CDC 3C251A

Communications-Computer Systems Control Journeyman

Volume 2. Soldering and Electrical Connectors

Extension Course Institute
Air Education and Training Command

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THIS SECOND volume of CDC 3C251A, *Communications-Computer Systems Control Journeyman*, covers the concepts of high-quality soldering for various types of pin terminals and printed circuit boards. The information presented introduces you to the equipment, tools, maintenance, and repair procedures you need to create and care for these critical electrical connections. It also details some of the construction, operation, care, and maintenance characteristics for various connector components and accessories.

Unit 1 covers the prerequisites of soldering, such as creating an efficient and safe working environment. It also describes the basic elements of soldering (materials, tools, and equipment) needed to do the job correctly.

In Unit 2, we discuss the procedures for soldering solid and stranded wire to different types of pin terminals, using both plated and unplated soldering iron tips. In addition, we include lessons about common types of distribution frames and methods used to create solderless connections found within them.

Unit 3 covers the design considerations, components, accessories, and contact characteristics of electrical connectors, as well as how to assemble, install, and maintain them.

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Acknowledgement

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then do the Unit Review Exercises (UREs).

Page

Please read the unit menu for Unit 1 and begin. ➔

Unit 1. Quality Soldering Prerequisites

IN a lengthy epilogue to Project Mercury, National Aeronautics and Space Administration (NASA) told a hair-raising tale of failures, ineptitude, and just plain carelessness among the contractors who built and equipped the space capsules. Each of Mercury's six manned flights had an average of 10 equipment malfunctions (any one of which might have resulted in fatal failures). Only emergency backup systems and the skill of the astronauts in manual control saved their lives and the missions.

NASA blamed private industry for crucial delays in the $384 million Mercury program. As originally scheduled, the first American astronaut would have blasted into orbit as early as April 1960, nearly a year before the Soviet Union's first manned flight. Instead, John Glenn's three-orbit trip was delayed 22 months.

Included among the specific indictments in NASA's harsh report were (1) electrical connectors had been improperly soldered in the escape towers of both Glenn's capsule and his backup capsule, leaving the escape devices useless, (2) oxygen and water at the time were contaminated because "the technicians generally were not aware of the strict cleanliness required," (3) on the Cooper flight, a capsule system designed to remove moisture and perspiration became clogged with metal shavings from a pump shaft, and (4) inspectors found 720 equipment "discrepancies" in Cooper's backup capsule (526 of which were "directly attributed to lack of satisfactory quality workmanship").

It has long been known to engineers and developmental technicians that many failures attributed to components were in fact due to faulty interconnections. Much work, investigation, and study has been done on soldering connection processes, and many improvements have been made. With a pound of orbiting payload worth $10,000 in propulsion gear, it is easy to see why industry is interested in package density and, consequently, interconnection reliability. It is said, "The best and most carefully engineered device is no better than its solder joints." This preoccupation with solder connections is illustrated very vividly in the industry's move to microelectronics. Even though many connections have been eliminated, micro devices still are connected to external circuits.

To reduce failure rates, and to provide an extremely high degree of reliability for all connections, NASA developed a set of standards for soldering. These rigid and demanding standards were fruitful in reducing mission failures and increasing reliability.

The Air Force also recognized the advantages of a soldering program of this type. Soldering which aided the space program so much would surely increase the reliability of equipment in the Air Force inventory. This is where *you* enter the picture.

This volume was developed to help you acquire soldering skills or update your existing skills.

1–1. General Soldering Requirements

For its high-reliability soldering, the Air Force uses Technical Order (TO) 00–25–234, *General Shop Practice Requirements for the Repair, Maintenance, and Test of Electronic Equipment,* as the basic document. Section III of the TO is "Soldering" and describes the materials and equipment used in soldering electronic equipment wiring.

Before getting into discussion on soldering techniques, we need to understand the elements of soldering. In this section we cover the characteristics of solder, flux, and solvents. But since safety always comes first, let's cover the safety ground rules in the soldering process.

200. Creating a safe work environment

Any time you are working with tools and putting your fingers in places where electricity flows, safety has to be your number one concern. ***Think*** before you act. Don't be in such a hurry to complete the job that you put yourself in danger.

The work area. Certain conditions are beneficial to the soldering process. Because of varying equipment, missions, and shop layouts, these conditions may not exist in all shops, but a similar environment is essential for consistent quality work. The general soldering work area and work benches should be clean and maintained in an orderly condition. Remove all dirt, grease, oil, solder splatter, wire and insulation cutting material, and other foreign matter. Do not smoke or eat in the soldering room. Perform all soldering in a room that's environmentally controlled to certain standards.

- Temperature—75°F ± 10°F.
- Relative humidity—30 to 50 percent.
- Pressure differential—Positive. (Fresh air should be introduced through a filter system to prevent infiltration of dust-laden air.)

Appropriate lighting and air circulation are also important safety considerations. Lighting fixtures should provide at least 100 foot-candles of shadowless illumination on the working surface. Any area used for cleaning parts, or where toxic and volatile fumes exist, needs an exhaust system that removes vapors as they are generated. This prevents contamination of parts and provides for personal safety.

A neat and orderly work area contributes to quality work by reducing confusion. Keep tools in a specified place within easy reach. Only the tools required for the job to be done should be at the work place. Misplaced or inaccessible tools cause delay and may tempt you to use the wrong tool. A professional work area helps prevent product rejects, delay, and degradation of our work.

The safety in a work area depends on the development and employment of safe practices by all personnel. The following is a list of general safety practices. Practice these rules and develop additional practices for special work areas.

a. Keep soldering irons in their receptacles when not in use and positioned where you don't have to reach over or around them.

b. Make sure there's no tension or spring to the lead wire as you unsolder a connection. If that's not possible, wear safety glasses to protect your eyes from the splattering of hot solder.

c. Use proper electrical outlets and keep power cord plugs free from strands of wire or metal.

d. Keep the open side of the cutter away from the body when cutting wires and point away from other work areas or personnel to prevent accidental injury from flying wire pieces.

e. Disconnect all electrical power from an equipment chassis before beginning working on it.

f. Keep blade-type screwdriver tips square and sharp and use screwdrivers only for their intended purpose.

g. Wear safety glasses when working with tools that may cause flying particles.

I'm sure you've heard it said a thousand times that there's no substitute for safety and it's true. Properly preparing your work area and exercising general safety practices makes you more productive and helps keep you on the job. Another part of safety is maintaining a thorough understanding of the materials you work with, whether on a daily basis or less frequently. Our next lesson describes in detail the minerals and chemical compounds you'll use when creating soldered electronic connections.

201. The elements of soldering

Soldering is the action of joining metals at a temperature below their melting points using a fusible alloy (solder). This process is aided by inclusion of a reducing agent (flux) that promotes the fusion of metals. After a soldering action is completed, the resulting connection must be cleaned free of contaminates (using a solvent) that could prevent the connection from working correctly. This lesson introduces you to the basic elements needed for soldering and explains how the chemical process takes place.

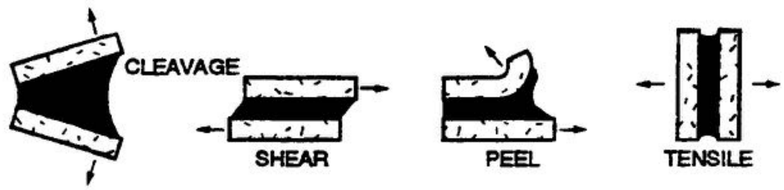
Solder. Ordinary soft solder is a fusible alloy consisting of tin and lead and used to join metals below their melting point temperatures. In addition to tin and lead, soft solders occasionally contain varying amounts of antimony, bismuth, cadmium, or silver, to alter the melting point or physical properties of the alloy. Soft solder joins by virtue of a metal solvent or intermetallic solution action that takes place at a relatively low temperature. Ordinary table salt (sodium chloride) is heated to 1,488°C before it melts, but when a little water is added, it dissolves at room temperature. The action of molten solder on a metal like copper or steel may be compared to water on salt. The solder secures attachment by dissolving a small amount of the copper or steel at temperatures below their melting points.

Therefore, soldering involves a metal solvent action between solder and the metal being joined. A solder joint is chemical in character rather than physical because the attachment is formed in part by chemical action and not by mere physical adhesion. The properties of a solder joint are different from those of the original solder because it is partly converted to a new and different alloy. The solvent action forms a completely new metallic combination.

A soldered connection is continuous in metallic continuity. Two metals soldered together behave like one. Two metals bolted, wired, or otherwise physically attached are still two pieces of metal. They are not even in direct contact because of an insulating film of oxide on the surfaces of the metals.

The permanence as well as the character of a soldered connection is also different. An unsoldered connection becomes more and more loosened by small differential movement from temperature variations and by the gradual accumulation of an increasingly thick film of oxides on the metal surfaces. Solder alloy lends itself to torsion stress and other strains (because of temperature change) without rupture of the joint.

Since the soldering operation creates a new alloy, it follows that the physical properties of this new alloy are not the same as those of the original solder. The tensile, shear, cleavage, and peel strength properties of a soldered connection (fig. 1–1) depend on the extent of alloy formation during soldering. These properties are subject to wide variations because of the inherent variables in soldering techniques.



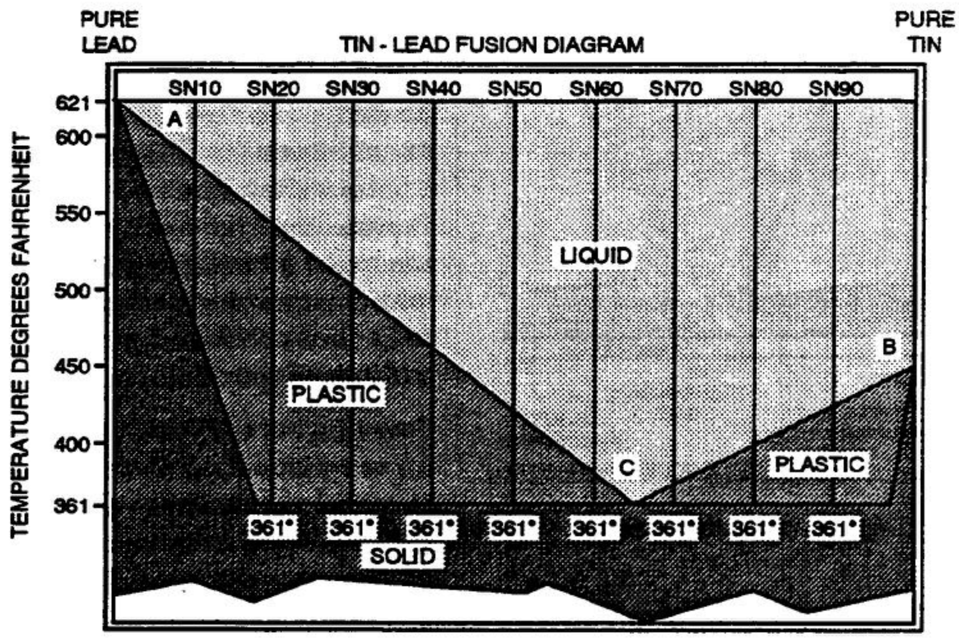


Figure 1–1. Tin-lead fusion diagram.

