# CHAPTER 13

# MAINTENANCE PROCEDURES AND TECHNIQUES, PART II

## CORRECTIVE MAINTENANCE PROCEDURES

To perform effective corrective maintenance the ET must have a good working knowledge of the basic principles of electricity and electronics. The only way to acquire this knowledge is by diligent study. The ET must also be thoroughly familiar with the theory of operation of the equipments that he must service. A knowledge of the theory of operation can be acquired through a study of the "Theory of Operation" section (generally, section 2) of the equipment instruction book. In the new technical manuals, a different procedure will be followed. This knowledge should be broadened to include other equipments at the earliest opportunity. As a matter of fact, ETs are generally rotated on the various electronic equipments so that their knowledge will be broadened and they will therefore be more valuable to the fleet.

Skill in the use of test equipment (and handtools) is also necessary for effective corrective maintenance. Skill in the use of test equipment comes with practice and with careful study of the instruction book that comes with each piece of test equipment. The ET should take advantage of every opportunity to learn more about every type of electronic test equipment used aboard ship. The ability to use test equipment effectively is an absolute must for every well-trained ET.

Chapters 6 and 7 of this training course introduced the prospective ET to some of the more common test equipments. Additional valuable information (both on test equipment and methods of troubleshooting) is contained in Test Methods and Practices Handbook, NavShips 900 000.103. A list of the various electronic test equipments (also troubleshooting methods) is included in the Electronics Installation and Maintenance Books, NavShips 900,000.

This chapter treats, in a general way, some of the corrective maintenance procedures used for the various types of electronic equipment. Detailed procedures for troubleshooting each piece of electronic equipment are contained in the instruction book of that particular piece of equipment. One of the most valuable aids in the instruction book is the troubleshooting chart. These charts will be discussed under the various types of electronic equipment.

Tests (opens, grounds, and shorts) and measurements (currents, voltage, resistance, frequency, power, etc.) enable the technician to diagnose troubles so that repairs may be made. In many instances tests and measurements will indicate conditions that may be corrected before an actual breakdown occurs. Thus, tests and measurements (particularly measurements) are important both in preventive and corrective maintenance.

The purpose of any type of electronic test equipment is to measure accurately certain circuit values or to indicate certain circuit conditions. Each of these measurements or indications is used to determine the operating condition of electronic or electrical equipment. The accuracy with which measurements are made depends on the type of instrument used, its sensitivity, its rated accuracy, its useful range, and the care that the technician uses in making the measurement.

The exact procedure for making tests and measurements is given in the technical manuals (instruction books) that accompany the various electronic equipments.

It should be emphasized that the mere taking of measurements means little unless they can be properly interpreted. For example, the presence of a voltage across a grid resistor in an audio amplifier would mean little to an ET unless he could interpret this in terms of a possible leaky coupling capacitor. In this connection, the necessity for a knowledge of basic circuit operation must be emphasized.

Before any attempt is made to interpret the results of measurements, an understanding of how the equipment operates should be acquired by a careful study of the applicable technical manual or instruction book.

The actual voltage, resistance, and current measurements that should be obtained are indicated in the circuit diagrams, charts, or in the maintenance standards books. The same is true of waveform measurements. Any deviation from the standard values (beyond the tolerance limits) means that some component is not doing the job that it should. By applying effect-to-cause reasoning, the defective component may be located. This is, of course, a job for a skilled technician.

According to the "quals," the prospective ET 3 must be able to localize equipment casualties to components or subassemblies and to make the repair by replacement of subassemblies or parts. However, it is conceivable that under certain circumstances, especially on smaller vessels, the ET 3 may have to effect the entire repair. In any case, the "quals" spell out only the minimum qualifications for advancement in rating, and the prospective ET 3 should in no way restrict his knowledge or his ability to make repairs.

There are numerous ways to isolate a fault to a component of a system, depending on the type of equipment. The technician must, first of all, know what each component does before he can know that it is not functioning properly.

Assume, for example, that the display on a certain radar repeater is faulty. The trouble could be in the repeater or it could be in one of the circuits that feeds into the repeater. If the other repeaters are working properly, it is probable that the trouble is in the repeater having the faulty display or in its power supply or in the transmission lines or switching system.

The best way (the most economical in time and effort) to isolate a fault is by using a logical troubleshooting method.

## TROUBLESHOOTING

Good troubleshooting is not a talent with which a person is born. It is, however, a skill that can be acquired by anyone with a suitable electronics background. One can become a good troubleshooter if he has:

1. Sufficient electronic knowledge to learn, or to be taught how an equipment works.
2. Suitable skill in reading and interpreting data contained in the equipment's technical manual.
3. Suitable skill in operating test equipment and interpreting test readings.
4. Has learned how to troubleshoot in a logical manner.

Logical troubleshooting does not recognize "easter-egging," "cook-booking," or "trial-and-error" methods. The "easter-egger" makes unsupported guesses; the "cook-booker" looks for trouble-locating clues in the trouble chart; and the "trial-and-error" technician starts at one end of the equipment and works toward the other. If any of the three finds the trouble in a reasonable length of time, he is lucky. An average size equipment will have 100 circuits, 700 electronic parts, and hundreds of wires and terminal boards and/or connections. A large size equipment may have 1000 circuits, 7000 electronic parts, and thousands of wires and terminal connections. Finding the one bad or partially bad part, wire, or connection among hundreds or thousands is not easy to do by illogical methods.

Logical troubleshooting is a time-proven procedure used by all accomplished technicians. Most of them have applied the procedure so often that they no longer pay attention to its fine points. Through habit and years of experience they may have forgotten its specific details, but the procedures are there and have remained the same.

Probably no two technicians would explain the procedure alike, but all would agree that logical troubleshooting consists of a series of sequential steps based on valid electronic decisions that systematically narrows the trouble down to the faulty part. Some would list the procedure in three or four steps others would count a dozen, fifteen, or more. Regardless of the number, the principle would be the same. Six steps have been chosen as the easiest method of learning and applying this procedure. The steps in their sequential order are:

1. Symptom recognition
2. Symptom elaboration
3. Listing the probable faulty functions
4. Localizing the faulty function
5. Localizing the faulty circuit
6. Failure analysis

### Symptom Recognition

The first step in any troubleshooting problem is recognition of a trouble indication. Recognizing a trouble condition in an equipment is not always easy to do since all conditions of less than peak performance are not always apparent. Lack of targets on a scope, timing error in a loran set, and a decrease in signal-to-noise ratio in a receiver are just a few of the hundreds of examples occurring throughout the Navy. Each of these is a trouble symptom that requires recognition and elimination.

There are many ways in which the existence of a trouble can be detected by a technician. The obvious troubles will undoubtedly be reported by the operator. These usually include complete or almost complete malfunction of the equipment. Troubles that are not easily noticed are those that cause a gradual decrease in equipment performance. For example, a 125-mile radar that is reaching only 105-miles, a 100-watt transmitter that is putting out only 87 watts, or a multimeter that provides readings that are 10% off, are equipment faults that are difficult to recognize because there are no visible or audible indications (built-in) that say they exist.

Since a ship must depend on full-performance equipment the hidden trouble symptoms must be found, the cause of the trouble located, and the repair made. If the technician makes a point of looking for them every time he touches an equipment most of the decreasing performance symptoms can be easily recognized. Often he can compare the performance between two similar equipments. He can actually make the Performance Standards sheet checks contained in the POMSEE program. By using the POMSEE books, he can verify any change in performance since the last time he tuned, calibrated, or aligned the equipment. Also while troubleshooting, he may look for and probably find symptoms that signify decreasing performance and future breakdown if left unnoticed. Trouble symptoms can be recognized if the technician will only look for them.

### Symptom Elaboration

Breaking out test equipment and equipment prints and proceeding headlong into troubleshooting on just the original identity of a trouble symptom is a very shaky premise. It could also be an unnecessary expenditure of energy. A dead scope, a hum in a receiver, a zero reading on a panel meter, or a missing transmitter pulse, by itself, is not sufficient identification of a trouble symptom. There is a tendency among less efficient technicians to attempt a solution of a troubleshooting problem before they have completely defined it.

The procedures involved are dependent upon the available aids designed in the equipment and the nature of the original symptom. The aids include front panel controls and built-in performance measuring indicators. Additional information can be obtained about any malfunction as the result of a systematic front panel check. If the technician has a fair knowledge of how the equipment works, manipulation of appropriate controls and switches and corresponding checks of equipment meters and scopes will reveal to the technician how the trouble is affecting the entire equipment. From these clues he is able to narrow down the probable areas of the equipment that could contain the trouble.

### Listing The Probable (Faulty Functions)

The third step requires that the troubleshooter make an educated guess as to the probable cause of the trouble. From the elements of the trouble symptom, as he has identified it, he determines its most logical locations. Locations are to be confined to the major subdivisions (major or functional units) of an equipment. Educated guesses are made from the knowledge of how the equipment works and a study of the equipment's functional block diagram.

For example, using a malfunctioning radar that has no targets on the PPI but the transmitter and modulator indications read good, the educated guesses could include: (a) remote indicator unit, (b) receiver unit, (c) low-voltage power supply, and (d) duplexor. Making an educated guess that a tube is bad (just because the greater percentage of all equipment troubles are caused by bad tubes) is not acceptable. The purpose here is to use valid reasoning to isolate all probable, technically sensible functional areas which may contain the trouble. It may well be that the specific trouble is a bad tube, but wholesale tube substitution takes a lot of time and quite often introduces additional troubles, particularly in those circuits that operate close to critical tolerances.

Even the accomplished technician may not be able to list all the functional units that are probable sources of the trouble. However, with the exception of a very obvious trouble, a multi-unit equipment will have many functional units that are probable sources of a trouble.

### Localizing The Faulty Function

In this step one of the educated guesses must be selected for testing. It is not necessarily the one that was thought of first nor the one that past experience suggests as being the most attractive. The selection of the functional unit to be tested (or verified) first should be based not only on priority of validity but also on the difficulty in making the necessary tests. Under some circumstances, a troubleshooter might elect to test the second best educated guess rather than the first because the latter might involve testing difficulties that should be initially avoided or require tampering with circuit parts that might later prove to be unnecessary. Like all the others, this step in the troubleshooting procedure places emphasis on common sense thinking rather than the resultant action.

After selecting the order in which the listed units will be checked, the troubleshooter proceeds to verify his first selection. This check normally is made at the output test point of the suspected unit. The test equipment reading is compared with the desired signal contained in the technical manual. No output is relatively easy to recognize. A distorted or nonstandard output, however, should be carefully verified before arriving at a technical conclusion.

If the technician does his mental work properly, manual work in gaining access to test points and using the test equipment can be limited to a bare minimum. This procedure is opposed to trial-and-error methods where the technician searches from point to point with test prods, hoping to locate the faulty test reading that identifies the trouble. Not only does the illogical technician waste valuable time, but his unwillingness to rely on his technical knowledge indicates that he will be very lucky if he finds the trouble.

Upon completing the verification of the propable faulty unit selected, the technician will have arrived at one of several conclusions. The test may verify that this is the unit in which the trouble lies; or that the trouble could be in this unit plus another unit(s) from which it receives signal or control voltages; or that the trouble is not in this unit at all; or that the output looks suspicious and further verifying tests need to be made.

Whatever the conclusion, the technician has discovered information that can be used to substantiate or eliminate suspected units or provide evidence for adding another. Tests of suspected unit outputs are continued until the single faulty unit is identified. At that point, the technician has narrowed down the trouble to a fraction of the total number of circuits and parts in the equipment. If at this time the proper procedure was carried out the search can be confined to the functional area isolated. NOTE: There are some equipments such as communications receivers, that cannot be easily divided into functional units. If this type of equipment is involved, steps 3 and 4 above, can be eliminated from the overall troubleshooting procedure.

### Localizing The Faulty Circuit

After the faulty unit has been isolated, the next step is to identify the faulty circuit. The same narrowing-down procedures are used here as before. The unit is mentally subdivided into circuit groups by function, and valid technical reasoning is employed to select those that might probably contain the trouble. Using this procedure the technician can find the faulty circuit without going through the unnecessary time-wasting chore of test-point to test-point checking from one end of the unit to the other.

The technician works from the servicing block diagram of the unit. He then applies the information obtained from the preceding steps regarding the nature of the trouble. In narrowing down the trouble to a single functional group of circuits, the process used is called "bracketing." In this process brackets are placed, mentally or in pencil, around the area in which the trouble lies. Initially, a bracket is placed at the input(s) to the units that are known to be good and at the output(s) known to be bad. As each deduction is made and verified by a test, the input or output bracket is moved to the next point in the block diagram where the test was made. In this manner the closing brackets systematically narrow the fault to a single circuit.

In selecting a point on the servicing block diagram to which one of the brackets is to be moved, the technician must consider two things: (1) the faulty characteristics of the improper output signal and (2) the types of signal paths contained in the unit. The waveshape of a signal contains characteristics—voltage, time, bandpass, noise content, frequency, etc.—that can be measured or observed. When these characteristics are in accordance with the designed standards, the signal is considered to be good. Bad signal characteristics that are improper can reveal clues that will help to identify a circuit group whose function is to originate or control that portion of the waveshape. For example, the output of a unit is supposed to be a sawtooth waveform with six pulses, equally spaced on its slope. If the pulses are there but the slope is insufficient or improper, the sawtooth generating and shaping circuits would be suspected. If the proper slope is there but there is insufficient number of pulses, the pulse generating or controlling circuit groups may contain the trouble.

Types of signal paths contained in the unit are the other items to be considered before moving a bracket. There are four general types: linear, switching, convergent/divergent, and feedback. In a linear signal path, the signal is processed through circuits that are connected in series. When identification of the faulty circuit group is difficult or impossible, brackets can be moved to successively smaller halfpoints in the linear string. Signals from two or more circuit channels that meet at a common point or a signal that leaves a common point into two or more channels are examples of convergent/divergent paths. Moving a bracket to the common point (after making the appropriate test) will separate the bad from the good signal paths. In the same manner, a test and bracket at the point where signal paths are connected by a switch will reveal the same information. The remaining type (feedback loops) provides a means of bracketing a group of circuits in the narrowing-down process.

There are no hard-and-fast step by step procedures in bracketing. But there are some realistic general rules.

1. Examine the characteristics of the faulty output to determine the circuit group function that either generates or controls the improper characteristic.

2. Study the servicing block diagram to determine the least number of bracket moves that will isolate the faulty circuit. Such moves will be dependent upon the types of signal paths contained in the unit and the electronic functions of circuit groups that may be responsible for distortions contained in the unit's output.

3. Move only one bracket at a time after verifying the suitability of the signal by making a test.

4. When the test does not reveal sufficient information for a valid bracket move, make another educated guess.

5. The determination of which bracket to move is dependent upon circuit configuration within the unit and the smaller number of circuits that will be enclosed.

The servicing block diagram can serve as the instrument for the completed bracketing process. In some cases it may be necessary to refer to a schematic diagram for bracketing or testing information. In any event there is sufficient diagram information available in the technical manual to support the bracketing procedure and preclude the wastefulness of unreliable circuit to circuit checking. This step is completed when the technician has isolated the trouble to a single circuit and verified that the output of this circuit is the cause of the distortion read at the output of the unit.

### Failure Analysis

The troubleshooting procedure thus far has narrowed the trouble to a single circuit consisting of a tube (or transistor) and a few electronic components. If there is no output from the circuit, it may be permissible to resort to rote testing of tube pin numbers. However, such checks can be minimized if there is an output that can be examined for distortions that will reveal the circuit part that is most likely at fault. Quite often the waveform will identify the malfunction to be in the grid, cathode, plate, or screen portion of the circuit. Such a study should be made before any of the parts are checked.

When the faulty part has been identified, it should not be replaced until the technician can SUBSTANTIATE THAT IT IS CAUSING THE ACTUAL TROUBLE. A suspected open resistor, shorted capacitor, detuned coil, or weak tube may not be the reason or the only reason causing the faulty output of the circuit. If the technician replaces the part without an adequate technical reason, he may (when replacing the part) not have cured the trouble and he may yet cause further trouble. ANALYZE THE FAILURE BEFORE MAKING THE REPAIR.

