30 through No. 60.
Pin vise.
Small metal pick.
One-half inch brush.

b. Material Needed. A list of materials needed, in addition to those used in troubleshooting conventional assemblies follows:

Rosin-alcohol solder flux, spec MIL–14256 (Sig C).
Varnish (MIL–V–173A).
Alcohol.

328. Removing Part

a. Removing Protective Coating. The protective coating on the assembly board must be removed before starting repairs. Chip the coating away with a metal pick, knife, or other suitable instrument. If chipping is not successful, apply a hot soldering iron to the coating to soften it. Never use a solvent to remove the coating. Solvents are difficult to control and may loosen the copper foil from the assembly board.

b. Unsoldering Defective Part. The point at which the defective part is jointed to the foil must be unsoldered. Be sure to use the small soldering iron, to avoid damage from excessive heat. Apply the iron tip to the pigtail lead on the part and not to the foil. This will cause the lead to absorb most of the heat and keep it away from the foil. Remove the iron as soon as the solder melts and brush the excessive solder away.

329. Installing New Part

a. Scrape the leads clean with a knife. Bend the leads carefully until the distance between them is such that they will fit into the holes from which the defective part was removed. Mount the part and clinch or swage the leads close to the foil. This will form a strong mechanical joint.

b. Apply a small amount of flux to the joint. Touch the soldering iron tip to the part lead and apply a small amount of solder (fluxless 60/40 solder) to the junction of the lead and the foil. Remove the iron as soon as the solder flows into the joint. Hold the lead firmly until the solder sets. Remove any excess flux with a small amount of alcohol.

c. The flux used is of great importance. There is no known commercial flux that is as noncorrosive and nonconductive as a rosin-alcohol mixture. Use no flux other than that specified.

330. Recoating Joint

a. Protective Coating. After the solder cools, inspect the joint to see that it is clean and that solder has not flowed or dropped where it can cause short circuits. Newly soldered joints will become corroded if left uncoated, especially in damp climates. Apply a coating of varnish (MIL–V–173A) to the bare areas. Cover the area completely and overlap the surrounding coated areas.

b. Removing Defective Part. If the ends of the part leads have been squeezed out of shape, cut them off to permit withdrawal of the leads. If the leads are bent, straighten them before removal to prevent damage to the foil when the part is removed. If some solder still remains on the leads, apply the soldering iron to the solder momentarily and pull the leads through the foil while the solder is soft. Pull the part straight up from the board without forcing or twisting it. Rough handling can damage the board or pull the foil loose.

c. Clearing Lead Hole.

(1) Molten solder will sometimes flow into the lead holes while the part is being removed. Avoid using a soldering iron to remove the solder because the amount of heat required may loosen the foil. Do not clean the hole by heating the solder when inserting the new part; the lead may catch the edge of the foil and tear it away from the board.

(2) On boards where the leads are passed through metal eyelets, the solder often will flow into the eyelet where it cannot be brushed away. Tap the board sharply while the solder is still soft, and force it to flow out. If the solder cannot be removed this way, chuck a twist drill of suitable size in a pin vise and carefully drill the solder out from the foil side of the board. This will form a hole large enough to insert the new part lead. Drilling from the other side of the board can loosen the foil as the drill passes through it.

331. Repairing Printed Conductor

The printed conductor, which is usually a thin copper foil, can become damaged and cause an open circuit. Generally, when the foil is damaged in one place, it probably is damaged at other points also. Therefore, the entire board must be replaced. A defect in more than one place on a very small board means that it must be discarded, because the space is inadequate. When repairs must be made and the space is adequate, the procedure below should be followed.

a. Remove the loose or charred portions of the conductor. Bend a piece of tinned copper wire, about No. 20 gage, into the shape of a staple. The staple must be long enough to span the defective portion of the conductor and be clinched about one-fourth inch from the end after being inserted through the assembly board.

b. Drill two holes of proper size to receive the staple ends. The holes must not be drilled through the foil, but near the foil so that the staple will be parallel to the foil. Insert the staple from the side opposite the wiring side, and bend the ends diagonally across the printed conductor. There is greater contact with the conductor when it is bent diagonally rather than at right angles to the foil. If possible, the staple should make contact for about ¼ inch. Use the same soldering procedure described in paragraph 421.

c. If the printed wiring is about ¼ inch wide, drill the holes through the foil from the wiring side. Insert the staple from the component side and clinch the ends as before. The soldering procedure is the same as in preceding operations.

d. Where it is convenient, insert the staple through the holes from the wiring side. Drill two extra holes in the board from the component side and adjacent to the original holes. Bend the staple ends back into these holes and clinch them diagonally across the conductor and solder as before. Apply a protective coating of varnish to all uncoated areas.

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NG: State AG; units—same as Active Army.

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For explanation of abbreviations used, see AR 320-50.

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