In order to understand the alloy or solvent action on molten solder, we need to consider the tin-lead fusion diagram shown in figure 1–1. This chart shows that pure lead melts at 621°F. Adding tin to the lead lowers its melting point along the line AC. Point C shows the lowest melting point of the tin and lead alloy. The alloy at this point consists of 63 percent tin (SN63) and 37 percent lead (by weight). It has a sharp and distinct eutectic or melting point of 361°F. This alloy is known as the eutectic composition. The eutectic point is the lowest possible temperature of solidification of any mixture of constituents.

Eutectic solder has no plastic state that benefits the soldering process because joints "set" very slowly. Changing from a solid to a liquid at the lowest possible temperature is also a desirable characteristic when soldering heat sensitive components. Other alloys that have eutectic characteristics are tin (62.5 percent), lead (36.1 percent), and silver (1.4 percent).

Solder is only one essential element of the soldering process. To fuse metals effectively another element called flux is added to the process.

Flux is a cleaning agent used in soldering and is essential to prevent oxygen in the air from combining with metals. Heating a metal causes rapid oxidation and prevents solder from reacting chemically with the metal. Using flux in the soldering operation cleans the metal by removing the oxide layer and preventing further oxidation. Solder then fuses readily with the surface of the metal (fig. 1–2).

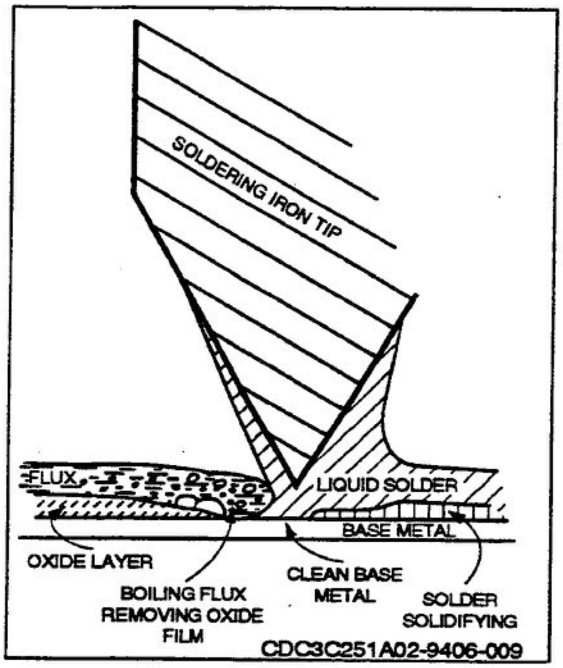


Figure 1–2. Action of flux.

The two classes of flux are corrosive (acid core) and noncorrosive. Zinc chloride, hydrochloric acid, and sal ammoniac are in the corrosive class. Corrosive flux is never used in electronic repair work since any flux remaining in the joint corrodes the connection and creates a defective circuit. Rosin (resin from pine trees) is a noncorrosive flux, and is available in paste, liquid or powder form. All electronic soldering must be done with noncorrosive, nonconductive rosin fluxes conforming to military and federal specifications.

Several types of fluxes are available for use with solders. When assembling electrical and electronic equipment use only tested rosin based fluxes that leave noncorrosive and electrically nonconductive residues. Types R, RMA, and RA flux meet these conditions. Use Type R flux for all critical electronic parts and if you use Type RA, *do not* use it on printed circuit boards with stranded wires. Keep in mind that Types RA and AC are more active than other fluxes in removing oxides from metals, but the flux residues are corrosive and are completely removed immediately after completing the soldering operation. Do not use corrosive fluxes in places where vapors or residues or splattered flux may come in contact with electrical insulation material. Type AC flux contains an organic binder that adds to the problem of removal of flux residue. Fluxes containing organic binders cannot be successfully removed by washing with water. They require a combination of washes with an organic solvent and water to remove flux residue.

Solvents. Flux residue is often "tacky" and collects dust and other foreign matter that causes electrical leakage paths across insulator surfaces. To prevent this, use a solvent for cleaning and removing flux and other contaminates. The solvent must be nonconductive and noncorrosive.

After the solder has solidified, dissolve the flux residue with an approved solvent by applying it with a bristle brush or spray. Then remove the dissolved residues with wiping tissues or other absorbent material. Use a clean part of the tissue each time to avoid transferring the dissolved flux back to the work.

Use caution when switches, variable resistors or any unsealed parts contain movable contacts as part of the assembly. The rosin dissolved in the solvent enters spaces from which it cannot be removed and causes malfunctions.

Some solvents authorized for removing excess flux from soldered connections and general cleaning of electronic parts are:

a. Dry-cleaning solvent.
b. Isopropyl alcohol, grade A, technical.
c. Aliphatic naphtha.
d. Ethyl alcohol, ACS grade, 99.5 percent or 95 percent by volume.
e. Trichlorotrifluorethane, clear 99.8 percent pure.

Realize that while the solvents listed above are authorized by specifications, the equipment technical order is the final authority. Some types of substrates are destroyed by use of one of these solvents and some conformal coatings dissolve in alcohol.

Soldering is not simply melting two pieces of metal together. It's more of a chemical process than a physical one. The correct type and amount of solder, flux, and solvent are used together to create a reliable electronic connection. Examine your understanding of these basic elements by completing the following self-test questions and if necessary, go back and review the material. The next area of the soldering process we'll cover is determining the types of tools and equipment we use to create soldered connections.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

200. Creating a safe work environment

1. What is the most important consideration when working with tools or electrical circuitry?

2. At what room temperature range is soldering done?

3. What is used to protect personnel against the generation of toxic vapors?

4. When do you wear safety glasses in a soldering environment?

201. The elements of soldering

1. What is the composition of soft solder?

2. What action does solder use to establish attachment?

3. Name four different strength properties of a soldered connection.

4. How is the melting point affected when tin is added to lead?

5. What role does flux play in the soldering process?

6. What are two classes of flux?

7. What is the purpose of solvents in the soldering process?

8. What two characteristics must a solvent have?

1–2. Soldering Tools and Equipment

Soldering is not difficult but requires a knowledge of different tools. The tools and equipment in your shop may vary from those we describe here, but the principle is the same. Just remember to use caution when working with these tools and always keep them clean.

202. The various tools and equipment used in soldering

The proper soldering and desoldering of electrical connections require certain basic tools. We'll discuss some of the more typical tools used in high-quality soldering, their proper use, care, and precautions when using them.

Proper lighting. Lamps are required to illuminate your work surface with a shadowless light to a minimum intensity of 100 foot-candles. Use a magnifying glass with not less than 4X power to visually inspect soldered work.

Cleaning materials. Use sponges and paper towels to clean soldering iron tips while the iron is still hot. Lightly drag the iron faces across a damp sponge. This thermal shock solidifies the solder, flux, dirt, etc. Use a lint free paper towel to wipe the iron tip clean. You can also use these paper towels to remove dirt, flux, and contaminants from your work surface. You'll use several types of cleaning aids to maintain your soldering tools, materials, and working surfaces.

A *solvent* dispenser (fig. 1–3) provides a small amount of cleaner while protecting the rest of the solvent from contamination and evaporation. The solvent is dispensed when the top is depressed and a lid prevents the solvent from evaporating.

Figure 1–3. Solvent dispenser.

Acid brushes are used with solvents to clean connections and circuit boards of contaminates. Use two brushes—one with long bristles for mild cleaning, and one with short bristles for strong scrubbing action.

Lead cleaners use an abrasive to rub the dirt, oxidation, and other contaminates from the leads. The two most commonly used are copper braid (fig. 1–4) and rubber abrasives. When using lead cleaners, be careful not to apply too much force. This can cause the lead-to-case seal of a component to crack or break. The seal is necessary to prevent contaminates (air, moisture, etc.) from getting into the device and destroying its function. For this reason, all the force of cleaning is exerted away from the component body or toward the end of the lead.

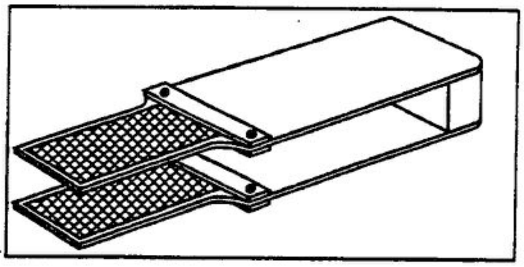


Figure 1–4. Lead cleaner.

Use *abrasive sticks* liberally to clean oxides from the surfaces of conductor pads and terminating devices. Make sure all surfaces within the solder joint are thoroughly cleaned and free of all dirt, grease, coatings, oxide, and scale. A typical abrasive stick is shown in figure 1–5.

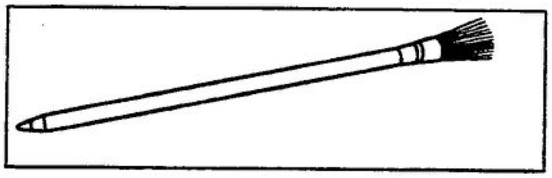


Figure 1–5. Typical abrasive stick.

Files are used to form and redress unplated soldering iron tips. They should be flat, fine, single-cut files. A file card is a double-sided stiff brush used to clean metal deposits from the file. Figure 1–6 illustrates the file characteristics.