It can now be seen that the six-step troubleshooting procedure is designed to isolate a trouble in an orderly manner. Success in using the procedure is dependent upon the technician's knowledge of electronics, the equipment under test, and his skill in using the technical manual and test equipment. The process is no more complicated than the ability to subdivide an equipment into progressively smaller functional areas, such as functional units into functional circuit groups, to a circuit, and finally a part or an adjustment within the circuit. It is the only logical way to troubleshoot any equipment, and it is more reliable and faster than any other method.

## TROUBLESHOOTING RADIO EQUIPMENT

Maintenance personnel must be prepared to repair and align units that have failed in operation. The source of the trouble must be located, the defect remedied, and the equipment restored to optimum operating condition. The following paragraphs (concerning radio and radar equipment) describe the theory of localization of faults and troubleshooting procedures as contained in the manufacturer's instruction books. Also contained therein are detailed instructions for the troubleshooting and repair of the various units of these equipments.

Maintenance personnel must try to find the source of the trouble causing the equipment failure, particularly when the trouble is a recurrent one. The recurrence of a fault usually indicates that the EFFECT, not the CAUSE, has been remedied.

Keep in mind throughout this study, that by far the largest section of the average instruction book is the one devoted to corrective maintenance (troubleshooting). This is the section written especially for the ET and when used with the six-step logical troubleshooting procedure described above can be for him the most valuable part of the book. The section on the theory of operation, however, is also very important and should be studied with care.

### Transmitters

Corrective maintenance in radio transmitters follows much the same pattern as in radio receivers, except that more indicators are likely to be involved in the use of the system troubleshooting chart. Consider for example, Radio Transmitting Sets, AN/SRT 14, 15, 16.

The following test equipment is required:

1. Multimeter (ME-25A/U or AN/PSM-4 series).
2. Oscilloscope (OS-8/U).
3. Frequency Meter (AN/USM-29).
4. Receiver (AN/SRR-11, 12, 13 series)
5. Audio oscillator (TS-382C/U).
6. Dummy Load (DA-91A/U).
7. R-f Signal Generator (AN/URM-25B).
8. Resistance Bridge (ZM-11A/U).
9. Radio-Frequency Bridge (Navy type 60094).
10. One-megohm, linear taper potentiometer.

Like most transmitters, this equipment operates at high voltages that are dangerous to life. Therefore, safety regulations must be observed at all times. Do not change tubes or make adjustments inside the equipment when the high voltage is on; do not use the "battle short" for bypassing interlocks. Never measure potentials in excess of 600 volts by means of flexible test leads or probes.

The manner in which this equipment operates or fails to operate often indicates the source of trouble. A knowledge of the control circuits (see chapter 9 of this training course) is most important for the localization of faults. It is, of course, necessary for the ET to become familiar with the simplified power and control schematic diagrams in the instruction book. The sequence of operations that result in the establishment of a carrier frequency is accomplished by visual panel indications.

The order in which the visual indications appear is shown in the system troubleshooting chart (in the instruction book), a small portion of which is included in figure 13-1. If the proper sequence of events does not take place, trouble is indicated.

The heavy blocks tell what is to be observed, and the heavy arrows between these blocks point in the direction of the sequence of indications that should be obtained (when the transmitter bay is operating properly) from the time that main power is applied to the time that the carrier is keyed on the air. Indications of proper operation are listed in the general order in which they occur. Each indication along the heavy path is evidence of proper operation only if all preceding indications have been obtained. However, some of the indications may occur simultaneously.

If the proper indication is not obtained, the lighter blocks (to the left) name the unit (or units) in which trouble may exist. The ET should then refer to the portion of the instruction book that gives troubleshooting information for that particular unit. If the proper indication fails to occur, the ET should first check the indicating component.

A dummy load (type DA-91/U) may be used during tests and maintenance procedures to

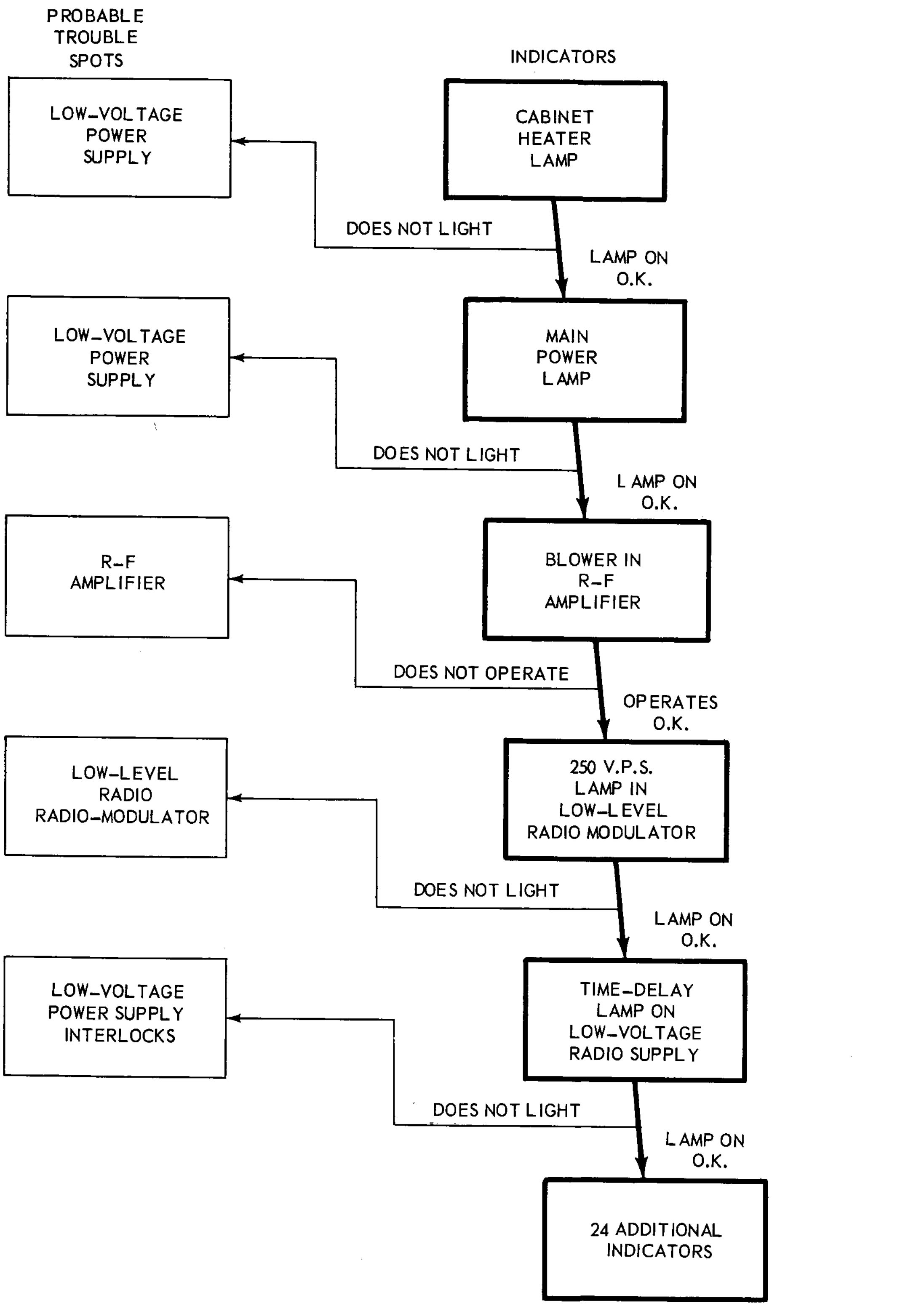



Figure 13-1.—First five indicators in the AN/SRT-14, 15, 16 troubleshooting chart.

avoid radiating an r-f carrier from the antenna.

Receivers

The following information, condensed from the corrective maintenance section of the instruction book for Radio Receiving Sets AN/SRR-11, 12, and 13, will give a general idea of the procedures used in performing corrective maintenance on radio receivers. Of course, the instruction book for the particular receiver being serviced must be used in every instance.

The following test equipment is needed:

1. Multimeter (AN/PSM-4, TS-352/U series).
2. Electronic Multimeter (ME-25/U series).
3. R-f Signal Generator (AN/URM-25B), with the necessary impedance adapter, antenna simulator, and test lead having isolating capacitor.
4. Audio Oscillator (TS-382C/U)
5. Heterodyne Frequency Meter (LM series).
6. Oscilloscope (OS-8/U series).
7. Tube Tester (TV-10/U series).

When trouble occurs, the first step is to establish in which assembly the fault exists. The faulty assembly can then be replaced if a spare one is available, or repaired if there is no spare assembly.

Most of the assemblies are divided into subassemblies, many of which plug into the assembly. Each plug-in subassembly contains a subminiature electron tube and associated parts.

Plug-in subassemblies are of two types: plug-in boards and plug-in units. The plug-in boards are located in the antenna, r-f mixer, and oscillator assemblies; the plug-in units are in the first i-f, second i-f, audio, BFO, and crystal-calibrator assemblies. The tuning dial and filter assemblies do not contain electron tubes.

The procedure given in the troubleshooting chart in the instruction book will permit the ET to quickly and systematically check the functioning of the radio receiver by observation of the indicators that are built into the equipment.

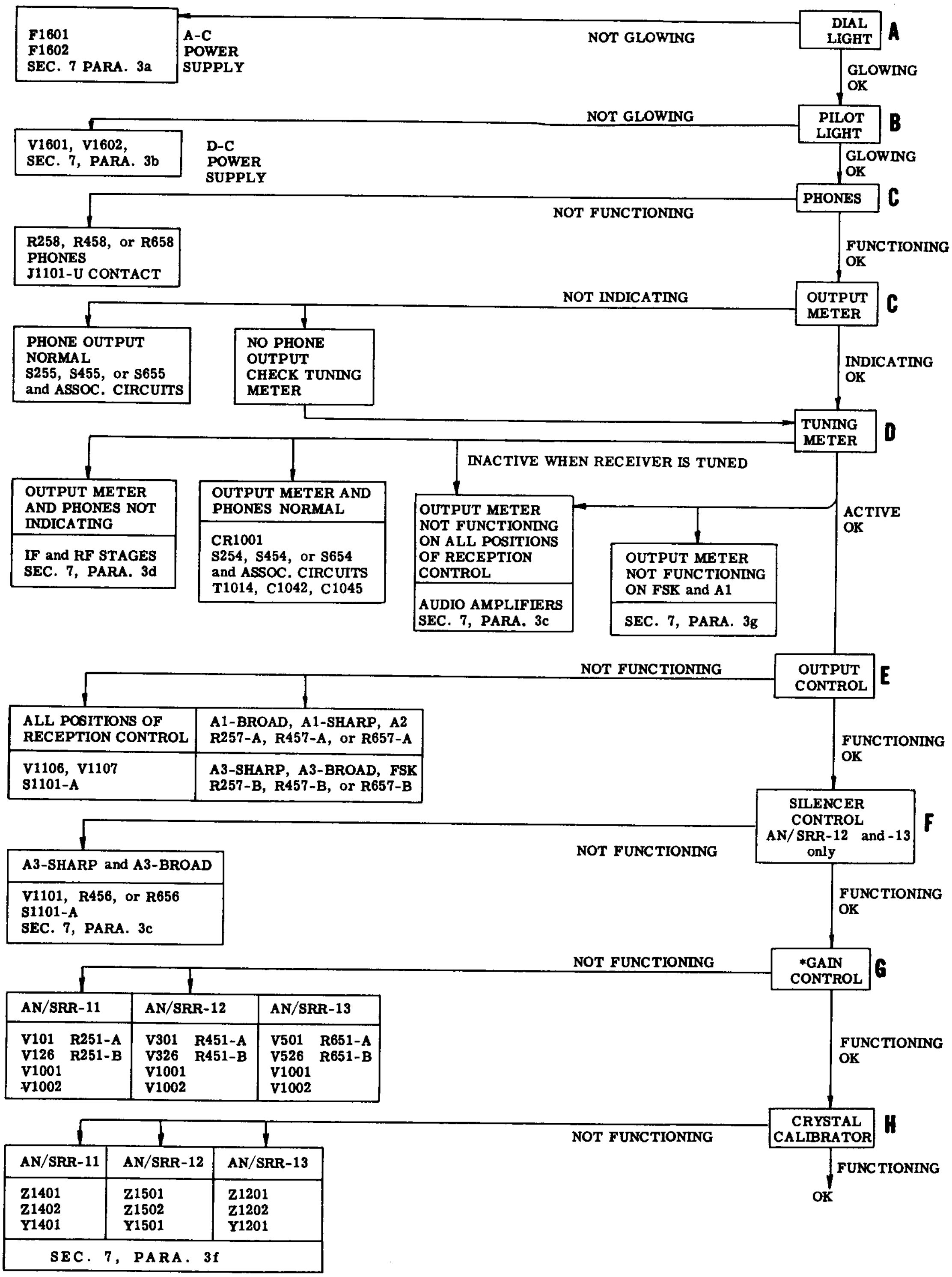
Two of the indicators (the tuning meter and the output meter) check the signal circuits; the other two indicators (the pilot light and the dial light) check the power circuits. If the technician follows the exact procedure given in the troubleshooting chart, he can localize the trouble to a subassembly or system. After the trouble has been localized to a subassembly or system the detailed troubleshooting procedure (also given in the instruction book) may be used to locate the defective component (tube, resistor, capacitor, etc.).

The troubleshooting chart from the instruction book is reproduced in figure 13-2. When trouble occurs, the chassis should be inspected for charred insulation, discoloration of parts, leakage of potting compound, or other indications of abnormal operation. If the parts appear normal, the ET then proceeds to track down the trouble by the use of the troubleshooting chart, as follows.

1. Turn the power switch ON and check the dial light. If the light glows, the power input and power transformer primary circuits are operating. In this case, move on the next step, B. If the dial light does not glow, switch the lamps control to the SPARE position; if the dial light still does not glow and the receiver is dead, then replace the fuses (F1601 and F1602) located in the bottom of the power supply assembly. If this does not cure the trouble, the ET should then consult the detailed troubleshooting procedure included in the instruction book.

2. Check the pilot light. If the light glows, the d-c power supply is operating. In this case move on to the next step, C. If the pilot light does not glow, replace it if it is burned out. If the light still fails to glow, replace V1601 and V1602 in the power-supply assembly. If these measures fail, consult the detailed troubleshooting procedure.

3. Check the output meter and phones while attempting to tune in a signal. If the output meter and phones BOTH give an indication of signal, then the receiver is operating, but other associated devices such as the crystal calibrator or tuning meter may not be operating. For a more thorough check, move on to the next step, D. If only one of the indicators (the output meter OR the phones) gives an indication of signal, then the trouble lies within the immediate circuits of the other. This trouble can be localized by taking resistance measurements of the faulty circuit. Refer to the appropriate schematic diagram. If the output meter AND the phones BOTH fail to give an indication of signal then move on to the next step, D.




*This control is active only on the A1 and A2 positions of the Reception Control.

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Figure 13-2.—Troubleshooting chart for Radio Receiving Sets AN/SRR-11, 12, 13.

The same general procedure is followed for six more steps, as indicated in the troubleshooting chart.

## TROUBLESHOOTING RADAR EQUIPMENT

The localization of trouble in an equipment as complex as a radar set (for example, Radar Set AN/SPS-8A) demands an orderly and systematic approach if the trouble is to be located and corrected as quickly as possible. To this end, the troubleshooting procedure should be an attempt to localize the trouble to a particular unit or circuit. This is usually accomplished by a process of elimination. The ET must take time to analyze the trouble and consider the possible sources before beginning to make actual physical or electrical checks on the equipment (use the six step logical troubleshooting method previously described).

Use should be made of the equipment oscilloscope (monitor scope) to help localize troubles. There are also test points throughout the equipment that afford readily accessible voltage and waveform checks. The corrective maintenance section of the instruction book includes voltage tables, troubleshooting charts, pictures, and circuit diagrams, all designed to make troubleshooting as easy as possible for the ET. The use of the instruction book is a must.