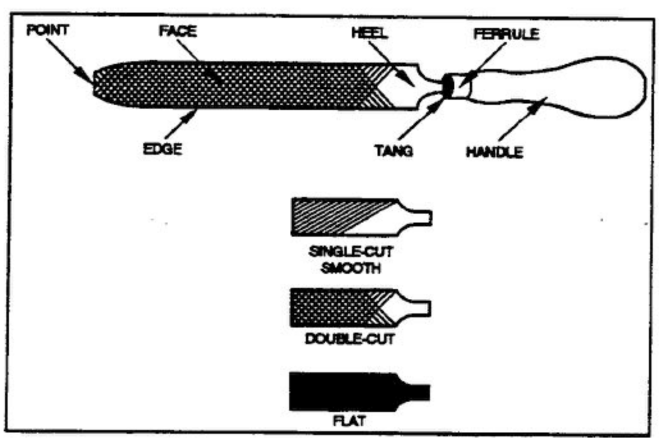


Figure 1–6. File characteristics.

Remember, you maintain the reliability of your tools and equipment by keeping them clean and serviceable. Some of the tools you'll use serve special purposes, such as for preparing wire leads prior to soldering them.

Cutting and bending tools. There are several types of wire cutting tools, including lineman's pliers (fig. 1–7,B) for use on large-diameter or hard metal wires. Diagonal side cutting pliers (fig. 1–7,A) are general-purpose cutting tools used on medium-diameter to small-diameter wire or component leads. Do not use them for high-reliability soldering.

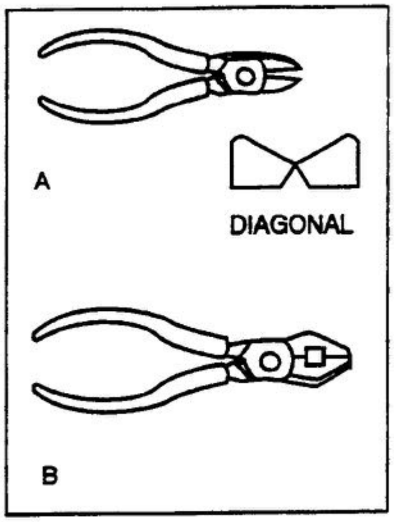


Figure 1–7. Wire cutting tools.

Flush cutting pliers (fig. 1–8) are only used on small-diameter-wire component leads. They are the cutters you use for high-reliability soldering. The flush cut they make on wire lead ends makes it easier to tin cut ends.

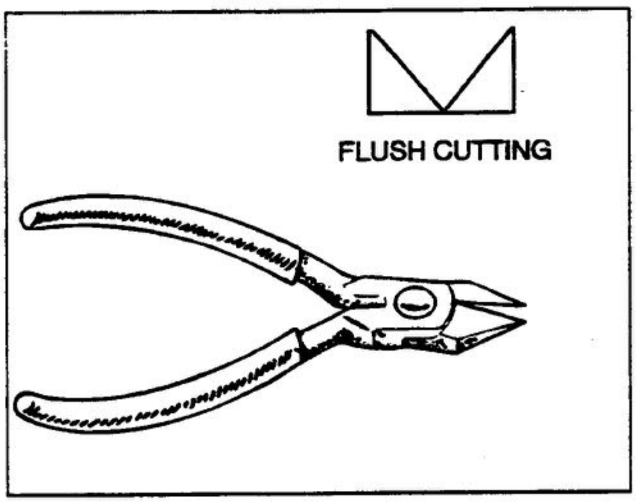


Figure 1–8. Flush cutting pliers.

While you can use toenail clippers instead of flush cutting pliers for most applications, they are cumbersome in hard to reach areas. Use care to prevent flying particles when performing any cutting operation.

Most cutting tools are made from steel and have a tendency to rust; however, you can inhibit rusting with proper cleaning and by applying a thin coat of oil to the surface of the tools.

Use a lead bending block (fig. 1–9) or round nosed pliers to form component leads. The lead bending block tool aids in forming leads without nicking or stretching, centers components between bends, and prevents stress on the joint (seal) between the lead and the case. We'll learn more about the use of bending blocks later. Of course, not all the tools you'll use are special-purpose tools. Some of the common general-purpose tools are covered in the following paragraphs.

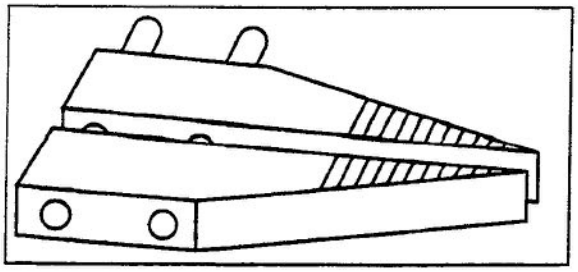


Figure 1–9. Lead bending block.

General soldering accessories. One of the general-purpose soldering tools you have in your shop is antiwicking tweezers, as shown in figure 1–10, used for tinning wire. They stop solder from flowing up under the insulation, act as a heat sink, and provide a way to grip wires without damaging the insulation. The capillary action of the strands of wire "pulling" the molten solder under the insulation is called wicking. Most antiwicking tweezers are plated with a material that is not solderable. If the plating is damaged, it is possible to solder the tweezers to the wire. To prevent flux from building up inside the tweezers' jaws, clean them frequently with solvent.

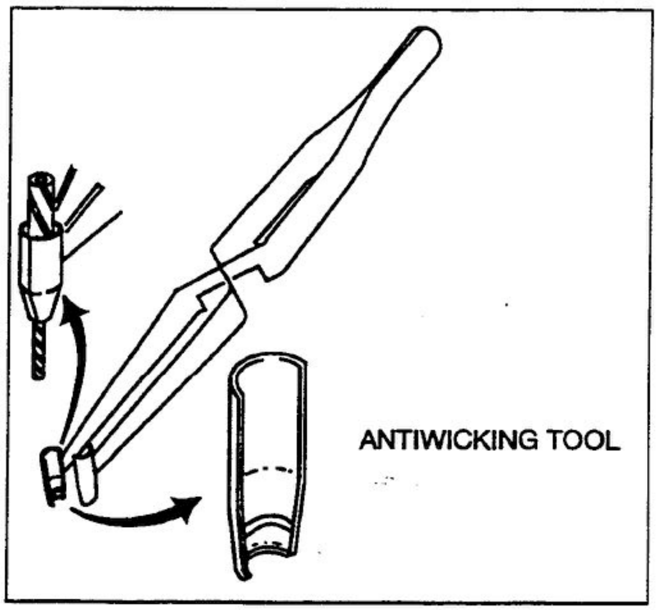


Figure 1–10. Antiwicking tool.

Another general accessory that comes in many different designs is printed circuit board holders. Most have a spring-loaded jaw so that the boards may be removed and replaced after the initial adjustment without readjusting the holder. Also, they hold boards in many different positions. Make sure the holder does not clamp the boards so hard they flex.

Soldering aids (fig. 1–11) are useful in soldering and desoldering connections. The pointed ends are for placement of wires prior to soldering or for removing solder from terminal holes and slots. The slotted ends are used to lift the ends of wires and part leads from terminals. These aids are strong enough to damage leads, wires, and printed circuit boards. Use extreme caution when force is applied with soldering aids.

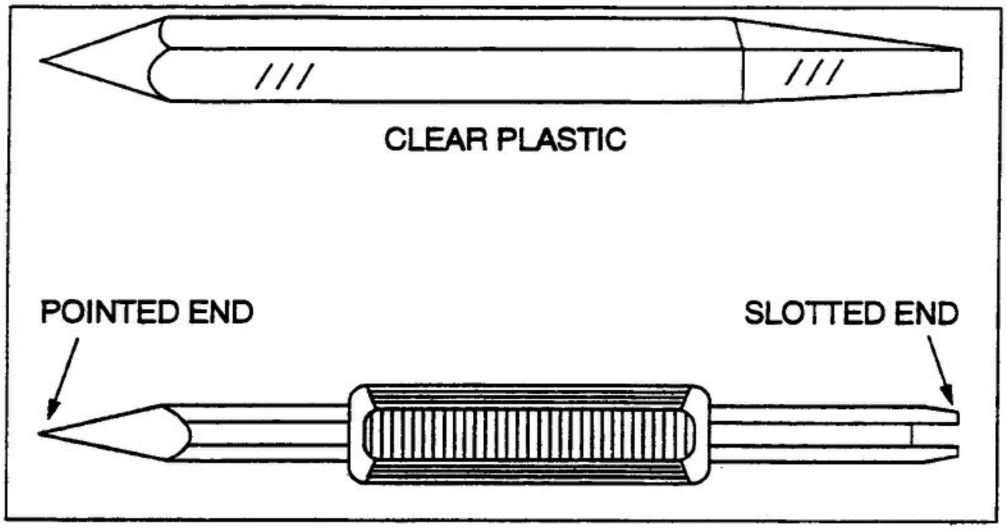


Figure 1–11. Soldering aids.

Wire strippers. Before wire ends can be soldered to connector terminals, the wire insulation must be removed. The three primary methods used to remove insulation from a wire are chemical, mechanical, and thermal.

Chemical stripping is only done on very thin insulation such as varnish or enamel. The manufacturer's procedures must be followed very carefully. Some of the hazards associated with chemical strippers are harmful vapors that require adequate ventilation, chemicals that can splash or sputter causing skin burns, and stripper residue that can cause connections to corrode if not neutralized on the wire.

Mechanical stripping is accomplished on most types of insulation. Most technical manuals specify the types of mechanical strippers as operator adjustable and precision-cutting, as shown in figure 1–12. The operator adjustable type is not acceptable for high-reliability soldering. Precision mechanical strippers are used if adjusted for wear (calibrated). Calibration is done when they cut, nick, or otherwise damage the wire.

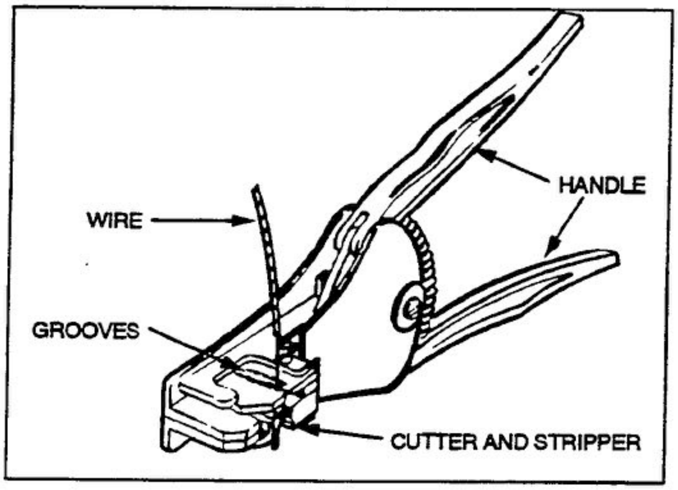


Figure 1–12. Mechanical wire stripper.

Thermal stripping is done on all but a few types of insulation—glass bead and Teflon are the major exceptions. The thermal method is preferred because it minimizes wire damage. Be cautious when stripping polytetrafluorethylene (Teflon) or polyvinylchloride because they give off toxic fumes when they melt. A heated element can cause severe burns to the skin. For that reason and to conserve energy, leave the unit off when not in use. A typical thermal stripper is shown in figure 1–13.

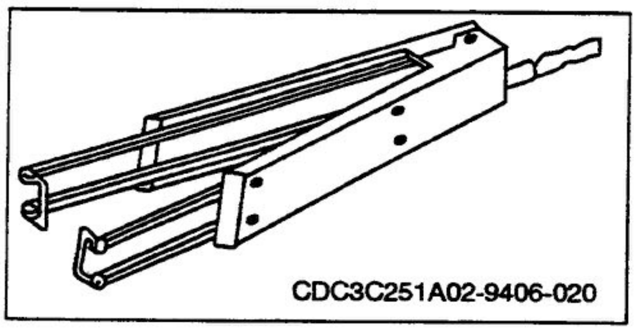


Figure 1–13. Thermal wire stripper.

Soldering irons. The primary tool for soldering is the soldering iron. They come as two different types, resistive and conventional. Either may be used depending on the type of connection to be made and conditions under which it must be created. As with all tools, soldering irons must be kept clean and serviceable to maintain their reliability.

Resistive soldering is an old, but effective method of supplying heat for soldering a connection. This system consists of a step down transformer or a control unit (fig. 1–14). The output of the control unit is connected to any of the hand-held attachments: resistive tweezers (fig. 1–14,A); conductive tweezers (fig. 1–14,B); lapp-flo soldering unit (fig. 1–14,C); or it can be used to control the temperature of a thermal wire stripper (fig. 1–14,D). A foot pedal (fig. 1–14,E) is normally incorporated for energizing and deenergizing the attachments. The tips are positioned on the connection to be soldered, thus allowing the current to pass through it. The current passing through the connection causes the temperature to rise rapidly.

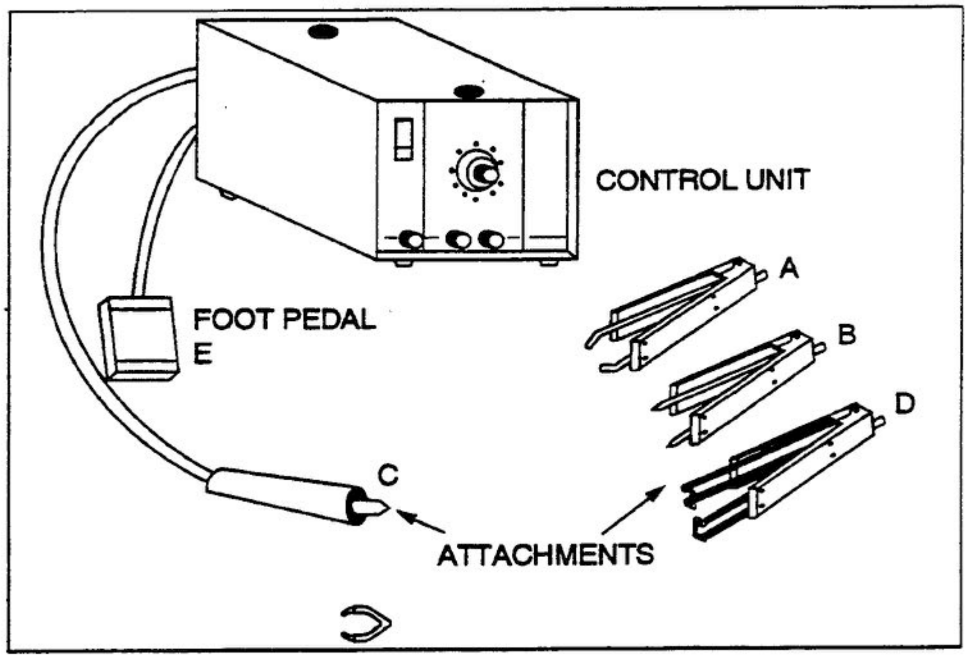


Figure 1–14. Resistive soldering unit and attachments.

Because resistance soldering generates heat directly to the area to be soldered, it affords a means of localizing the heat to a given area. The unit is well adapted to the soldering of terminals, especially connector pins in multiple pin (multipin) connectors such as "C" or "D" connectors. Dirty tips cause arcing and damages the terminal. Use a fine abrasive cloth (300 to 400 grit) to clean dirty tips. A word of caution—the AC field around the resistive unit can destroy some integrated circuit devices.

Soldering irons come in a variety of sizes and wattage ratings. The one you use is determined by the type of soldering operation and your personal preference. The size and shape of the connection being made determines the wattage rating of the soldering iron required. Ratings of 15 to 35 watts are commonly used for soldering electrical connections. Twenty-five watts is normal for high-reliability soldering. Ratings of 100 watts and up are used for soldering large terminals and metal chassis. Control the soldering iron temperature by using a variable voltage supply. Some newer irons maintain a preset temperature at the tip of the iron and the power ranges from 10 to 50 watts without the tip temperature changing much from the preset level. These irons use a temperature sensitive tip that causes power to be applied when the tip cools. The more heat drained from the tip, the more power applied. Two typical soldering irons are shown in figure 1–15.

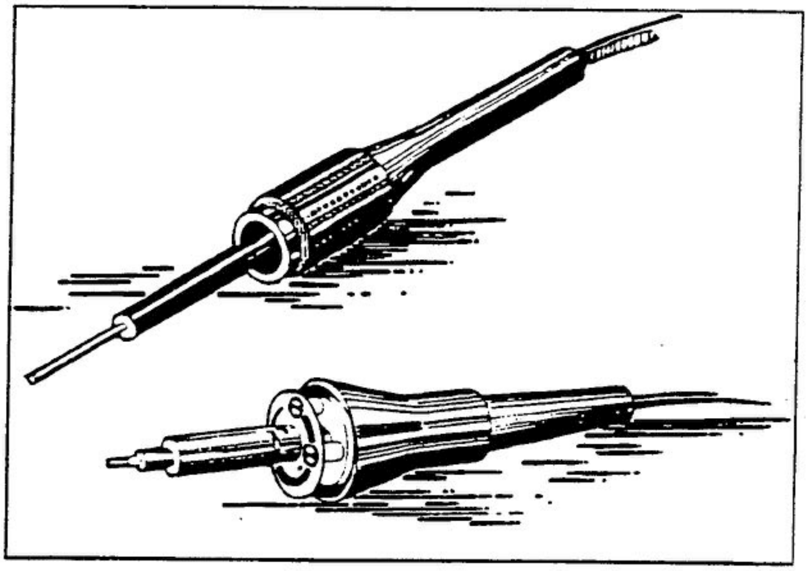


Figure 1–15. Typical soldering irons.

Soldering iron tips are available in numerous shapes and sizes. The most common shapes are the pyramid, screwdriver, and chisel (fig. 1–16). Soldering iron tips should be redressed with a file as often as necessary to ensure quality workmanship. Tin the tips as soon as the maximum temperature is reached to reduce the possibility of oxidation and pitting. Don't file a hot tip because it will oxidize quickly and tinning will be difficult.

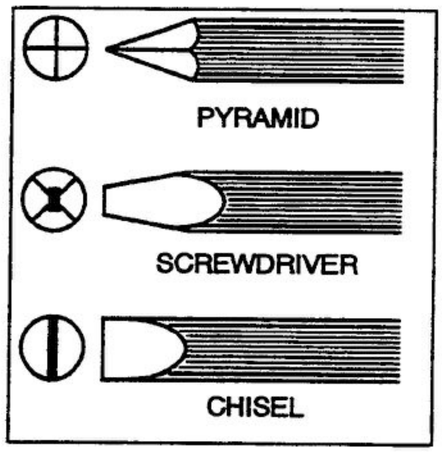


Figure 1–16. Common soldering iron tips.

You may use tips plated with an oxidation-resistant metal such as nickel or aluminum, provided solder connection quality is maintained. Always clean plated tips while hot by applying solder to the tip and wiping with a tissue or while cold, using an abrasive cloth (300 to 400 grit) until the surface is bright. **DO NOT FILE A PLATED TIP.** *Always* assume a soldering iron tip is hot and handle it with pliers.

Use a small screwdriver or offset (Allen) wrench to tighten the setscrew holding the soldering tip in place. Check these setscrews periodically for wear.

Do not use soldering guns because their temperatures cannot be controlled. Research shows that the best solder joints are produced within a narrow range of temperature and application time. Another reason for not using a soldering gun is they generate a relatively large inductive field that can damage sensitive electronic devices.

Notice that the tools discussed so far are used for a *new build* soldering operation (new components, new wire, new printed circuit boards, etc.). For a repair job or to rebuild a component, these and other more specialized tools are needed.

Thus far in this volume we've discussed what soldering actually is and safety considerations associated with the soldering process. We also identified the basic elements of soldering as being solder, flux, and solvent. Finally, we covered some of the general- and special-purpose tools used in soldering and how to care for them. Our next section introduces us to some of the particulars associated with soldering and the actual soldering process itself. Complete the following self-test questions and unit review exercises to check your understanding before moving ahead to our next lessons.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

202. The various tools and equipment used in soldering

1. What is the minimum light level required for soldering?

2. What is used to clean connections?

3. What wire cutting tool do you use for large-diameter or hard metal wires?

4. Name three methods for removing wire insulation.

5. What mechanical stripper is acceptable for high-reliability soldering?

6. Name two types of insulation that cannot be thermally stripped.

7. What soldering method localizes generated heat?

8. What factors determine the required wattage rating of a soldering iron?

9. What is the normal wattage rating for a high-reliability soldering iron?

10. Why shouldn't soldering guns be used?

Answers to Self-Test Questions

200

1. Your safety.
2. 75° ± 10°.
3. An exhaust system.
4. When working with tools that cause flying particles.

201

1. Tin and lead.
2. Metal solvent action.
3. Tensile, shear, cleavage, and peel.
4. Lowers it.
5. Cleaning agent.
6. Corrosive and noncorrosive.
7. Cleaning and removing flux and other contaminants.
8. Nonconductive and noncorrosive.