In the case of Radar Set AN/SPS-8A, a large number of troubleshooting charts are included in the instruction book. The first chart covers system troubleshooting. Following this, there are unit and sub-unit charts on the power systems, the synchronizer, the trigger amplifier, the modulator, and so forth; actually, there are 17 troubleshooting charts in all.

The following test equipments are needed:

1. Multimeter (AN/PSM-4 or TS-352/U series)—used for general-purpose testing.
2. Synchroscope (AN/USM-24)—used to check waveforms.
3. Electronic Multimeter (ME-25/U series) —used for general-purpose testing.
4. 30-mc Signal Generator (AN/URM-25 or 26 series)—used for checking receivers.
5. 39-mc and 60-mc Sweep Signal Generator (TS-452/U series)—used for checking receivers.
6. 3400-3600-mc Signal Generator (AN/URM-61A)—used for checking AFC and minimum discernible signal.
7. Crystal Checker (TS-268 E/U)—used for checking receiver crystals.
8. Dummy Director (Mark 1 Mod 3)—used for checking servo systems.
9. Ammeter—used for measuring amplidyne outputs.
10. Gunner's Quadrant (Mark 6 Mod 1)—used for checking antenna level.
11. Resistance Bridge (ZM-11A/U)—used for checking sine and cosine potentiometers.
12. Power Bridge (TS-295 B/UP)—used for transmitter power measurements.

The system troubleshooting chart for Radar Set AN/SPS-8A is shown in figure 13-3. This chart is much the same as those discussed under radio receivers and transmitters. However, it is a SYSTEM troubleshooting chart. If a system defect is indicated the ET must then use the tables (actually, individual troubleshooting charts) indicated on the left of the figure. As has been mentioned, there are 17 troubleshooting charts in all. The ET will find the overall servicing block diagram a great help when he uses the system troubleshooting chart.

## TROUBLESHOOTING TECHNIQUES FOR MINIATURE COMPONENTS AND DEVICES

The use of transistors, crystal diodes, and other semiconductors in Naval electronic equipments is constantly increasing. Because of its versatility, the transistor is used in amplification, modulation and demodulation, and other electronic circuitry applications. Its miniature dimensions make the transistor particularly suitable for use in unitized and modular constructed equipment. For the same reason—miniaturization and compactness—troubleshooting in equipment containing transistors is made more difficult. Because of these developments, procedures relating to the servicing and testing of semiconductors are covered in more detail in this chapter and chapter 6 of this training course.

The successful installation, repair and maintenance of electronic equipment, especially equipment using transistors, has raised many questions concerning proper servicing procedures and troubleshooting practices that previously have been used in electron-tube circuitry.

Transistors perform many of the functions of electron tubes. It will therefore be instructive to compare these devices.

1. In a tube, the cathode is the source of electrons and electrons constitute the current carriers. In a transistor, the emitter is the source of electrons or holes and these constitute

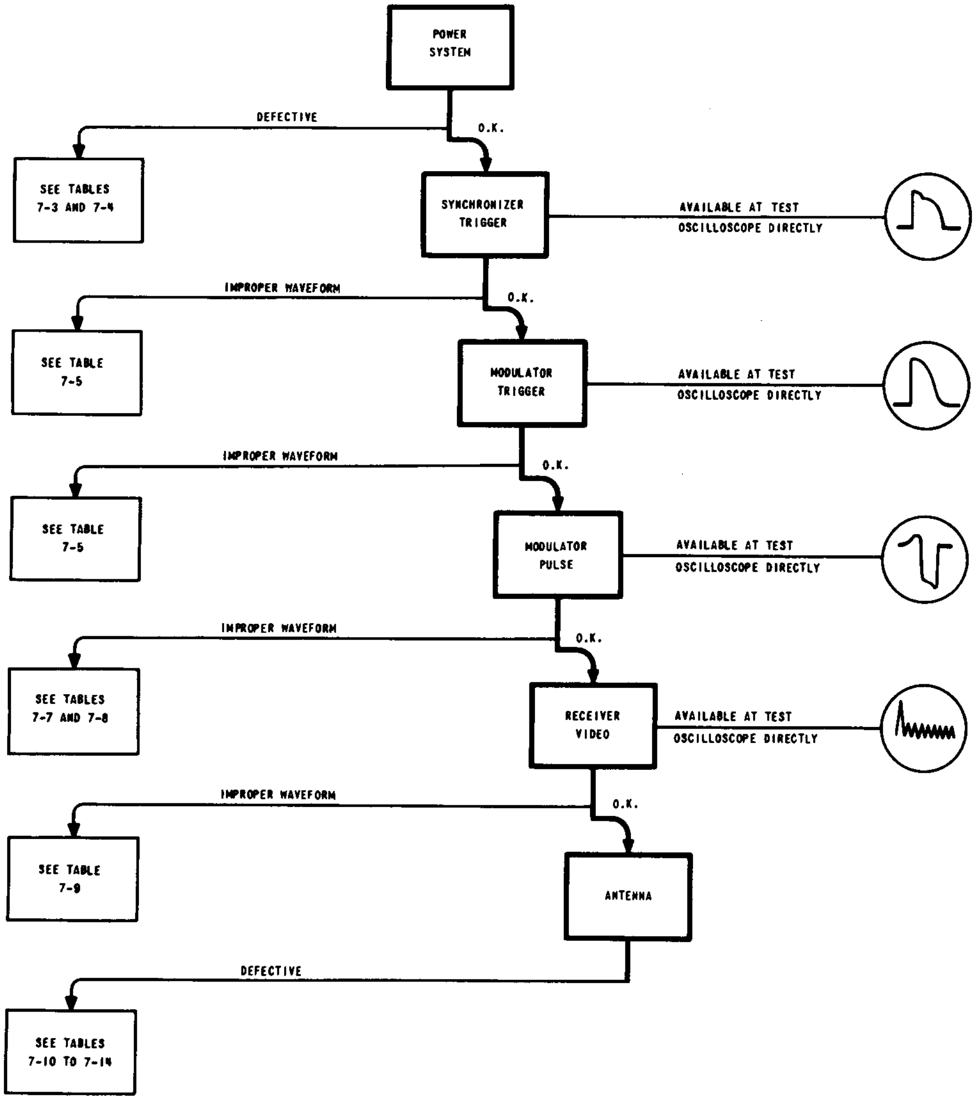


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Figure 13-3.—System troubleshooting chart for Radar Set AN/SPS-8A.

the current carriers. Thus the emitter may be compared to a cathode (figure 13-4).

2. In a tube, the plate receives the electrons emitted by the cathode. In a transistor, it is the collector which receives the electrons or holes originating in the emitter. Thus plate and collector perform similar functions.

3. In a tube, plate current is controlled by control-grid-to-cathode bias. Similarly, in a transistor, collector current is controlled by base-to-emitter bias. In a tube, the input signal is most frequently applied between the control grid and the cathode. In a transistor, the input

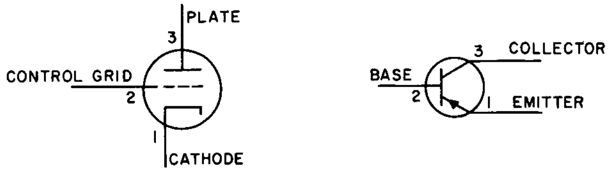


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Figure 13-4.—Comparison of transistor and vacuum tube elements.

signal is most frequently applied between the base and the emitter. It thus is apparent that the base of a transistor is comparable to the control grid of an electron tube.

Like electron tubes, transistors come in various shapes and sizes and often are classed in special categories according to their use and application. The characteristics of each of these devices are usually presented in SPECIFICATION SHEETS or they may be included in tube or transistor manuals.

It should be noted that the primary difference between the operation of a transistor and an electron tube is that the electron tube is a voltage-operated device and the transistor is a current-operated device.

The comparison of a given transistor and electron tube shows that there is great similarity between the functions of a transistor and those of an electron tube. Therefore, any knowledge picked up by the technician in his work on electron tube equipment will be useful in the servicing of transistorized circuits. However, there are great differences between a transistor and an electron tube from the stand point of servicing. For instance, the reliance placed on the senses of sight, touch, and smell in the visual inspection of electron tube circuits is not feasible in the case of transistor circuits. Many transistors develop so very little heat that nothing can be learned by feeling them. High-frequency transistors hardly get warm. Usually, if a transistor is hot enough to be noticeable, it has been damaged beyond use (except special or high-power transistors).

In the case of an electron tube, which is usually of the plug-in type, a quick test is sometimes made by the PART SUBSTITUTION method; that is, by replacing the tube suspected of being faulty with one known to be good. In transistorized circuits, the transistors are frequently soldered and part substitution becomes impractical. Furthermore, indiscriminate substitution of semiconductors should be avoided; it is preferable to test transistors IN-CIRCUIT.

The technician will find more transistors than tubes in two similar equipments, which means more stages to check out. This is true because of the lower gain and power capacity of the transistor. However, the first step in troubleshooting transistor circuitry, as in the troubleshooting of electron tube circuitry, is a visual inspection of the entire equipment. Loose connections, broken leads, and any other visible damage should be repaired before undertaking the next step of the troubleshooting procedure. A careful visual inspection will frequently shorten what could otherwise be a lengthy service job.

When the visible defects have been corrected, experience has shown that it is more efficient first to determine the defective stage by means of a signal-substitution or signal-tracing method and then to analyze carefully that stage for defective components. To apply the troubleshooting method recommended, a voltmeter, ohmmeter, and a signal generator are required.

The general rule (logical troubleshooting method; steps 3, 4, 5, and 6) to be followed in servicing electron tube or transistor equipment is: first, use the signal generator to locate the defective stage or interstage components, then apply the voltmeter and ohmmeter to determine the defective part or parts.

Most good-quality test equipment used for electron tube circuit troubleshooting may also be used for transistor circuit troubleshooting. However, before employing any test equipment, make sure that it meets the requirements given in the paragraph below.

Signal generators, both R-F and AUDIO, may be used if the power supply in these equipments is isolated from the power line by a transformer. Before any tests are made with a signal generator, a common ground wire should be connected from the chassis of the equipment to be tested to the chassis of the signal generator before any other connections are made.

Signal tracers may be used with transistor circuits if the precautions concerning the power supplies in signal generators are observed. Many signal tracers use transformerless power supplies; therefore, to prevent damage to the transistor, an isolation transformer must be used.

Multimeters that are used for voltage measurements in electron tube equipment or transistor circuits should have a high ohms-per-volt sensitivity to provide an accurate reading. A 20,000 ohm-per-volt meter or an electronic voltmeter with an input resistance of 11 megohms or higher on all voltage ranges is preferred on transistor circuits.

Ohmmeter circuits which pass a current of more than 1 ma through the circuit under test cannot be used safely in testing transistor circuits. Therefore, before using any ohmmeter on a transistor circuit, check the current it passes on all ranges. DO NOT use any range that passes more than 1 ma.

Conventional test prods, when used in the closely confined areas of a transistor circuit, often are the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage but in transistor circuits this momentary short can ruin a transistor. Also, since transistors are very sensitive to improper bias voltages, the practice of trouble-shooting by shorting various points to ground and listening for a CLICK must be avoided. In electron tube circuits, momentary shorts may occasionally cause a component to burn out, although they rarely affect tubes. In a transistor circuit, the transistor is usually the weakest link, and it becomes the victim.

The sensitivity of a transistor to surge currents should always be borne in mind whenever making any voltage measurements in transistor circuits.

Another change from conventional trouble-shooting procedure that is required by transistors is the use of a small, low-wattage soldering iron (or pencil) possessing a narrow point or wedge. Wattage ratings on the order of 35 to 40 watts are satisfactory. The common type of soldering gun or iron used on electron tube circuits should never be used on transistor circuits.

Always remember that because these units are small and have many features and characteristics which differ from those of the more familiar electron tubes, the servicing of transistor equipment requires a modification of presently used and familiar techniques. REMEMBER, TRANSISTORS ARE CURRENT-OPERATED DEVICES: ELECTRON TUBES ARE VOLTAGE-OPERATED DEVICES.

### Transistor Specifications

Semiconductors, like electron tubes, are available in a large variety of types, each with its own unique characteristics. The characteristics of each of these devices are usually presented in SPEC SHEETS, or included in tube or transistor manuals. The specifications usually cover the following items:

1. The lead paragraph of a semiconductor specification sheet is a general description of the device, and contains three specific pieces of information:

   a. The kind of semiconductor. This covers the semiconductive material used, such as germanium or silicon; whether type PNP or NPN, etc., and the type of construction, whether alloy-junction, grown or diffused junction, etc.

   b. Some of the major applications are listed, such as audio amplification, oscillator, and high-gain R-F amplification.

   c. General sales features, such as size and packaging.

2. The ABSOLUTE MAXIMUM RATINGS of voltages and collector current. These ratings should not be exceeded under any circumstances, as semiconductor failure may result.

3. Collector power dissipation. The power dissipation of a transistor is a function of its junction temperature and the ambient temperature. The higher the temperature of the air surrounding the transistor, the less power the device can dissipate. A factor telling how much the transistor must be derated for each degree of increase in the ambient temperature is usually given.

4. Current transfer ratio. This is another name for alpha or beta (discussed in detail later).

5. Collector cutoff current. This is leakage current from collector to base when no emitter current is being applied.

Additional information is provided for engineering design purposes.

### Diode and Transistor (Designation System)

A standardized system of numbers and letters is used for designating diodes and transistors:

1. The first number indicates the number of junctions. Thus 1 designates a diode; 2 designates a transistor (which may be considered as made up of two diodes, the base-emitter and base-collector diodes); 3 designates a tetrode, a four-element transistor.

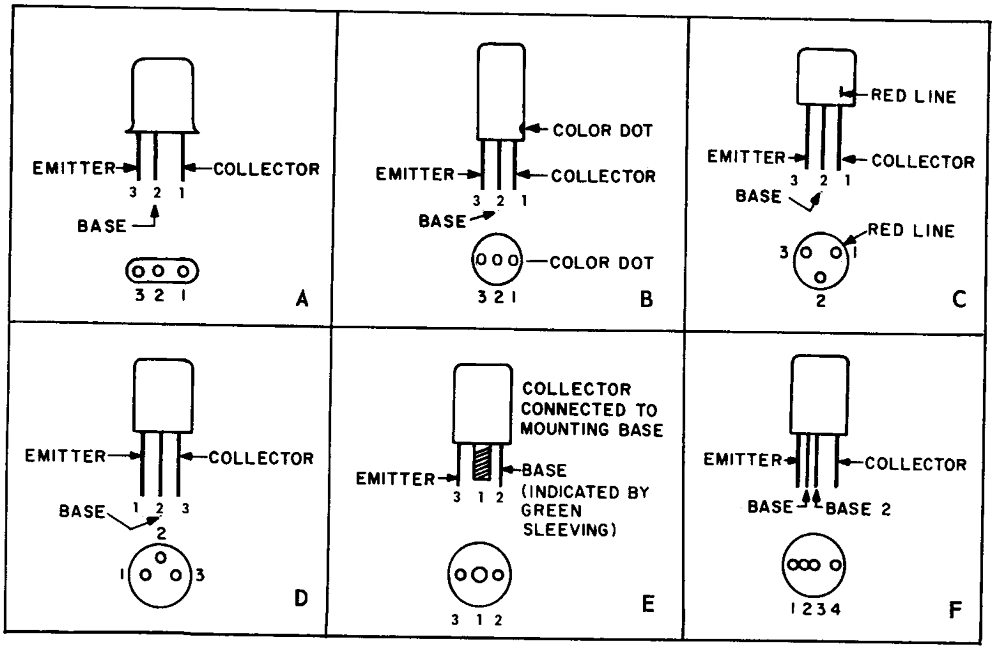
2. The letter N following the first number indicates a semiconductor.

3. The 2 or 3 digit number following the letter N has no particular significance, except that it indicates the order or registration. When this number is followed by a letter, it indicates a later, improved version.