202

1. 100 foot-candles.
2. Acid brushes and solvent.
3. Lineman's pliers.
4. Chemical, mechanical, and thermal.
5. Precision cutting type.
6. Glass bead and Teflon.
7. Resistive soldering.
8. Size and shape of the connection.

9. 25 watts.

10. Temperatures are not controlled and inductive fields can damage some components.

Do the Unit Review Exercises (URE) before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to ECI Form 34, Field Scoring Answer Sheet.

Do not return your answer sheet to ECI.

1. (200) A soldering work area should be environmentally controlled to a temperature between
   a. 65°F and 70°F.
   b. 65°F and 85°F.
   c. 70°F and 80°F.
   d. 75°F and 85°F.

2. (200) Soldering needs to be performed in an area where the relative humidity is maintained at
   a. 5 percent to 25 percent.
   b. 20 percent to 40 percent.
   c. 30 percent to 50 percent.
   d. 45 percent to 65 percent.

3. (201) The essential elements for soldering are
   a. solder and flux.
   b. solder, tin, and solvent.
   c. solder, solvent, and lead.
   d. solder, flux, and solvent.

4. (201) A characteristic of eutectic solder is that it has
   a. no plastic state, which lets solder joints "set" quickly.
   b. no plastic state, which lets solder joints "set" slowly.
   c. a plastic state, which lets solder joints "set" quickly.
   d. a plastic state, which lets solder joints "set" slowly.

5. (201) Two features of a resin-based flux are that it is
   a. noncorrosive and nonconductive.
   b. corrosive and nonconductive.
   c. noncorrosive and conductive.
   d. corrosive and conductive.

6. (201) All electronic soldering must be performed using a/an
   a. rosin flux.
   b. acid core flux.
   c. corrosive flux.
   d. sal ammoniac flux.

7. (201) The purpose for using solvent during the soldering process is to
   a. fuse solder with other metals.
   b. remove flux and other contaminates.
   c. dissolve old solder from connections.
   d. clean solder from plated soldering iron tips.

8. (201) During a soldering operation, solvent is applied
   a. before the solder solidifies.
   b. after the solder has solidified.
   c. at the same time flux is applied.
   d. at the same time solder is applied.

9. (202) The proper procedure for using a lead cleaner is to move its
   a. brass braid along the lead from the component body towards the end of the lead.
   b. brass braid along the lead from the end of the lead towards the component body.
   c. copper braid along the lead from the component body towards the end of the lead.
   d. copper braid along the lead from the end of the lead towards the component body.

10. (202) What tool is used to form and redress unplated soldering iron tips?
   a. A file card.
   b. A flat, fine, single-cut file.
   c. A flat, coarse, double-cut file.
   d. None. Unplated soldering iron tips cannot be redressed.

11. (202) What soldering aid tool or device can be substituted for flush cutting pliers?
    a. Diagonal side cutting pliers.
    b. Needle nose pliers.
    c. Toenail clippers.
    d. Lineman's pliers.

12. (202) Antiwicking tweezers are used during soldering to
    a. prevent solder from flowing underneath wire insulation.
    b. aid heat in passing through the wire to the connection.
    c. prevent flux from contaminating the soldering iron tip.
    d. regulate the amount of heat applied to the connection.

13. (202) Before wire leads are soldered to connector terminals, they *must* be
    a. cleaned with solvent.
    b. stripped of insulation.
    c. squarely cut and filed.
    d. angularly cut and filed.

Please read the unit menu for Unit 2 and continue. ➔

STUDENT NOTES

Unit 2. Soldering Wires and Solderless Connectors

THIS unit is devoted to soldering terminals and printed circuit boards. We'll study various soldering iron tips and wire leads, the procedures used in the soldering process, and the types of wire terminals you'll encounter. Then we investigate the different types of printed circuit boards in electronics equipment and learn about their construction and proper maintenance procedure. Lastly, we discuss methods for creating "solderless" connections for common types of distribution frames.

2–1. Soldering Wires to Terminals

Every seasoned systems controller remembers staring for the first time into a large mainframe and discovering that jungle of multiple-colored, twisting, snaking, and turning plastic-coated conductors of electronic intelligence. Until that moment, this maze was silently hidden behind cold, flat-gray cabinet doors of steel just waiting to provoke that look of fear and utter dismay on the unsuspecting trainee's face. With eyes bulging from their sockets, the inexperienced systems controller frantically gasps for breath only to exclaim, "Ohhhh... What have I gotten myself into?"

If you haven't already experienced this, you will. Just remember the heart and soul of our business is electrical paths of conduction. Now, we'll discover how to maintain their prime performance. There is no standard method to connect wires to terminals in a mainframe. Some are soldered and others are solderless connections. This section gives you information on soldered connections. But of course, knowledge of the subject is not enough. To become proficient, hands on experience is absolutely essential. As you read this material, examine the illustrations carefully so you fully understand the processes and procedures.

203. What do you do before the soldering process begins?

Before you begin soldering, you must understand the importance of soldering iron tips. The tip's size and shape, voltage and wattage rating, and temperature is selected and controlled for optimum performance for the work being performed. The temperature of the soldering iron is controlled through the use of a variable voltage supply, tip selection or a combination of both. The care and preparation of soldering iron tips is important and determines the quality of your work. The type and size of wire to be soldered also helps determine the type of soldering iron tip to be used. In addition, each wire lead must be carefully prepared to ensure a proper solder connection will be achieved.

Soldering iron tips. The two types of soldering iron tips are plated and unplated. Each has advantages and disadvantages and neither is perfect for every soldering task.

Plated soldering iron tips. These tips consist of a commercially pure copper, tellurium copper or lead copper which are plated/coated with another metal that prevents the copper tip from melting. A plated tip is preshaped and cannot be reshaped (filed). It is long wearing and is best cleaned by applying solder while the tip is hot and wiping with a tissue. Plated tips can be temperature controlled.

Unplated soldering iron tips. These tips consist of a commercially pure copper of the type found in most electrical wiring. A No. 8 American Wire Gauge (AWG) electrical copper wire makes an excellent tip for *most* 25-watt soldering irons which do not require a threaded base. An unplated tip can be shaped as required for each task. It is soluble in molten solder (requiring frequent reshaping), is cheap, and is best cleaned by wiping with a tissue and/or damp sponge. They cannot be designed to be temperature controlled, and they corrode easily.

An unplated soldering iron tip must be redressed often to ensure quality workmanship. Whenever oxidation forms or pits occur, use the following steps to redress the tip:

(1) Remove the tip from the soldering iron by loosening the setscrew. Always use round nose pliers to handle the tip.

(2) Clean the entire length of the tip with a clean wire brush.

(3) Clean the barrel (hole in the iron where the tip fits).

(4) File the tip to the required shape and specifications. Make sure it's cool; never file a hot tip.

(5) Insert the tip in the barrel until it's fully seated, then tighten the setscrew.

(6) Plug the iron in. As soon as the tip reaches the lowest temperature required to melt solder, apply resin core solder to each face of the tip.

Wire leads. The two general wire types are solid and stranded.

Solid wire leads are used on many components but should not be used for other connections unless required by the design. Solid hookup or bus wire exceeding 1 inch in length between soldered connections must be rigidly secured. Technical control facilities use solid wire almost exclusively for circuit wiring in mainframes and patch panels because of its versatility. It's easy to solder and can be connected to terminals using solderless methods such as "wirewrap" and "punch on." We'll cover these solderless connections in a later lesson.

Solid wire is measured by a numerical system identified in AWG sizes. These sizes run numerically from the largest (No. 40) to the smallest (No. 44) wire. Note that AWG numbers are inverse to the size of the wire. That is, the smaller the AWG number the larger the wire. AWG diameters have a direct relationship to each other. From a known AWG diameter, the next larger AWG diameter can be determined by multiplying by 1.122932. Stranded wire sizes are determined somewhat differently.

Stranded wire is often given an AWG number, but this is only an approximation and is technically incorrect. The diameter of a stranded wire is always different from its equivalent solid AWG. This difference is the current carrying capability of the wires. This is determined by the Circular Mil Area (CMA). The CMA of a solid wire is determined by multiplying the diameter (in mils) of the wire by itself. The CMA of a stranded wire is obtained by multiplying the diameter (in mils) of one strand by itself times the number of strands, as illustrated in figure 2–1.

Stranded wire is actually identified by letter and number combinations such as B22 or KK24. The combination identifies insulation requirements (voltage, temperature, and coating), number of strands, and strand diameter. After the appropriate type and size wire is selected, each wire lead must be carefully prepared for the soldering operation.

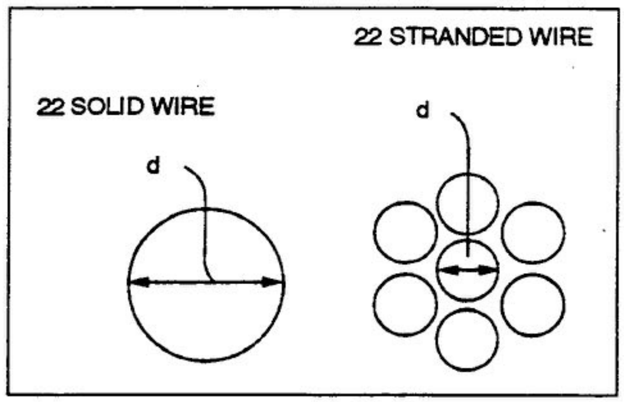


Figure 2–1. Comparison of circular mil areas.

Wire preparation. Before soldering a wire to any terminal, it must be prepared. You must strip (remove insulation) and tin the wire.

Insulation removal is accomplished with an approved stripper. The length of stripped wire (called a shiner) is determined by the type of terminal, whether maximum or minimum wrap is used, and the required amount of insulation clearance. Insulation clearance is the length of exposed bare wire between the insulation and the terminal after the connection is complete. The minimum insulation clearance is one-wire diameter including insulation, and the maximum clearance is twice that amount. The desired insulation clearance is one-wire diameter, including insulation.