Thus, a semiconductor designated as type 2N345 signifies that it is a three-element transistor of semiconductor material and that it is an improved version of type 345.

### Transistor Lead Identification

The arrangement and coding of transistor leads is shown in figure 13-5. Part A shows a




1.288(70)

Figure 13-5.—Transistor lead identification.

transistor in an oval case. The collector lead is identified by a wide space between it and the base lead, which, in turn, is followed by the emitter lead. Part B shows a round case with three leads in line and equally spaced. The collector lead is marked on the case by means of a color dot, usually red. The other two leads are the base and emitter, in that order. In part C, the collector lead is marked by a red line on the case. The base and emitter leads follow clockwise around the circle, in that order. In part D the leads are located at three points of a quadrant. When viewed from the bottom in a clockwise direction, the first lead following the blank space is the emitter, followed by the base and collector. Part E shows a conventional power transistor where the collector is connected to the mounting base, the mounting bolt forming the conductor for the collector. The base lead is identified by its green sleeving.

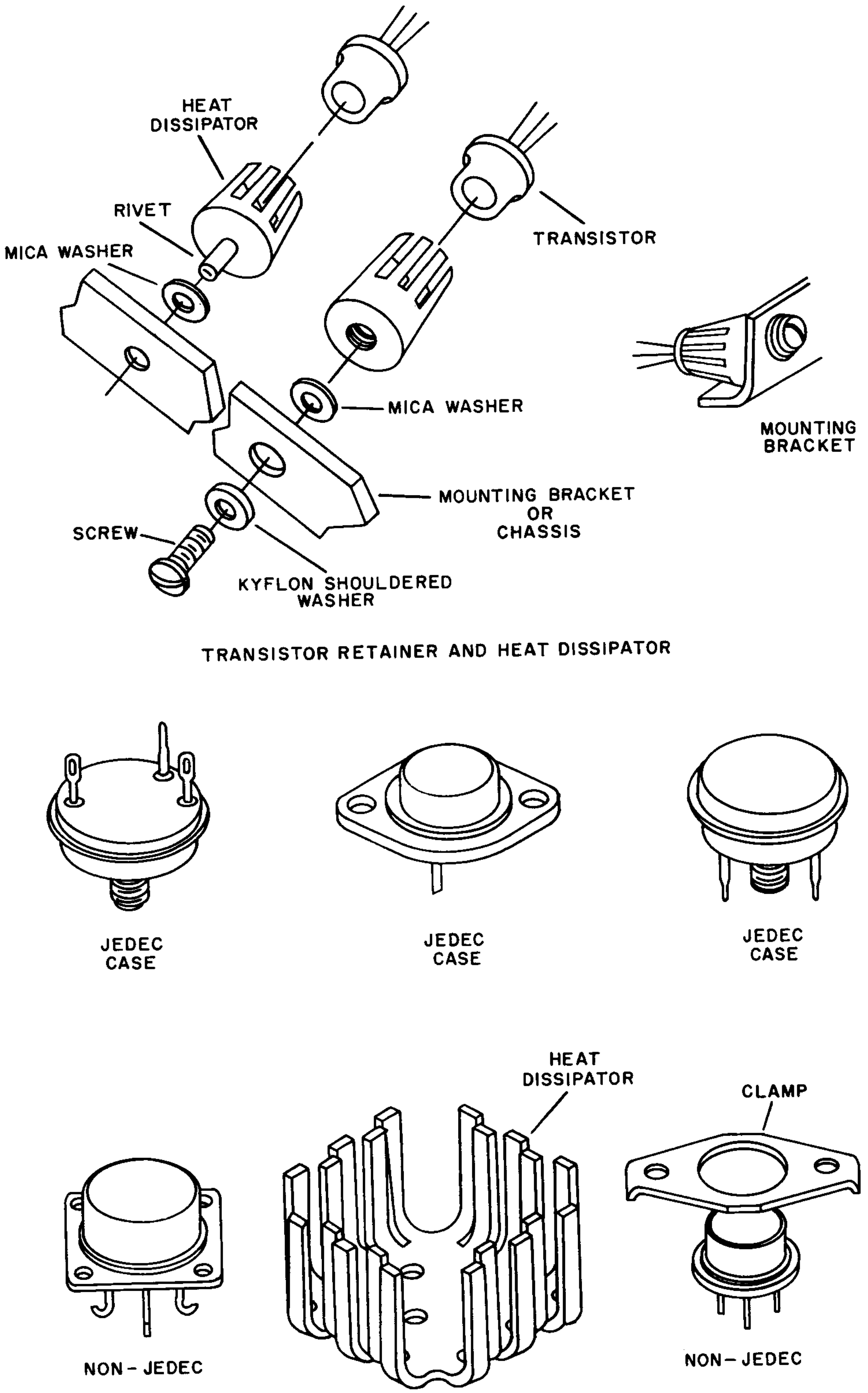
It should be noted that sometimes, even where all three leads are present, one of the elements may be connected to the mounting base to provide additional cooling.

Part F shows a tetrode. The collector is identified by the wide space between it and the other leads, which are: base 2, base, and emitter, in that order.

### Transistor Heat Dissipators

As the complexity of transistorized electronic equipment has increased, the space available for individual components has almost disappeared. This trend in design has meant more heat generated with less space in which it can be dissipated, causing an ever-increasing environmental temperature in which the transistor must operate. The reliability of a transistor, like that of an electron tube, is dependent on its ability safely to absorb and dissipate the internally generated heat while operating at the increased temperature resulting from its own heat. For this reason, transistor heat dissipating devices are finding widespread application to prevent the effects of higher operating temperature and to increase the power dissipating ability of the transistor. These devices utilize the natural methods of conduction, convection, and radiation to reduce case and junction temperatures and to increase overall reliability.

Transistor retainer and heat dissipators (figure 13-6) are relatively simple in their design and construction and require little or no maintenance other than to ensure that the mounting hardware used to attach the heat dissipator to the chassis or metal bracket is




70.108

Figure 13-6.—Transistor heat dissipators.

secure and in place. In some cases, the removal of the heat dissipator may be required to reach inaccessible locations in equipment. In removing the dissipator, be careful not to damage the fragile, brittle leads of the transistor. When the dissipator is disassembled, all mating surfaces should be inspected to ensure that they are free from burrs or sharp edges. Any existing burr or sharp edge must be removed, otherwise, the thin mica washer or mica material used to insulate electrically the transistor from the chassis or metal surface areas may be punctured, impairing its dielectric properties and forming a path for current leakage.

NOTE: A thin coat of silicone grease or similar compound applied to the surface areas of the mica insulating material will improve its dielectric properties.

### Servicing Precautions

Since the transistor is probably one of the most reliable components, it should be the last to be suspected. Again, this is contrary to the long-established practice used in electron tube equipments, where the tubes normally are checked first. Because of their reliability, transistors are generally soldered in the circuit, particularly in printed circuits. Removing and testing each transistor will not only unnecessarily subject the transistor to heating, but may also result in damage to some other component, particularly in the case of a printed circuit board.

However, if the transistor itself is suspected it can be removed from the equipment for testing. In sets employing sockets for the transistors, it is only necessary to remove the transistor from the socket. If the transistor is soldered and it becomes necessary to unsolder it, extreme care must be taken to prevent damage to the transistor by the heat from the soldering iron. Also, the leads must be handled carefully as they are very brittle.

CAUTION: Never remove or replace a transistor while the battery or power source is connected to the set. Failure to observe this caution may result in damage to the transistor from surge currents, etc.

Although generally more rugged than the electron tube, the transistor is affected by electric shock, heat and humidity.

One of the most frequent causes of damage to semiconductor units is the electrostatic discharge from the human body when the unit is handled. Such damage may be avoided by discharging the body to the equipment before handling the unit.

A semiconductor unit may also be damaged by r-f fields. It is therefore essential that the unit be protected by a metal container until ready for use, at which time the equipment should be deenergized before the semiconductor is inserted.

When it becomes necessary to replace a transistor where the leads have been soldered, the following precautions should be taken. Before removing the old transistor, note the orientation of the collector, base, and emitter leads. Cut the leads of the new transistor to the proper length, using sharp cutters to prevent undue stress on the leads entering the transistor. Then, with the transistor properly positioned, solder the leads to the connections, using the proper solder, soldering iron, and a heat sink.

For stability of the electrical characteristics, the maintenance of the tranistor hermetic seals cannot be over emphasized. They not only maintain the carefully controlled environment in which the transistor is sealed, they also exclude moisture which causes instability. (While a transistor is warming up after exposure to low temperature, moisture may collect on the transistor surfaces, causing a large temporary increase in the collector current.)

The minute power requirements of transistor circuits make it economically feasible to operate transistorized equipment with batteries, even where the equipment is subject to continuous use. By using careful construction techniques, the transistors of today are capable of operation in excess of 30,000 hours at maximum rating without appreciable degradation. Either conventional zinc-carbon batteries or the newer mercury batteries may be used. BATTERY ELIMINATORS SHOULD NEVER BE USED AS THE SOURCE OF POWER FOR TRANSISTORS OR ANY OTHER SEMICONDUCTOR DEVICE. Because of the low current drain of transistor circuits, the voltage regulation of battery eliminators is poor.

In handling transistors, it should be remembered that temperature is the most important factor affecting transistor life, and that it is important to keep both the transistor and the ambient temperature as low as possible. It has been estimated that for every 10°C the junction temperature is lowered, the life of the transistor is doubled.

## Printed Circuits

Although the troubleshooting procedure for printed circuits are similar to those for conventional circuits, the repair of printed circuits requires considerably more skill and patience. The printed circuits are small and compact; thus personnel should become familiar with the special servicing techniques required.

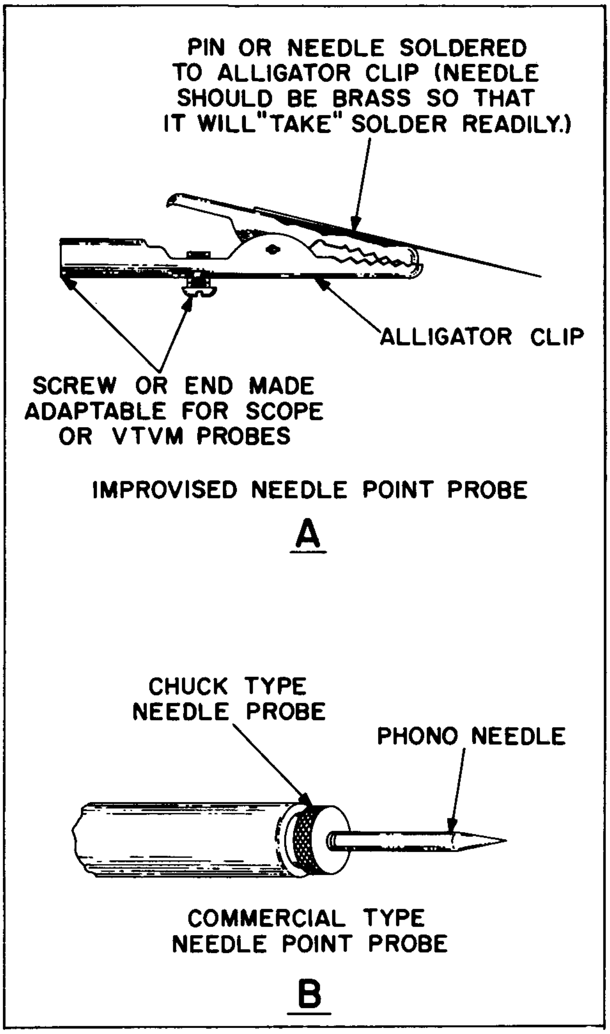
In all instances, it is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been performed. Not all personnel having access to this type of equipment have the skill and dexterity required; hence some preliminary service may be necessary. By observing this precaution you may save a great deal of time and labor.

The defective part should be pinpointed by a study of the symptoms and by careful and patient analysis of the circuit (using the logical six-step method) before attempting to trace trouble on a printed circuit board. Ascertain whether the conducting strips are coated with a protective lacquer, epoxy resin, or similar substance. If so, carefully scrape it away, or, better still, use a needle or chuck type needle probe, as shown in figure 13-7, which will easily penetrate the coating for continuity check.

Breaks in the conducting strip (foil) can cause permanent or intermittent trouble. In many instances, these breaks will be so small that they cannot be detected by the naked eye. These almost invisible cracks (breaks) can be located only with the aid of a powerful hand- or stand-held magnifying glass, as illustrated in figure 13-8.

The most common cause of an intermittent condition is poorly soldered connections. Other causes are: Broken boards, broken conducting strips, fused conducting strips, arc-over, loose terminals, etc.

To check out and locate trouble in the conducting strips of a printed circuit board, set up a multimeter (one which DOES NOT pass a current in excess of 1 ma) for making point-to-point resistance tests, as shown in figure 13-9, using needle point probes. Insert one point into the conducting strip, close to the end or terminal, and place the other probe on the terminal or opposite end of the conducting strip. The multimeter should indicate continuity. If the multimeter indicates an open circuit, drag the probe along the strip (or if the conducting strip is coated, puncture the coating at intervals) until the multimeter indicates continuity. Mark this area and then use a magnifying glass to locate the fault in the conductor (figure 13-8).

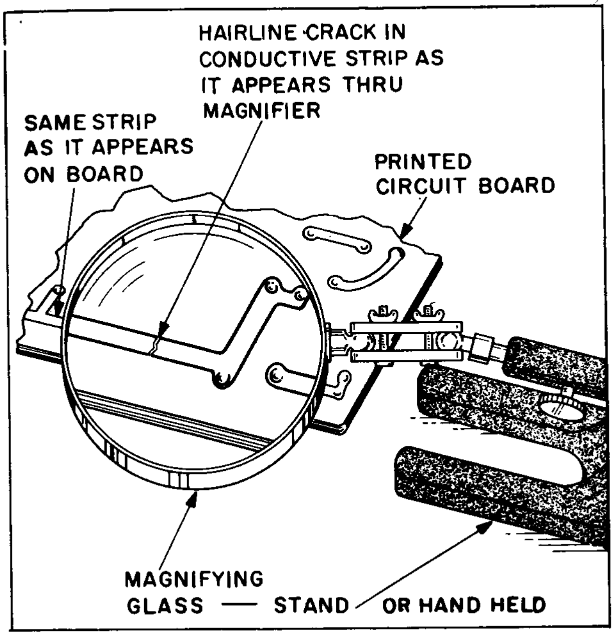



70.109

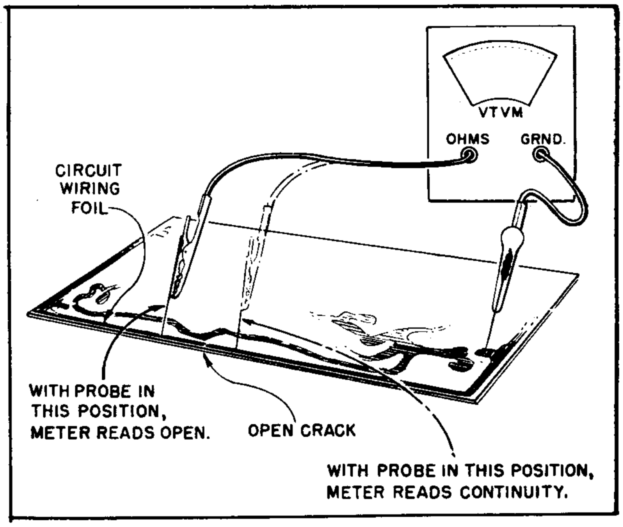
Figure 13-7.—Needle probes.

CAUTION: Before using an ohmmeter for testing a circuit containing transistors or other voltage-sensitive semiconductors, check the current it passes under test on all ranges. DO NOT use a range that passes more than 1 ma.

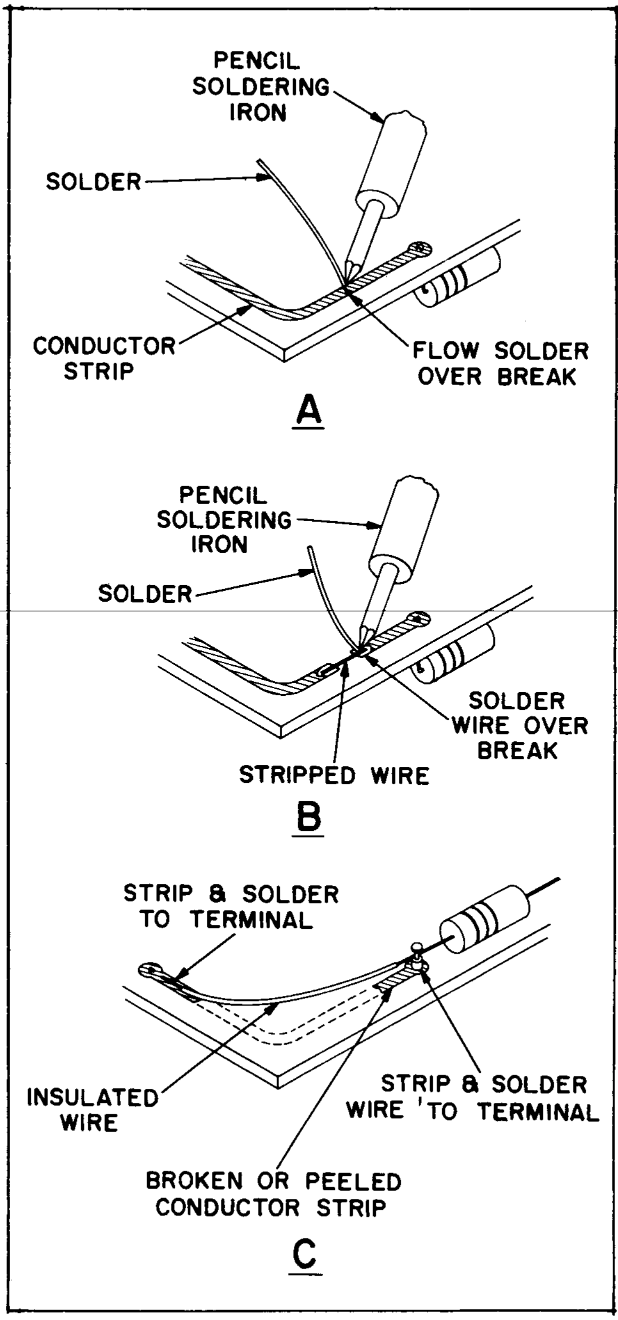
If the break in the conducting strip is small, lightly scrape away any coating covering the area of the conducting strip to be repaired. Clean the area with a firm-bristle brush and approved solvent (see Handbook of Cleaning




70.110
Figure 13-8.—Using a magnifying glass to locate a hairline crack.




70.111
Figure 13-9.—Using a VTVM to locate a break in a conductive strip.




70.112
Figure 13-10.—Three methods of repairing broken conducting strips.

Practices, NavShips 250-342-1), then repair the cracked or broken area of the conducting strip by flowing solder over the break (fig. 13-10A). If there is any indication that the strip might peel, bridge the break with a small section of bare wire (approximately 2 inches) by the method shown in figure 13-10B. Apply solder along the entire length of the wire to bond it solidly to the conducting strip. Considerable care must be exercised in applying the solder to prevent it from flowing onto or near an adjacent strip. Keep the solder within the limits of the strip that is being repaired.

If a strip is burned out, or fused, cut and remove the damaged strip. Connect a length of insulated wire across the breach or from solder-point to solder-point (fig. 13-10C).

It is best not to glue or bond a conducting strip that has been lifted or peeled from the board at a terminal or solder point. Instead, clip off the raised section and replace it with insulated hookup wire from solder-point to solder-point.

Printed circuit boards are frequently subject to leakage and shorts, especially if the spacing between conductors is very close, or by the careless formation of a solder bridge between the conducting strips during soldering. NOTE: After repairs, always scrutinize the board for solder droppings that may cause possible shorts.

Frequently, a low-resistance leakage path will be created by moisture and/or dirt that has carbonized onto the phenolic board. This leakage can be detected by measuring the suspected circuit with a multimeter. To overcome this condition, thoroughly clean the carbonized area with solvent (methyl Chloroform GM 6810-664-0387) and a stiff brush. If this does not remove it, use a scraping tool (spade end of a solder-aid tool or its equivalent) to remove the carbon, or drill a hole through the leakage path to break the continuity of the leakage. When the drilling method is used, be careful not to drill into a part mounted on the other side.

Occasionally, a conductor will rupture or fuse, usually because of a current overload. Generally, the rupture, or fusing, is the result of limited spacing and narrow conductors. Do not try to repair this type of damage, other than to bridge the rupture, or fused area, with a length of insulated wire (fig. 13-10C).

Most printed circuit boards have areas of conduction, known as GROUNDING CONDUCTORS, at each edge of the board or on the parts-mounted side of the board. These grounding conductors are conducting strips, used for grounding parts and as a mounting contact for the chassis or common ground. Sometimes an intermittent condition will result if the grounding, screws or mounting screws, become loose. If this occurs tighten the screws and then solder a good bond directly from the grounding strip to the chassis or equipment ground. If this is not practical, bond the screws (after tightening) with an epoxy resin or similar compound.

The most common cause of broken boards is droppage. Some boards are broken because of careless handling by service personnel while the equipment is under repair. Be extremely careful at all times while handling a board. Do not flex the board indiscriminately; be especially careful when removing the board or replacing parts; do not force anything associated with the board.

A printed circuit can be flexed to a certain extent; however, flexing may break the board which must then be replaced at a considerable loss of time. To prevent this possibility, it is always good policy to use a chassis-holding jib or vise when servicing printed boards.

Before repairing a broken printed-circuit board, assess the damage. Inspect the condition of the board and the extent of the break. If the board is not too complicated or the damage not too extensive the board can probably be repaired.

After the repairs are completed, clean the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, and then coat the repaired area with an epoxy resin or similar compound. This coating not only will protect the repaired area but will help to strengthen it.

NOTE: When a board is broken, it is much better to replace the entire board. The repair techniques given above are for temporary repair only.

### Special Techniques

It is always desirable to replace parts on a printed circuit board without applying heat directly to the conducting strip. This procedure prevents damage to the printed circuit conductors, feed-through devices, eyelets, or terminals, and saves time in repair. It also prevents damage to semiconductors and other heat-sensitive parts that may be in proximity to the part being repaired.

Replacing parts requires that each type of part mounting be considered individually for the best method of removal.

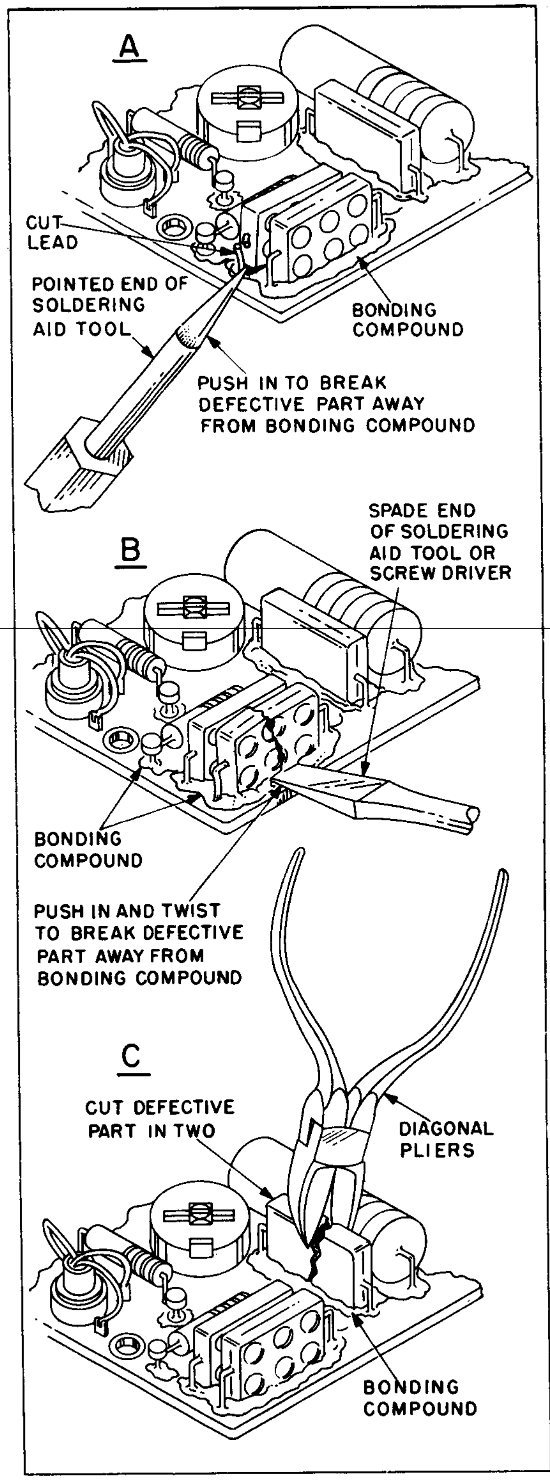
A part to be removed may be too close to a heat-sensitive semiconductor or other part to allow the hot pencil-soldering iron to be applied. A quick test to determine this safe distance is to place your finger between the semiconductor (or heat-sensitive part) and the part to be removed. Place the hot soldering iron in the position to be used. If the heat is too great for your finger it is too hot for the semiconductor. After determining that the heat-sensitive part is too close, place a shield (asbestos or like substance) between the parts before applying the hot soldering iron, and place heat sink clamps on all leads from the heat-sensitive part.

Solid-state parts and their associated circuitry are extremely sensitive to thermal changes. Therefore, particular care must be taken to prevent exposing them to heat. Heat sink and shunts must be applied with shields inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron. Solid-state parts and associated assemblies require the same care in handling and skill of repairing that is applied to assemblies in equipment of unitized or modular construction containing transistors, tantalum capacitors, crystals, etc.

Removal of an axial-lead part that has been bonded to a printed circuit board (with an epoxy resin or similar compound) can be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to be used depends upon the part itself and its location.

If the defective axial-lead part cannot be removed by heat, cut or break the part away from the bonding compound. Figure 13-11 illustrates two different methods of breaking the part away from the bonding compound where the part is too close to other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool. Wherever possible, cutting the defective part with end-cutting pliers or diagonals, as shown in part C, is the preferred method to use.

Regardless of which tool is employed (round-pointed or spade type), great care must be used in its application to prevent the printed circuit board or other parts from being damaged or broken. Apply the point of the tool against the bonding compound, between the part and the printed circuit board. Use the tool in such a manner that it works away the bonding compound from the part to be broken away until enough has been removed for the tool to exert




70.113

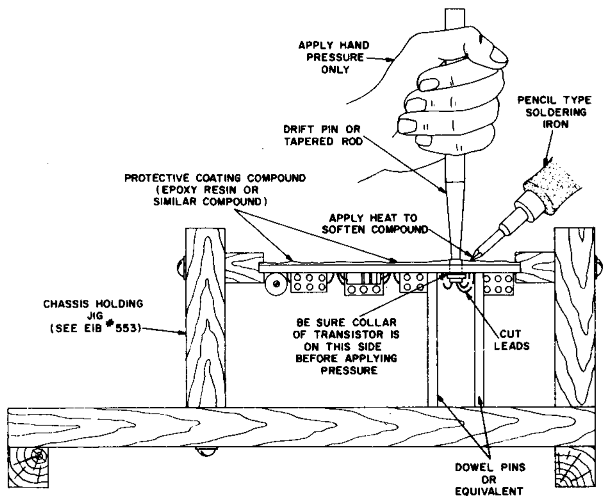
Figure 13-11.—Removing a defective part from bonding compound.

pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board.

CAUTION: NEVER APPLY MUCH PRESSURE AGAINST A PRINTED CIRCUIT BOARD.

After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board. Clean the area thoroughly before installing the new part. Do not remove the compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as the new part; thus, inserting the new part in this mold helps to secure it from vibration. After the repairs have been completed and the circuit tested, spray the newly soldered area with an insulating varnish or equivalent. Coat the new part or parts with a bonding compound (ECCO-BOND-"55" by Emerson and Cuming, Inc,; relix-R-313 by Carl H. Briggs Co.) or equivalent.

To replace a proven defective transistor, first cut all of its leads, and then remove it from the assembly. Transistors are mounted on circuit boards in many different ways; thus it is necessary to study how a particular transistor is secured before attempting to remove it. A transistor with clamp-type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire or spring clamp around it. Remove this clamp before pulling the transistor out of the socket. In some instances the transistor is bolted through the board. Remove the nut and washer, and then remove the transistor. Where vibration is a prime factor, the manufacture mounts the transistor through the circuit board and bonds it (with epoxy resin or similar compound). For this type, a flat-ended round-rod type tool (drift punch) of a diameter less than that of the transistor case is required. Be sure that the printed circuit board on which the transistor is mounted is secured in a proper device, and in such a way that pressure exerted against the board will be relieved by a proper support on the other side (fig. 13-12). Apply a hot-pencil soldering iron to the bonding compound and simultaneously apply the drift punch against the top of the transistor, exerting enough pressure to remove the transistor from the softened compound, and then on through and out the board (fig. 13-12).




70.114

Figure 13-12.—Removing a transistor that has been through-board mounted.

Before installing the new transistor, great care must be taken to prepare the part for installation.

Test the transistor in a transistor tester (TS-1100/U or equivalent) before installing. This precaution will assure that the transistor is good before it is installed. For several reasons transistors can and do become defective in storage. Therefore, always check them before installation.

Pre-shape and cut the new transistor leads to the shape and length required for easy replacement. Use sharp cutters, and do not place undue stress on any lead entering the transistor. The leads are fragile, and are therefore susceptible to excessive bending or too sharp a bend. Shape any bend required in a gradual curve, and at least 1/4 inch to 3/8 inch from the base of the transistor. A safety measure which can be taken to ensure that the lead will not break off at the base is to use two pairs of needle-nose pliers. With one pair grasp the lead close to the transistor base, while shaping the rest of the lead with the other pair.

NOTE: The above procedure and precaution should be applied to any and all semiconductors, tantalum capacitors, and other miniaturized parts in equipment of modular or unitized construction.

After the remianing pieces of the defective transistor-terminal leads have been removed and the terminals on the board cleaned and

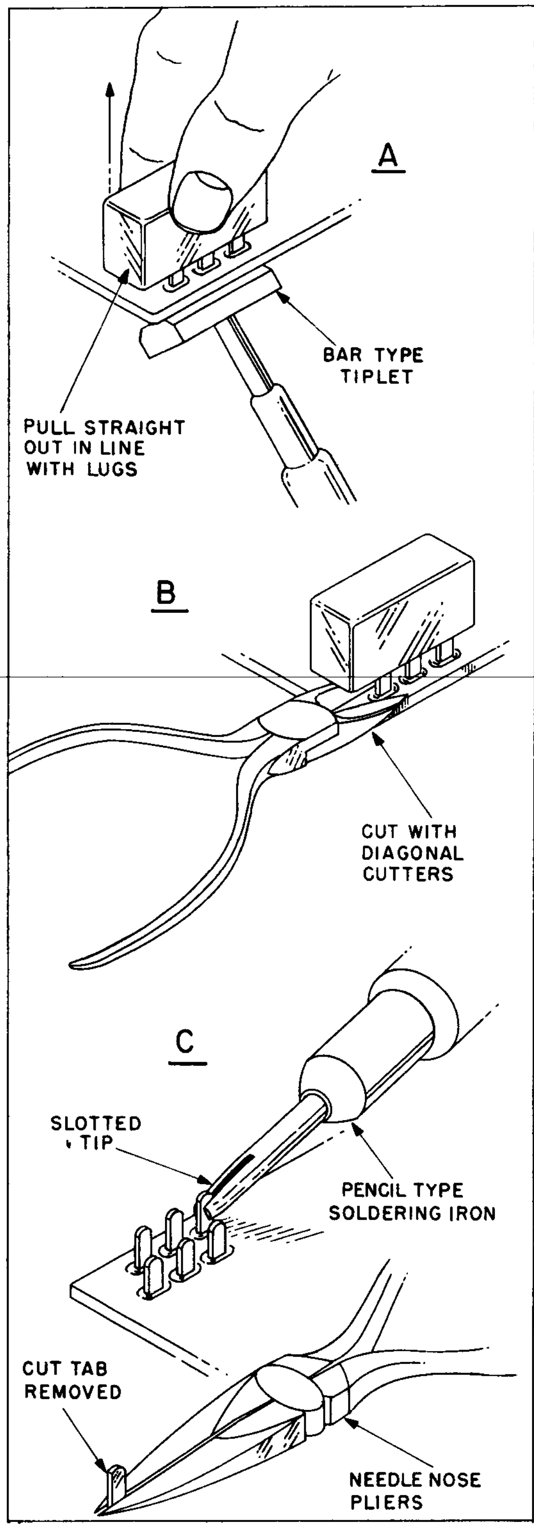
prepared connect the new transistor to its proper terminals.
REMEMBER: Handle any semiconductor or miniaturized part carefully; be gentle and be precise.