When insulation is removed using a precision cutting stripper, check the cutter to ensure the correct stripping hole is used for the corresponding wire size. During the stripping operation, twist stranded wire in the direction of the lay (the direction the wire is already twisted) to maintain the original form and prevent separation of the individual strands.

After stripping, examine the wire for insulation damage. Wires with cut, split or burnt insulation is not used. However, slight discoloration from thermal stripping is acceptable. Examine the wires to ensure the outside strands have not been stretched, nicked, cut, scraped or in any way damaged. Damaged wires degrade connection reliability and are not used. Figure 2–2 illustrates acceptable and unacceptable stripped wire conditions. Once stripped, wire leads need to be properly tinned.

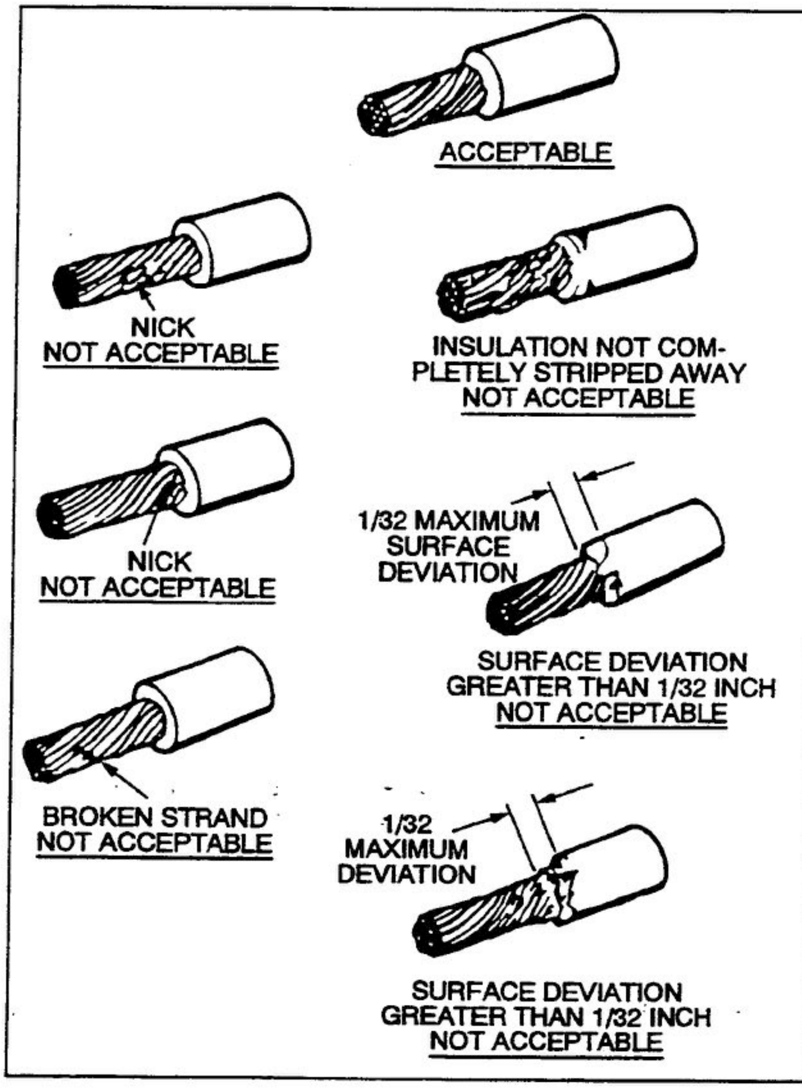


Figure 2–2. Wire conditions after stripping.

Wire tinning is the process of applying a thin coat of solder prior to the soldering process. A properly tinned wire provides rapid heat transfer during the soldering operation. Without tinning, soldering iron temperatures would have to be increased to a point where damage occurs.

All portions of stranded wires coming in contact with the area to be soldered must be tinned. Without tinning, a disturbance of the natural lay of the strands, called birdcaging, occurs during bending procedures.

The distance between the end of the wire's insulation and the beginning of the tinned portion is about 0.02 inch. This distance is determined by the antiwicking tweezers used and the workmanship of the person soldering. The tinning should be even all the way around as seen in figure 2–3, *not* like figure 2–4.

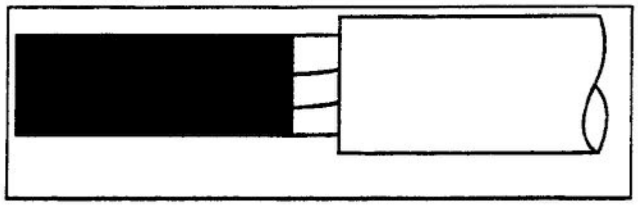


Figure 2–3. Properly tinned stranded wire.

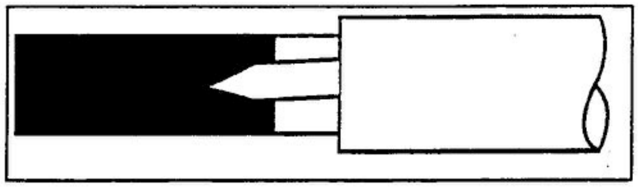


Figure 2–4. Improperly tinned stranded wire.

Avoid wicking (the flow of solder under the insulation) when tinning stranded wire. This in itself does not create a conductivity problem, but it leads to a serious situation. When moved, stranded wires tend to break near a solid juncture. The tinning line itself is a solid juncture. Therefore, if this line is hidden by insulation, broken strands may go undetected.

OK, you've selected the type and size wire to use for creating your soldered connection and you've properly prepared each wire lead. Are you ready to start soldering? Not quite yet. First you need to determine the most effective soldering technique to use.

204. The reasons for soldering a connection and the proper soldering techniques to use

In order to create an effective solder connection, you must understand why it's needed in the first place. You must also know what criteria you must follow when soldering your connection to ensure the finished product will work correctly. There are techniques you may use to assist in creating that perfect solder joint. With this knowledge to support you, the soldering operation can now be accomplished.

When practical, connections must be mechanically secure prior to soldering. Soldering a connection should be done to aid the mechanical strength of the connection, increase electrical conductivity, and provide an airtight covering to prevent corrosion from developing between the wire and the terminal. Do not use activated flux cored solders (acid), activated liquid fluxes or paste fluxes unless specifically directed.

Solder connection criteria. The criteria for a properly completed solder connection are shown in figure 2–5,A. Notice that the wire is connected to the terminal and that the contour of the wire is visible under a thin coating of solder. Also notice that solder forms a concave fillet (narrow band of solder) on each side of the wire and the fillet blends into the terminal's surface in a smooth continuous feathered edge. When a wire is insufficiently cleaned or insufficiently heated, an incorrect solder connection results as shown in figure 2–5,B. Notice that solder does not cover the wire, but instead terminates in small convex fillets on each side of the wire. Another possible result of insufficient cleaning or heating is shown in the connection of figure 2–5,C. Notice that the solder fillet does not spread into a smooth blend with the terminal surface on each side of the wire.

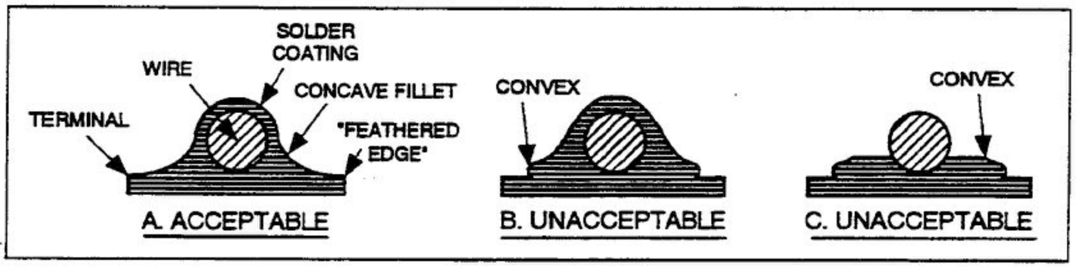


Figure 2–5. Solder connections.

Soldering techniques. The soldering operation cannot ensure a quality connection unless steps taken during the soldering process are done properly. The first of these is lead support.

Lead support. Properly support the wire and terminal during soldering to prevent joint fracturing. This is done during joint formation and maintained until the joint has solidified. On a single terminal, do this in a vise with an adapter as shown in figure 2–6,A. If the terminal is mounted in a chassis, use an alternate method as shown in figure 2–6,B. In general, use any means that does not damage the insulation but will apply sufficient tension to keep the wire from moving.

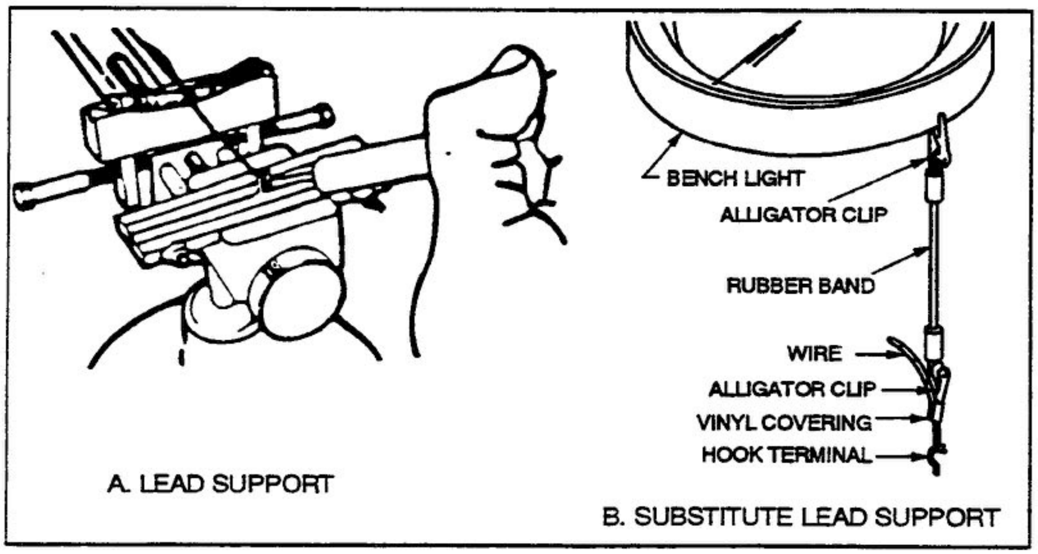


Figure 2–6. Proper support of a wire.