When the defective transistor is removed from a through-board mounting, and bonded, care must be taken that the new transistor clears the hole before it is connected to its terminals. If the hole is too large, shim with a thin plastic sleeve (fabricated). If the hole is too small, ream it to accept the new transistor. Rebond the fitted transistor after TESTING the repaired circuit, and it is proven to be operative. CAUTION: DO NOT USE HEAT TO REBOND REPLACED SEMICONDUCTORS.

To remove and replace a multi-lug part, such as a transformer, choke, filter, or other similar potted, canned, or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove such a part, inspect it carefully to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise, you may break the board by applying undue pressure to it. Never wrench or twist a multilug part to free it, because this will cause the conducting strip to become unbonded from the board. Work this type of part in and out in line with its lugs, while applying a hot-pencil soldering iron (fig. 13-13), using a bar type tiplet adapter or similar desoldering tool.

Whenever possible, cut the conducting or mounting leads and lugs of the defective multi-lug part on the mounting side of the board (fig. 13-13B). Heat and straighten the clipped leads with a hot-pencil soldering iron and slotted soldering-aid tool (or slotted soldering-iron tiplet adapter or similar desoldering tool) applied to the circuit side of the board; pull the leads or tabs through with pliers as shown in part C.

To replace the new multi-lug part, check to be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the multi-lug part. DO NOT FORCE ANY PART INTO POSITION ON A PRINTED CIRCUIT BOARD, BECAUSE THE BOARD MIGHT BREAK OR THE PRINTED CIRCUIT STRIP AND EYELET TERMINAL LIFT. If the part does not position easily, check and rework the terminals and holes (or slots) until it does seat freely; then proceed to solder.




70.115
Figure 13-13.—Removing a defective multi-lug part.

Be very careful when replacing defective parts that have leads terminating on stand-offs, feed-through terminals, etc. In most instances, stand-offs, feed-through terminals, are very small, and mounted on a thin phenolic board; thus they are susceptible to damage by heat and undue pressure.

Emergency Techniques

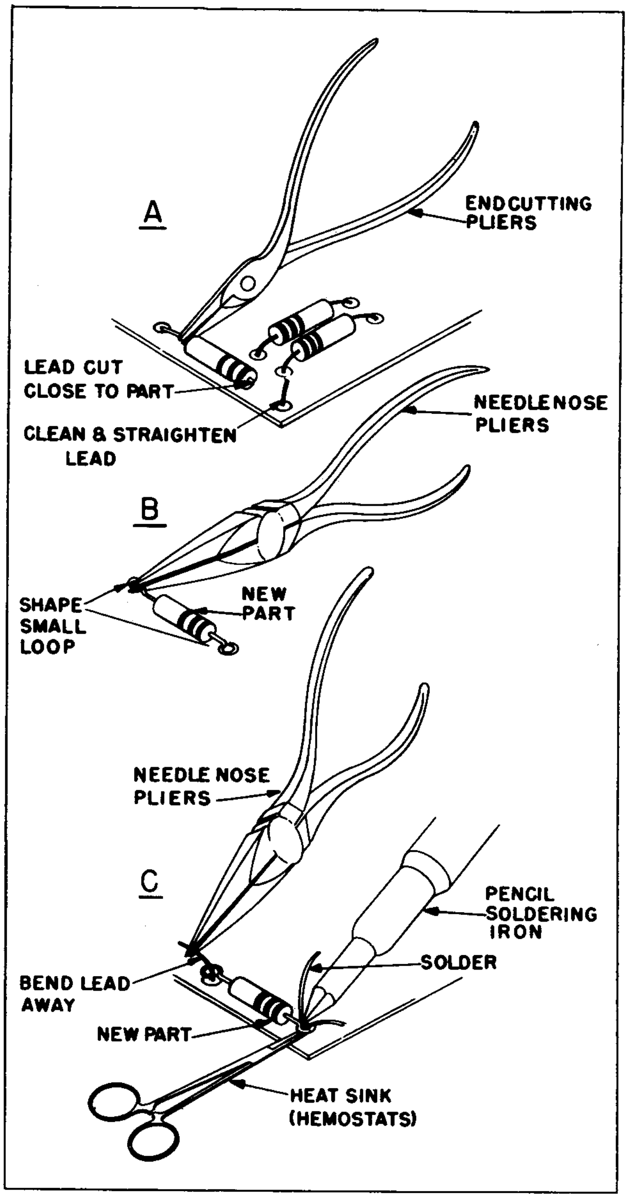
In many instances there is a need for a time-saving technique and procedure for electronic assembly emergency repair. It is desirable, when making an emergency repair, to avoid unnecessary disassembly to expose the defective part when testing and/or repairing. In many instances this can be accomplished by removing only the cover from the assembly.

To remove and replace an axial-lead part (a part mounted by leads that extend from each end, such as a common resistor or capacitor), cut the leads as close as possible to the body of the part, and then connect the leads of the replacement part to the leads remaining on the board. The cutting is accomplished with a pair of end-cutting pliers (fig. 13-14). Clean and straighten the leads remaining on the board. Fashion small loops in the leads of the replacement part (fig. 13-14B) making the loop size and lead length such that the loops slip easily over the leads projecting from the board. Secure these connections by bending the old leads away from the part. Place a heat-sink clamp on the lead from the board, between the board and the connection to be soldered, and then solder the connection (fig. 13-14C). The heat sink prevents the leads connected to the board from becoming unsoldered and causing a short, or open circuit. Always check to be sure that the old leads are properly connected to the conducting strip.

If cutting the leads of a defective axial-lead part would result in leads that are too short for the replacement part to be connected properly, cut the faulty part in half with a pair of diagonal or end-cutting pliers (fig. 13-15A). Then carefully cut away the pieces of the part from each lead (fig. 13-15B). This will yield leads of sufficient length to permit the replacement part to be fitted and soldered as shown in figure 13-14.

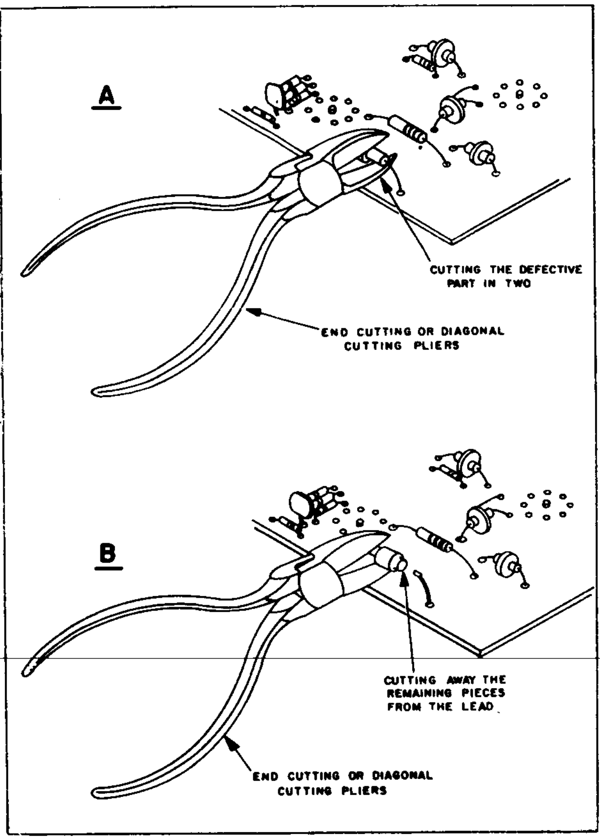
Considerable care must be taken when replacing a defective part that terminates on miniaturized stand-offs, feed-through terminals, etc. These small terminals break easily from applied pressure, or they may melt loose from excessive application of the hot soldering iron. Do not attempt this type of repair on an assembly unless there is no replacement available.

For emergency or temporary repair purposes, the following techniques may be used. Cut the lead close to the defective part (fig. 13-16A). Use a heat-sink clamp (or pliers) next to the




70.116

Figure 13-14.—Replacing a defective part by cutting its leads.

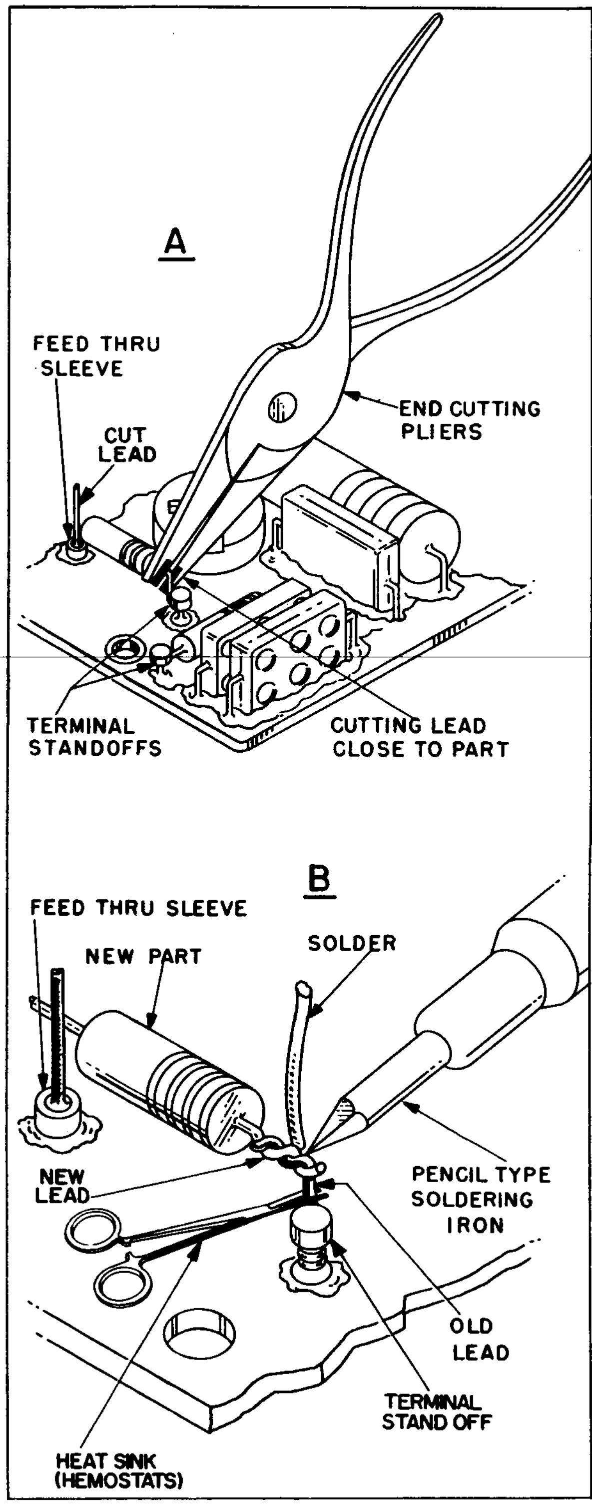



70.117
Figure 13-15.—Cutting the defective part for maximum lead length.

terminal, then solder a spliced lead from the terminal to the new part (fig. 13-16B).

A helpful heat control technique is to place a small piece of beeswax (W9160-253-1172) on the terminal behind the heat sink. When the beeswax melts, the temperature limit has been reached. This is a warning to remove the source of heat immediately. Allow the area to cool thoroughly before attempting to complete the soldering of the connection. Apply a new piece of beeswax to the terminal, repeating this procedure until the connection is satisfactorily soldered.

It is best not to glue or bond a conducting strip on a printed circuit board that has been lifted or peeled from the board at a terminal or solder point. Instead, clip off the raised section and replace it with insulated hookup wire from solder-point to solder-point. However, for temporary or emergency repair, a loose or peeled strip may be bonded back onto the board, using



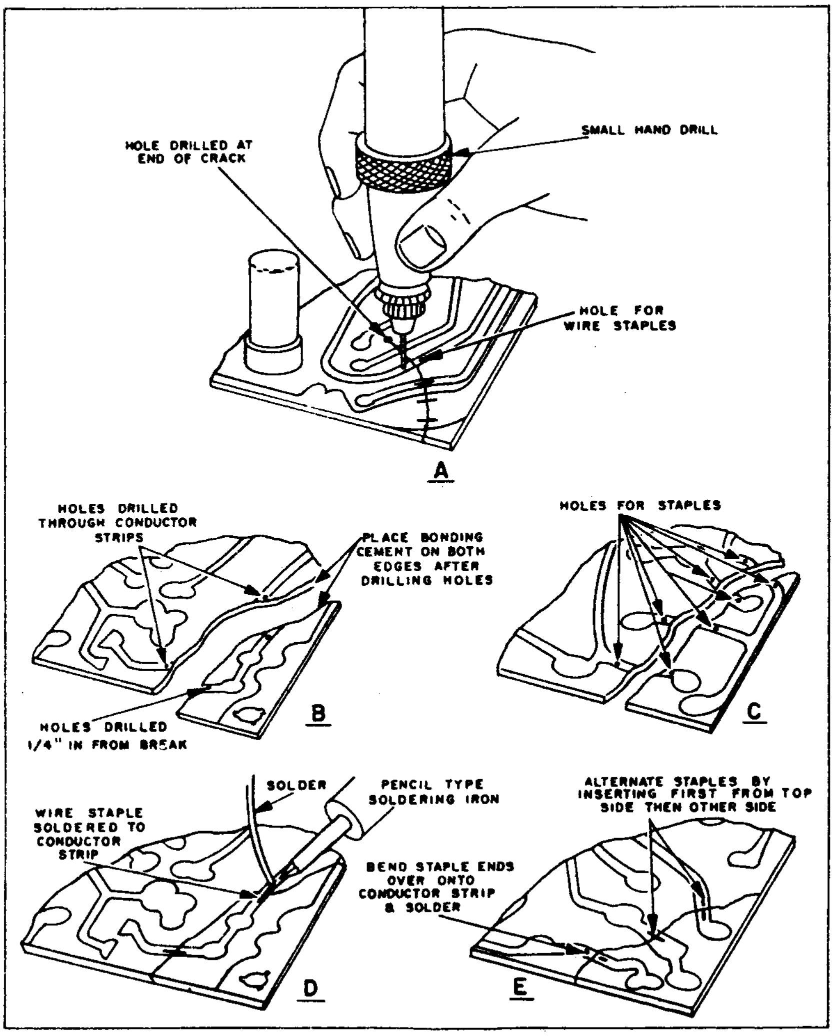

70.118
Figure 13-16.—Removing a defective part from a miniature standoff terminal.

a nonconductive bonding compound ECCOBOND "55" epoxy adhesive, or its equivalent. A silver conductive paint or similar material can also be used to repair printed circuit conductive strips. This technique is satisfactory for temporary or emergency repair, but is not satisfactory for permanent repair.

A broken printed circuit board may have to be repaired in an emergency where no replacement is available. Before repairing the broken board, assess the damage for the extent of the break and the amount of damage to the parts involved. If the board is not too complicated or the damage too extensive, the board can probably be repaired.

If a small portion or corner of the board is broken off, it may be rebonded to the larger section with a nonconductive cement or its equivalent. If cementing is not feasible or does not hold satisfactorily, the pieces can be fastened together with wire staples cut from solid conducting wire of the diameter and length required, depending on the width of the conducting strip to be repaired.

To insert the staples, drill holes about 1/4 inch in from each side of the break (fig. 13-17). The holes should be just large enough to accommodate the wire used for stapling. (This may vary, depending on the width of the conductive strip to be repaired.) Drill the holes through the




70.119

Figure 13-17.—Repairing a broken printed circuit board.

conducting strips so that the staples will provide a good electrical contact across the break; this method will permit the use of enough staples to hold the pieces together without danger to shorts b tween conductors. If the break is sufficiently large, position additional staples at all points possible to give the board more support.

Where the adhesive and stapling method described above does not provide structural strength or sufficient rigidity, splints or a doubler may be used. Strips of thin card material are glued across the fracture with a nonconductive adhesive. Where needed, additional strength may be obtained by gluing a plate of the card material to the splints with the nonconductive adhesive.

Rebond any loose conducting strips with a non-conductive bonding cement; then apply nonconductive cement to both sides of the break, and join the sections together (fig. 13-17B). Insert half of the measured and precut wire staples from top to bottom, and the other half from bottom to top, bending the ends flush against the board (fig. 13-17E). Solder these staples to the conducting strip (Fig. 13-17D).

If the board is not completely broken but is only cracked, drill a hole at the end of each crack (fig. 13-17A) to prevent further lengthening of the break. Then repair the crack in the same manner as the complete break discussed above.

After the repairs are completed, clean both sides of the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, then coat the repaired area with an epoxy resin or similar compound. This coating not only will protect the repaired area, but will help to strengthen it.

NOTE: The repair techniques given above are for emergency repair ONLY.

## Modular Assemblies

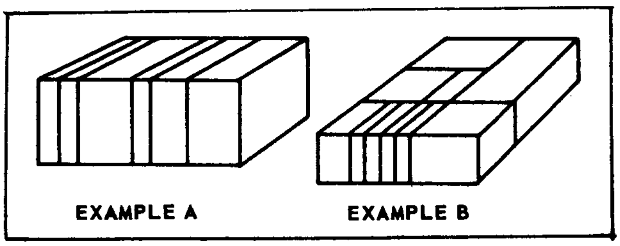
This section provides information so that a technician, using the techniques and procedures discussed in this chapter, can repair and restore modular constructed equipment quickly and efficiently.

The following established definitions will be helpful in understanding the terms involved. A MODULE is defined as A UNIT or STANDARD of measurement—a fixed dimension. A MODULAR ASSEMBLY has outline dimensions which are multiples of a MODULE. An equipment which consists of replaceable assemblies (any type tubes, transistors, etc.), is said to be of unitized construction. MODULAR CONSTRUCTION, then, is a type of unitized construction consisting predominately of MODULAR ASSEMBLIES.

The sketches in figure 13-18 show two possible arrangements of modular construction. Note that the blocks can be arranged in more than one way to approximately the same dimensions.

The original concept of many modular assemblies was that they should not be maintained in the field. The intention was to replace the assembly and ship it back to some repair facility. As assemblies became more complex, the point was soon reached where the extensive supply system required for the replacement concept was too costly. Many equipments built during this initial stage were potted with some secret ingredient to discourage maintenance personnel from tampering with the insides of a black box. When the Navy reassessed this concept, realizing that the fleet must maintain everything it could, most of the equipment manufacturers began to make components accessible. However, many technicians are still convinced that modular assemblies are impossible to repair. This conviction may stem from a lack of experience in working with the printed circuits and the other components in modular assemblies. While it is true that special tools and techniques are required, it is also true that satisfactory repairs can be made to any printed circuit by using just a little care and common sense. Actually, with a little experience, repairs can be made as easily as in conventional assemblies—often more easily because of improved accessibility.

The techniques and procedures previously discussed concerning soldering techniques,




70.120

Figure 13-18.—Two examples of modular construction.

transistors (and heat dissipators), printed circuits (and printed wire, etc.), removing and replacing components and/or parts, and special and emergency techniques, are applicable to all modular constructed MODULAR ASSEMBLIES.

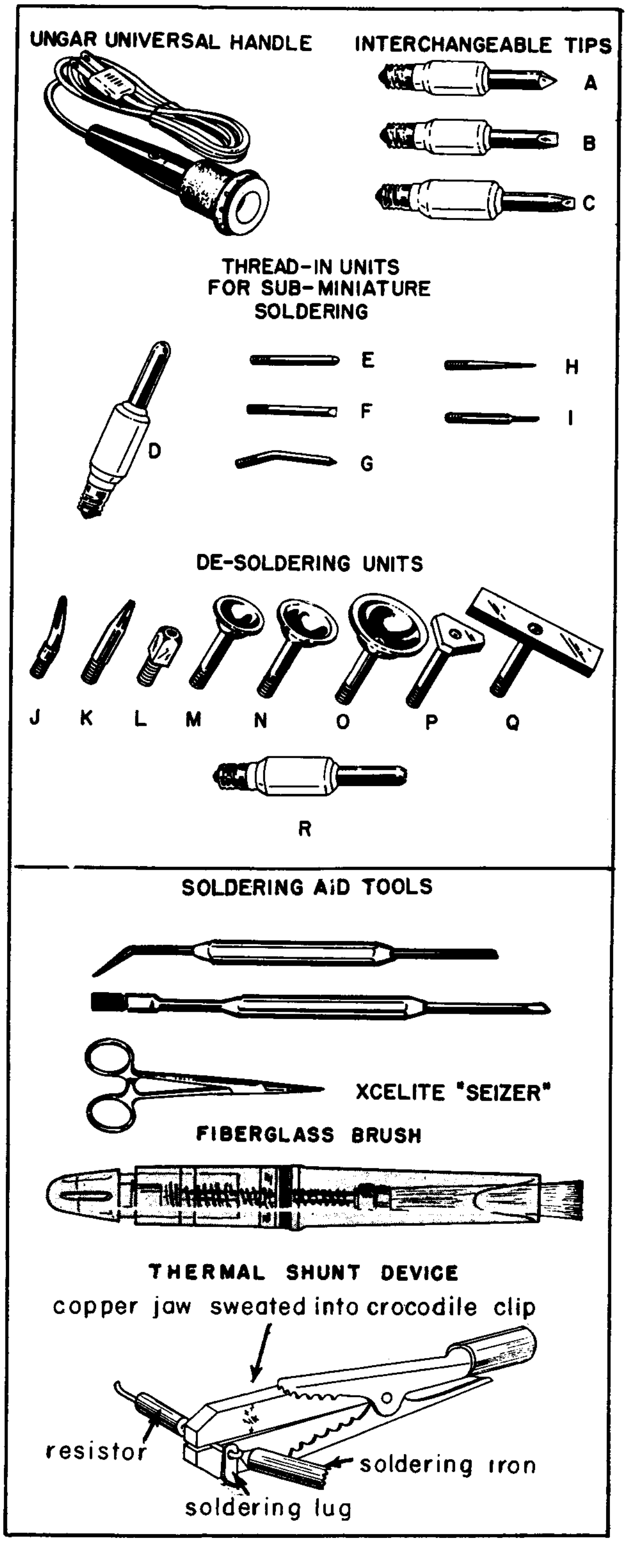
A few examples of techniques and tools needed for the repair and maintenance of modular assemblies are shown in figures 13-19, 13-20, 13-21 and 13-22. Figure 19 shows some of the recommended tools and aids for maintenance; figure 20 shows proper methods of applying and removing solder; figure 21 is an improvised tip for modular repair; and figure 22 gives a few additional soldering iron adapations.

An easy way to reduce the number of hands required for working on printed circuit boards is to construct a chassis holding jig. The one shown in figure 13-23 is versatile enough to accommodate most types of modular assemblies. Along with supporting the board during repair, this jig will prevent slipping or flexing which could result in damage to the board.

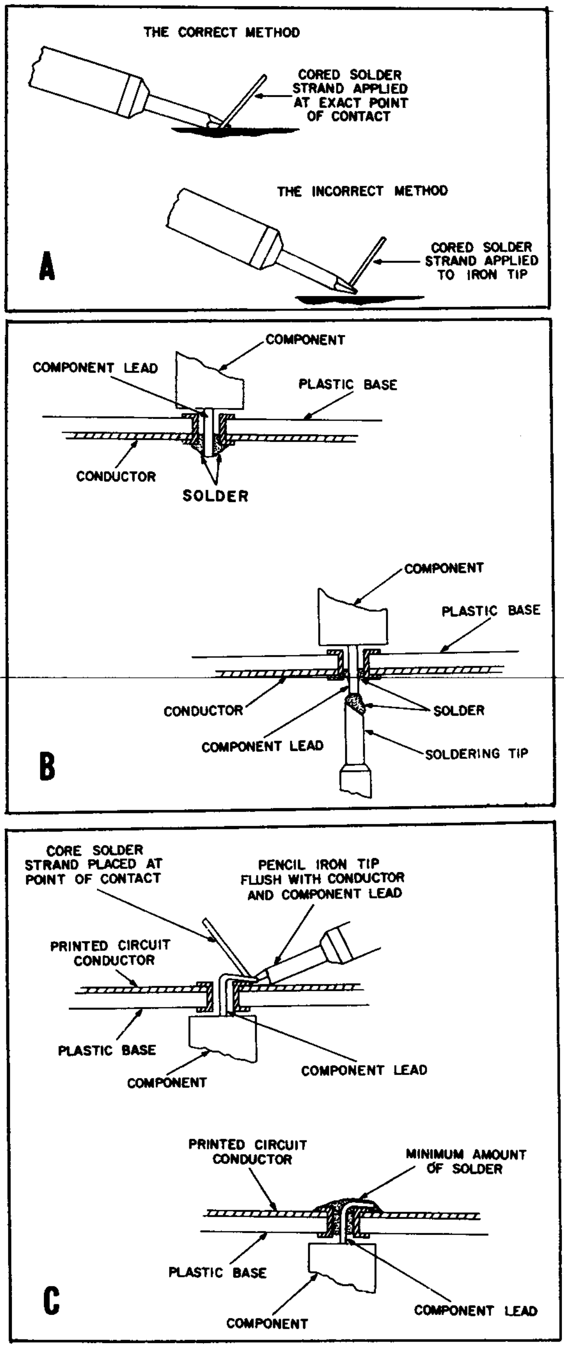
The jig in figure 13-23 is constructed of 1-inch by 4-inch milled lumber of which only 2 feet 3 inches are required if cut to the dimensions given. Three round-head slotted machine screws (10-32, 1 3/4 inches long), three flat washers (0.199 ID, 3/8 inch OD--.064 inch TK), and three common hexagon nuts (No. 10-32) are required. The fixed head and feet are dowel fitted and glued as shown in the illustration. The illustrated jig will hold a modular assembly up to approximately 10 inches wide. The jig should be secured to the work area by utilizing the existing threaded holes on the top of the work bench.

Most of the other tools required for working with modular assemblies are readily available. Items such as diagonal cutters, long-nose pliers, curved needle-nosed pliers, flush-cutting pliers, and tube socket adapters should already be in the shop.

Care in handling and proper packaging, to provide adequate protection against damage in transit or storage, is a must for an electronic assembly or associated repair part. In many cases, misplacement, improper identification or nomenclature, and damage to equipment repair parts in transit and storage are a direct result of thoughtless, careless action in the handling or packaging of the replacement or repairable part by the shipping activity.
REMEMBER: Assembly parts are fragile; careless handling and packaging may damage a

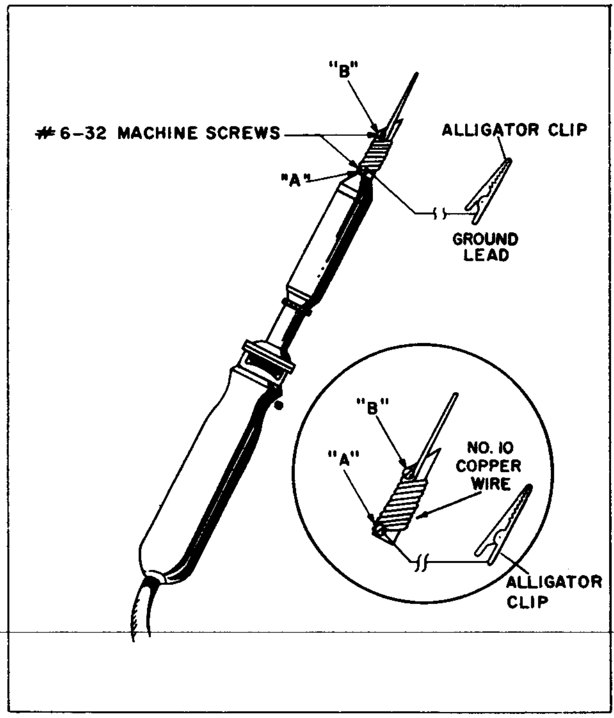



70.121
Figure 13-19.—Recommended tools and aids.




A. The correct and incorrect methods of soldering application.
B. Correct method for removing solder from component without damaging the printed wiring circuits.
C. Correct method for applying solder to a replaced component.

70.123
Figure 13-20.—Soldering techniques.



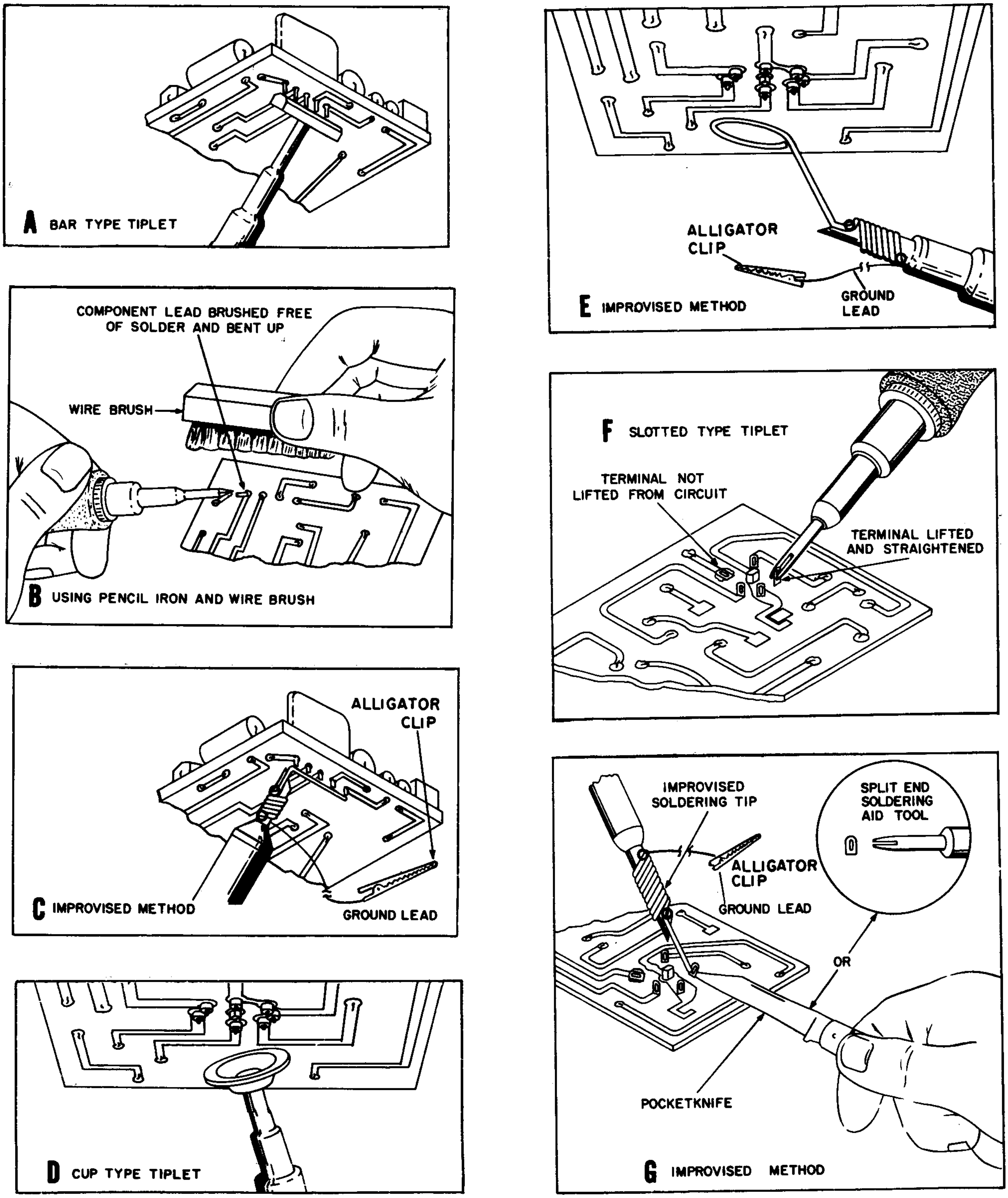

70.123
Figure 13-21.—Improvised soldering tip for modular repair.

replacement or repairable elctronic assembly or associated part beyond use.