Heat sinking. A heat sink is a heat absorbing device that prevents heat from reaching a thermally sensitive device. When insulated wire is soldered to a terminal, use a heat sink to prevent insulation damage. Figure 2–7 shows the use of a "triple notched" heat sink. It has one notch for AWG 20/22 wires and two closely spaced notches for AWG 20/22 side-by-side wires. Heat sinks must be free of burns and rough edges and not touch the terminal or the insulation. Keep the heat sink applied until the joint has cooled. When removing a heat sink, do not slide it along the wire as this will scrape or notch the conductor's strands.

Soldering operation. Wires and component leads must be attached to terminals and supported so there is no movement during soldering or cooling. Connect thermal shunts between heat sensitive parts and the connection to be soldered, and clean the connection with solvent. If solid wire solder is used, apply Type R, QQ–S–571 flux to the connection. Maintain a clean, well-tinned soldering iron tip during the soldering operation. Do not use more solder than is necessary. The core size and wire size of the solder should be the minimum required to complete a satisfactory connection.

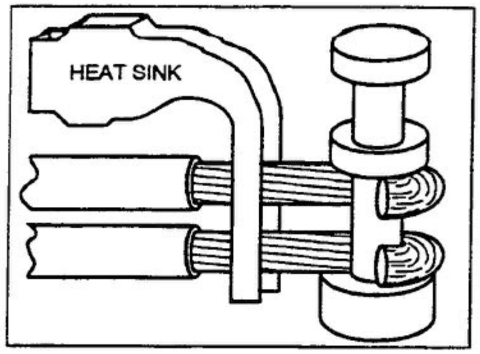


Figure 2–7. Proper heat sink installation.

When the clean (dry) working surface of a heated soldering tip is applied to the connection, optimum heat transfers to the surface by means of a heat bridge. As the surface of the connection reaches a sufficient temperature, apply the solder *directly* to the connection. *Do not* melt the solder on the soldering tip and then allow it to flow onto the connection. Maintain contact between the soldering tip and the connection until all flux is boiled out and the solder has completely wetted (fused in a smooth continuous blend) with the wire and terminal surfaces. *Do not* overheat the connection.

Don't subject the connection to stress while the solder is cooling and solidifying. To do so produces a mechanically weak joint that has a high electrical resistance. Allow solder joints to cool naturally at room temperature. Don't cool them with liquid or forced air.

205. Turret, hook, bifurcated, and connector pin terminals

We've covered soldering iron tips, solid and stranded wire, and the procedures and techniques of soldering. Now let's discuss the various terminals (the turret, hook, bifurcated, and connector pin) that are used with wires in the soldering operation.

The turret terminal is the most common type of terminal used in electronics work (fig. 2–8). Its shape allows wire leads and components to be installed or removed. When installing a single lead to a turret terminal, place it on top of the bottom base (point A in the figure). It's placed here rather than point C because it's less likely to bend the terminal. The shank of a turret terminal is relatively small in the area between the bases. If two leads are to be installed, one would normally be placed on top of the bottom base (point A) and the other on top of the center base (point C). The soldering procedures for leads at these two points are the same. A third and fourth lead can be connected to this type of terminal, but a different soldering technique must be used. The third lead is positioned on the bottom of the center base (point B), while the fourth lead would be installed at point D.

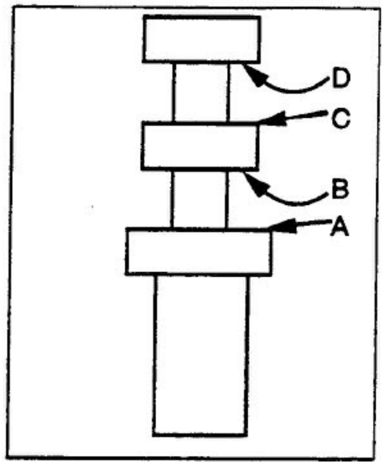


Figure 2–8. Turret terminal.

When a lead is placed on the base of a terminal, proper insulation clearance must be observed. An antiwicking tool is used to get this clearance. The minimum insulation clearance is "visible clearance" and the maximum is one diameter as shown in figure 2–9,A. The lead must be bent a minimum of 180° and a maximum of 270° as shown in figure 2–9,B.

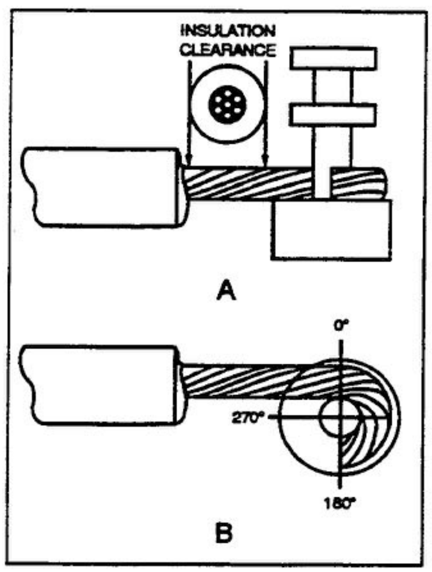


Figure 2–9. Formed lead on turret terminal.

Because of the construction features of most turret terminals, the specification on abrasion points (the amount of wire protruding from a soldered connection) must be modified. In most turret terminals, the top and center bases are smaller than the bottom one. As a result, wires on either of these bases may have a small abrasion point if wire leads do not protrude beyond the bottom base.

A proper setup prior to soldering is necessary to make a reliable connection. Always take the time to prepare the setup. Remember that fifty percent of the job of making a reliable connection is having a proper setup. Always inspect the components before and after the soldering operation. Bear in mind, a solder connection is of no value if it doesn't hold up under operational conditions. Another type of connector is the hook terminal.

The hook terminal (fig. 2–10) has little real use in electronics work today. If used, it is important that it is soldered properly. The most common use is on relay packages with a few used on terminal boards.

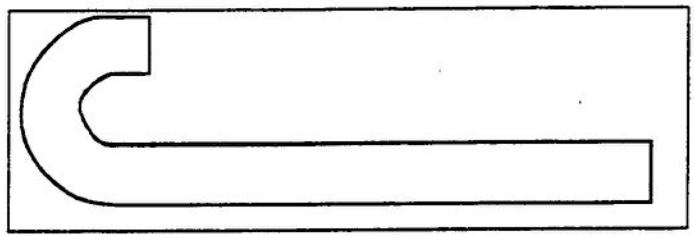


Figure 2–10. Hook terminal.

If you do not give your complete attention during the forming and soldering operation, the result may be a reject solder connection. The first problem encountered is the small amount of tinning required on the lead (less than half that required for other terminals). Because of this, it is extremely difficult to form the lead without causing a birdcage (an unraveling of the stranded wire). This might be in the insulation clearance area or the tinned area. Standards state the lead must be formed at least 180° and no more than 270° around the terminal. A 180° bend reduces birdcaging but leads to other problems in applying solder to all the required places.

The insulation clearance for a hook terminal is visible clearance as a minimum (to one wire diameter including insulation as a maximum) as shown in figure 2–11.

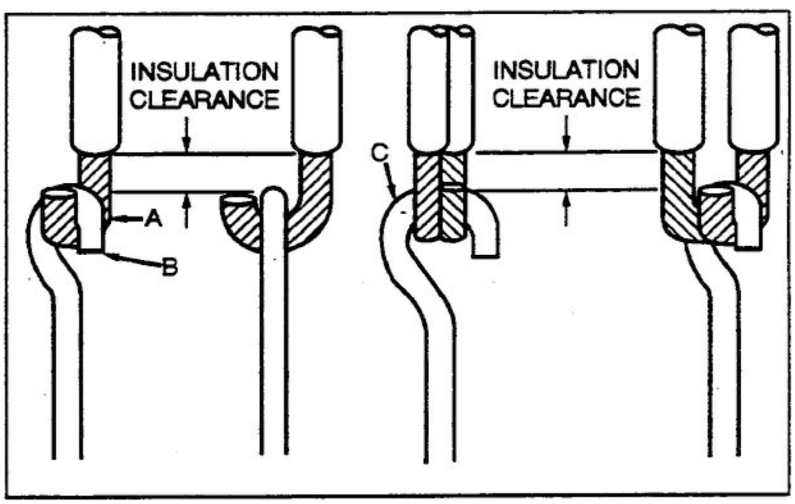


Figure 2–11. Hook terminal with lead.

When the lead is attached to the terminal, it is positioned in the exact center of the curve of the hook. This center is determined by the direction the lead enters the terminal. If it is not in the center, tension on the lead will fracture the soldered connection. When placing two leads on a hook, the center of the hook is exactly between the two leads.

A small abrasion point is allowed on a single-wire hook terminal if it does not exceed one-half the diameter of the tinned wire. While this is normally considered a major fault, it is better to have this fault than a weakly soldered connection. The strength of a hook connection is at the point where the wire contacts the hook, shown as point A in figure 2–11. When the hook and wire are heated, the tinning melts and the spring tension on the lead causes the wire to move in the direction of the arrow. If it should move far enough, there is a little contact at point A. By cutting the wire a little longer than normal at point B, any movement of the wire will leave enough wire at point A for a strong connection. If it doesn't move, the abrasion point is acceptable.

On hook terminals with two leads attached, the cut ends protrude one diameter of the tinned wire because the elbow of the other lead is already out that far (point C).

Hook terminals should be used sparingly because of the difficulties in creating them. When used they should be closely examined to ensure a proper and reliable connection is achieved. A more popular type of connector is the bifurcated terminal.

A bifurcated terminal (fig. 2–12) is one of the most versatile of all terminals. Lead entries can be made from the side, top or bottom. Pierced and slotted terminals are variations of the bifurcated terminal.