Care in handling and protection from damage are just as important for a defective module that can be repaired as for a new module. A new module receives special handling and protection against all normally encountered situations that could either damage or destroy.

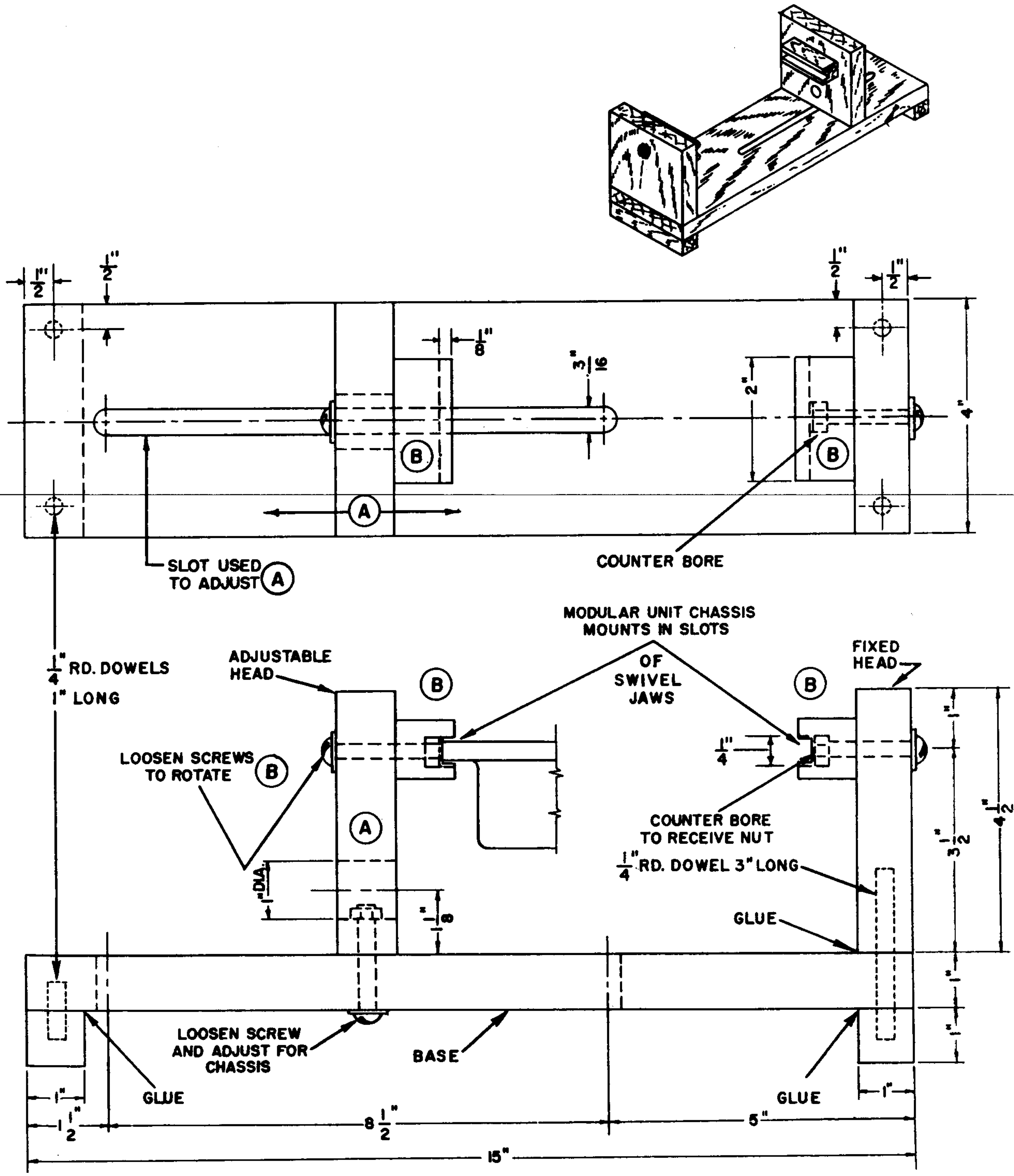
Modular assemblies are shipped in accordance with the applicable packaging specifications. When the issuing activity receives the assembly, the outer casing (crate or carton with the paper packing) is removed and the assembly is stored in a watertight package until drawn by the using activity. Thus the using activity receives with a new module the necessary packaging material to properly protect a defective module.

The correct methods and the proper material to use for protective packaging of defective modular assemblies are shown in figures 13-24,25, and 26. The material shown is available to all activities and should be used as



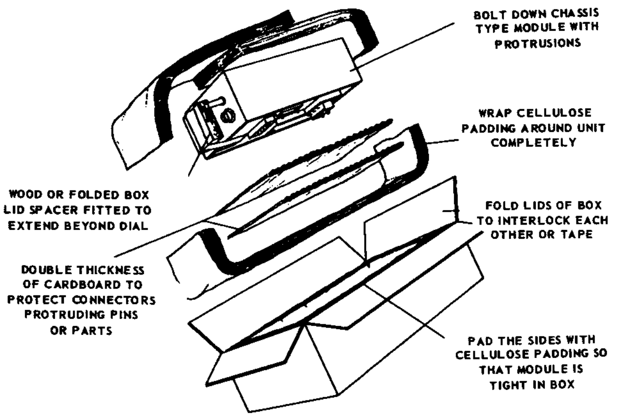

70.124

Figure 13-22.—Special soldering iron adaptations.

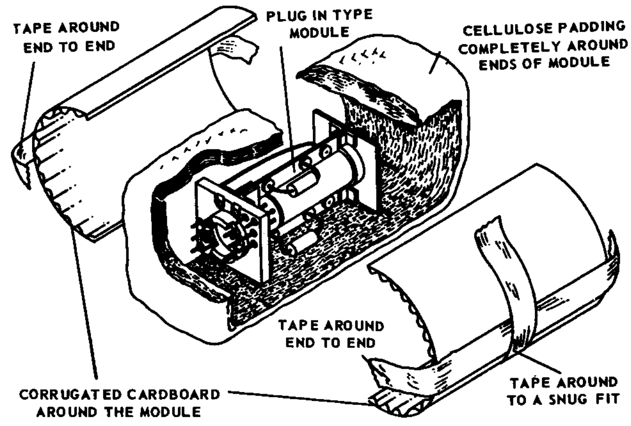



70.125

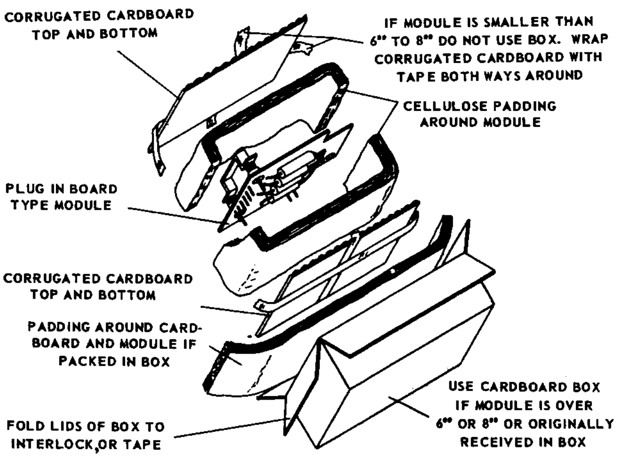
Figure 13-23.—Chassis holding jig.




70.126
Figure 13-24.—Packaging a bolt-down chassis.




70.128
Figure 13-26.—Packaging method for a plug-in module.




70.127
Figure 13-25.—Protective packaging of a plug-in board.

prescribed for storing or transferring defective modules until they are received by a shipping facility, which will properly package them for the trip to the factory or restoration facility.

The using activity will have done its part in preventing transport damage to the modular assembly if the pins, shafts, dials, protruding parts, and so forth, are adequately fitted with packing spacers and if the module is properly wrapped with protective cellulose (Kimpak or similar material).

Desiccant crystals are normally packaged with assembled equipment crated for shipping. These are retained in a bag and placed within the crated or packaged equipment in such a manner as to prevent them from coming loose. Do not use these desiccant crystals when packaging DEFECTIVE modules. The modules must be packaged too tightly for the use of crystals in bag form, and loose crystals may cause unnecessary damage—plus a cleaning problem.

If a modular assembly becomes exposed to loose desiccant crystals, clean the assembly immediately.

Much unnecessary damage has occurred to modular assemblies because of rough handling. Particular care must be given to the method of removing or inserting a module into the equipment. If the module is a plug-in board assembly, be sure the guide pins are properly aligned before pressing the assembly in place. If the board should tilt while it is being inserted, do not continue to press it into position; straighten it, and then apply even pressure to avoid tilting. Forcing any tilted or cocked modular assembly into position may result in bent or broken pins.

When removing a modular assembly, be sure to pull it straight out from the equipment. Do not cock, twist, pry, or carelessly jerk a module or modular assembly to remove it from its mounting or connector. Sometimes it may be necessary to loosen each screw little by little consecutively to prevent damaging by cocking.

Because of the miniaturization of parts for modular construction, leads, connectors, pins, and so forth, have been stiffened to ruggedize them. As a result, these fragile parts are brittle and will break easily if bent too often or pulled on too hard. When handling a module that has been removed from its chassis, be careful not to press against the leads and pins; if a lead or pin is accidentally bent, do not try to straighten it unless it is absolutely necessary.

When repairing a modular assembly, be very careful that the tool employed does not inadvertently press against leads, pins, or other parts that are easily bent, for such pressure can destroy a good part, and cause needless repair.

One of the time-consuming elements of troubleshooting is the identification of specific components. In conventionally wired equipment, components are not always easy to locate; even the circuitry in the chassis can become confusing since related components are often positioned in decentralized areas of the chassis.

In equipment which includes printed circuit boards, identification of circuitry and components may be relatively simple; this type of circuit construction allows uniform placement of components and complete sectionalization of related circuitry. Just a quick, once-over glance of such circuitry is often all that a technician requires to formulate the overall layout of the chassis in his mind and quickly focus his attention on the area of particular concern.

Many of the commercial manufacturers have developed methods of quick identification. One of the most common ways is to impose a grid over a drawing of the board, and then furnish a table which lists the part location. Another technique is to number points of interest on the schematic, then provide a pictorial guide to locate the points on the board.

Circuit tracing of the printed wiring board may be simpler than that of conventional wiring due to increased uniformity. If the wiring board is translucent, a 60-watt light bulb placed underneath the side being traced will facilitate circuit tracing. Test points can be located in this manner without viewing both sides of the board.

Resistance or continuity measurements of coils, resistors, and some capacitors can be made from the component side of the board. In some cases, a magnifying glass will help in locating very small breaks in the wiring. Voltage measurements can be made on either side of the board. However, a needle point probe like the one in figure 13-7 is needed to penetrate the protective coating on the wiring. Hairline cracks can be located by making continuity checks as shown in Figure 13-9.

A number of general precautions are nec-ecessary when working with modular assemblies.

Observe power supply polarities when measuring the resistance of the circuits of modular assemblies containing transistors, or other semiconductors. Such parts are polarity-and voltage-conscious. Reversing the plate-voltage polarity of a triode electron tube will keep the stage from operating; but generally will not injure the tube; however, reversing the voltage applied to a transistor, or other semiconductor, will ruin it, INSTANTLY AND PERMANENTLY.

Since transistors and similar components require different power supply connections, the personnel who work with these parts must always be alert in connecting test equipment. Make sure that the correct polarity and range are observed. Recheck your work before turning on the power—the WRONG POLARITY will DESTROY the part.

GUARD AGAINST HIGH TRANSIENT CURRENT OR VOLTAGES when testing or servicing. A damaging transient pulse may be caused in a number of ways. The list that follows represents some of the most frequent accidental acts that should be and can be prevented.

1. Applying of a-c power operated test equipment or soldering iron without first making certain that power line leakage current is not excessive. Use of an isolation transformer is a good precaution to employ with all test equipment and soldering irons operated on a-c power, unless it has been determined that the equipment contains a transformer in its power supply or shows no current leakage. With all test equipment (whether transformer-operated or not), it is good practice to connect a common ground lead first from the ground of the circuit to be tested, and then to the test equipment ground.

2. Application of too high a pulse from test equipment. The safest procedure is to start with a low output signal setting, and then proceed to apply the required signal levels. Be sure that the signal applied is below the rating given for the circuit under test. Relatively high current transients can occur when test equipment is connected to a circuit where low-impedance paths exist.

3. Moving loose connections, disconnecting parts, inserting or removing transistors or

similar components, and changing modular units, while the equipment power is on or while the circuit is under test. Moving a loose connection, or any of the actions mentioned, will cause an inductive kickback (due to stray inductance, if nothing else). This can be prevented by being sure that all parts in the circuit are secure before starting the test or turning on the equipment power. Be sure to remove all possible capacitance charges from parts and test equipment before applying them to a modular assembly. When changing modular assemblies, be sure the equipment power is off.

### Transistorized Training Aids

There are two general requirements for a skilled electronics technician. First, he must have a good knowledge of the theory, construction, and design features of the electronic equipment; and second, he must have sufficient mechanical skill and knowledge to successfully install, repair, and maintain the equipment. No matter how methodically and quickly the technician can locate a defect in the equipment, the final results will be unsatisfactory unless he has the necessary skill to repair the equipment in a workmanlike manner. Under proper supervision, the necessary skill can be obtained by the personnel who complete the following recommended Transistor Training Aid Program.

### Transistor Training Aid Program

The training aid program calls for the construction of five transistor circuits mounted on printed wiring circuit board plug-in units similar to those used in electronic assemblies.

The training aid series in the EIB consists of five separate articles; (1) Phase I, keying oscillator (EIB 585); (2) Phase II, amplifier (EIB 586); (3) Phase III, AM radio receiver (EIB 587); (4) Phase IV, transceiver (EIB 592); and (5) Phase V, FM receiver (not yet in print). After satisfactory completion of all five phases of the training aid program, the person completing it should have acquired the experience needed to qualify him to make emergency repairs on equipment of modular or unitized construction.

The training aids to be built during this program will be duplicates of modular or unitized units in parts, material, and compactness, and their construction will involve most of the problems encountered in the repair of this type of equipment.

Additional procedures and techniques are also included in this training aid program, to give participating personnel further insight into the principles employed in the design and fabrication of a printed circuit.

An additional source of information that will acquaint repair facility personnel and ship's electronics technicians with some of the more important techniques required for the repair and restoration of electronic assemblies is currently appearing in the EIB entitled "Repair and Maintenance Techniques for Electronic Assemblies." This series consists of eight articles, the first appearing in the 3 January 1961 (551A) issue. Article numbers two through eight are contained in the following EIBs—552, 553, 566, 567, 568, 569, and 570. It is recommended that these articles be read by all who are participating in the training aid program, and before attempting to repair electronic assemblies. These articles also serve as an educational guide for a better understanding of the techniques and procedures required in the design, mounting, and soldering of minature and subminiature components onto plug-in board assemblies similar to those used in the training aid program.