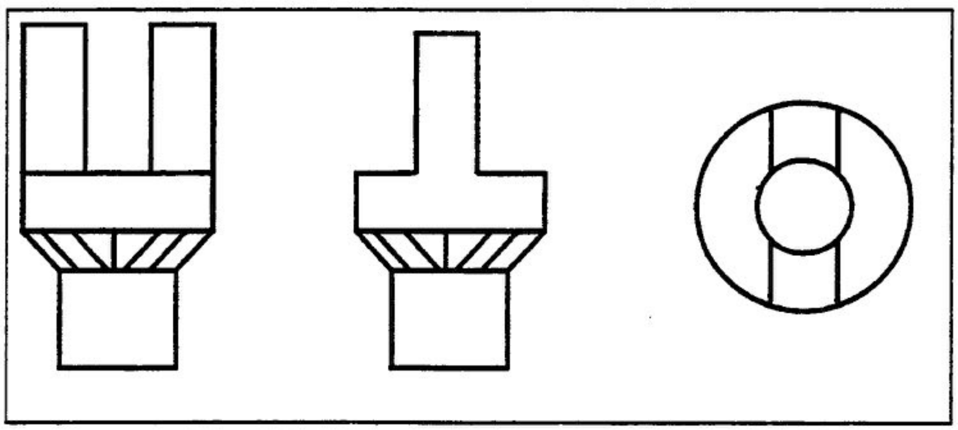


Figure 2–12. Bifurcated terminal.

The inspection criteria for a bifurcated terminal wire connection is like other terminals, except there are strict specifications concerning the hole through the center. It *must* be *capped* with solder without filling the entire hole.

Using the side-entry method on a bifurcated terminal, you can have a single-wire lead or as many leads as needed, provided the soldered top lead does not protrude above the forks. When more than one lead is installed, they are bent in an alternating direction. Figure 2–13 illustrates both methods. The strength of a side-entry bifurcated terminal connection is obtained where the lead touches the forks on the back side of the bend. As a result, the lead here should be as long as possible without causing an abrasion point. To do this, the end is cut at an angle rather than a square.

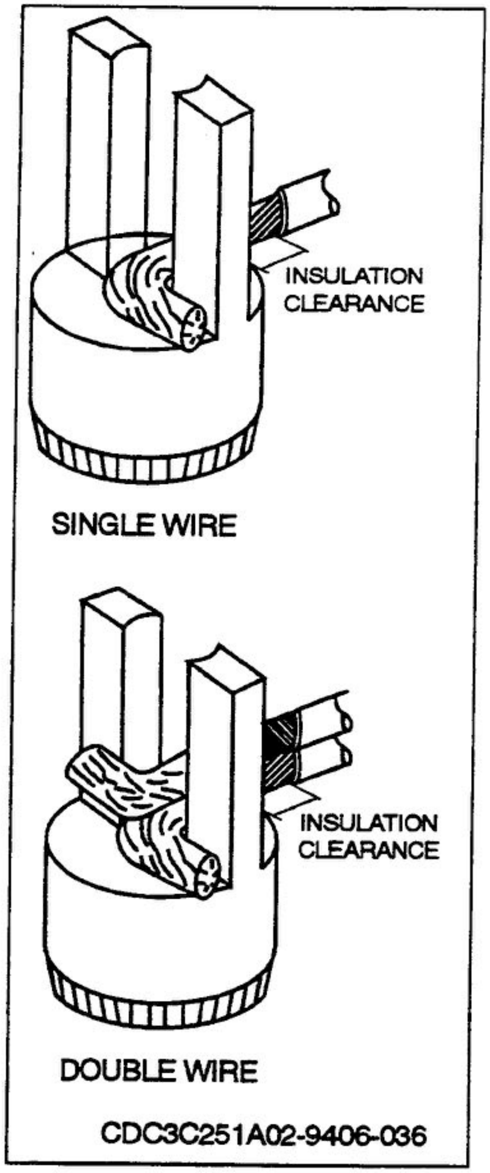


Figure 2–13. Side-entry bifurcated terminal.

The lead for a side-entry connection enters the terminal so it forms a 90° angle with the forks it passes between. The entire tinned wire is flush on the base of the terminal. Insulation clearance is visible clearance as a minimum and two wire diameters including insulation as a maximum.

A top-entry connection on a bifurcated terminal (fig. 2–14) permits only one lead to be installed. It is used when the lead approaches the terminal from above such as from another chassis, printed circuit board or terminal. The terminal is connected to a conductor.

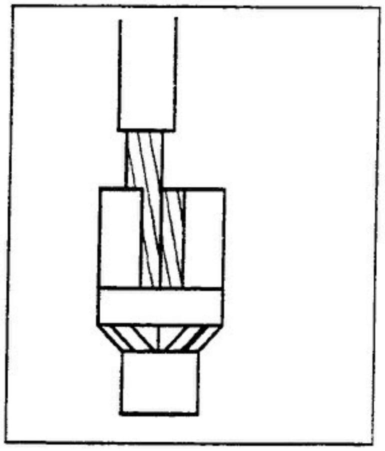


Figure 2–14. Top-entry bifurcated terminal.

The strength of the solder connection is gained from the snugness of the lead's fit between the terminal's forks. In most cases, a filler (support) wire is used with the conductor lead. Depending on the AWG of the wire, the filler wire is smaller, the same size or larger than the conductor wire. Two separate wires are used if the required filler wire is not the same size as the lead to be soldered. The lead can be bent back (doubling its overall diameter) and used to fill the terminal without using an extra wire.

The conductor and filler wires enter the base of the bifurcated terminal approximately 1/16 of an inch. The top of the support wire is flush with the top of the forks (after the cut end is tinned). Any extension above the forks (an abrasion point) or depression below (greater than one-half the diameter of the tinned conductor wire) is cause for rejection of the terminal. The insulation clearance for the top-entry bifurcated terminal is visible clearance as a minimum to two-wire diameters including the insulation as a maximum.

The bottom-entry bifurcated terminal in figure 2–15 is used for leads approaching the terminal from below. Though it is not usually done, a side-entry connection may be used on the same terminal as a bottom entry.

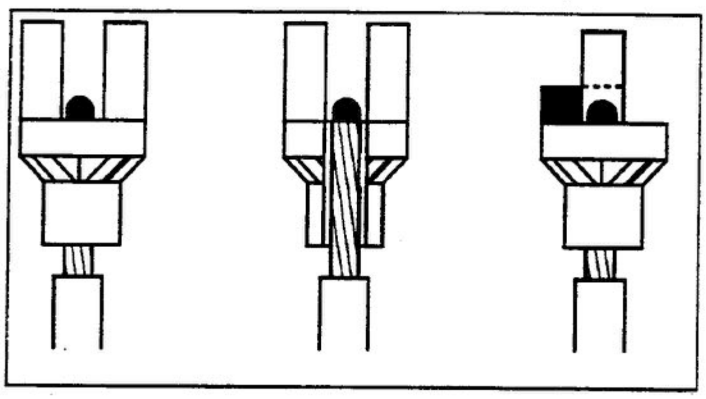


Figure 2–15. Bottom-entry bifurcated terminal.

The strength of the solder connection is gained where the lead lies across the terminal's base. Here, the lead should be as long as possible without causing an abrasion point. If the cut end from the edge of the terminal is more than one-half the diameter of the tinned lead, it is rejected.

Notice that most of the lead through the hole of a bottom-entry bifurcated terminal is not tinned. If the wire is tinned, it draws solder down from the cap at the top of the hole, and it tends to stick to the side of the terminal during the soldering operation. When the lead is free at the bottom of the terminal, wear is decreased from any motion that occurs. There is no specified insulation clearance for a bottom-entry bifurcated terminal, but the insulation should almost touch the terminal.

As you can see, the bifurcated terminal is indeed very versatile allowing for lead connections from the side, top or bottom. The last type of connector we'll cover is the connector pin terminal.

A connector pin terminal (fig. 2–16) has a hollow shaft or cup where the wire is inserted. This type of pin is found most often in some form of connector such as "C" or "D" connectors (*cannon plugs*) that are used to make multilead cables. There are occasions when more than one wire is soldered into a connector pin terminal. Many new electronic systems are replacing these pins with a "crimp" terminal that uses a mechanical rather than a solder connection.

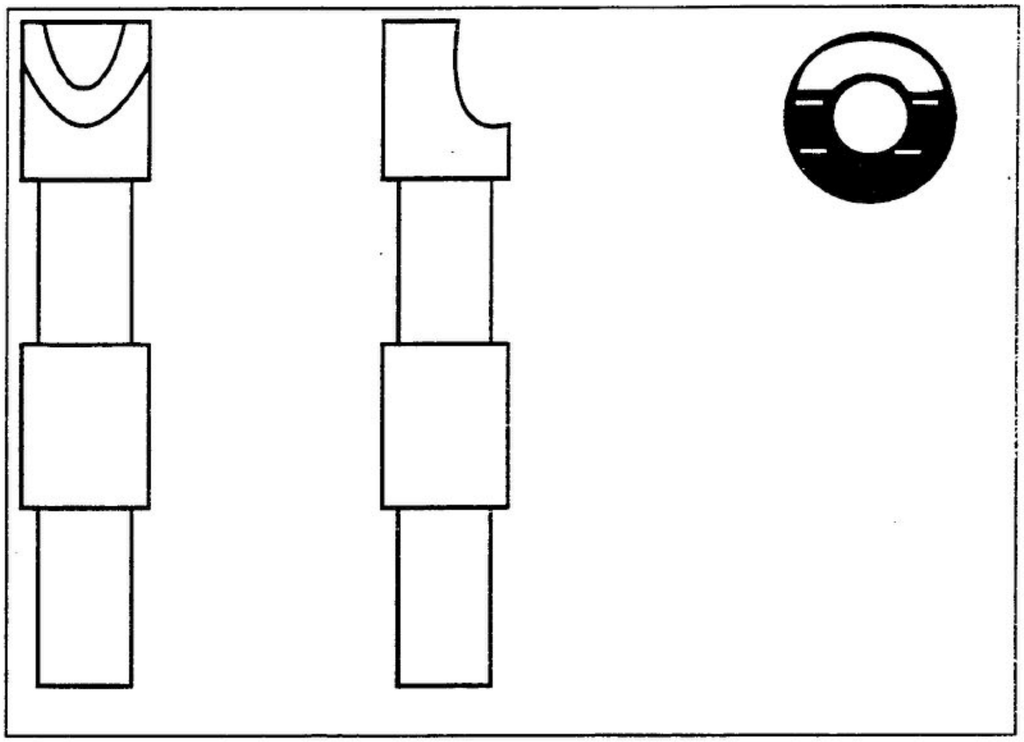


Figure 2–16. Connector pin terminal.

The cup of some connector pins has a small exit hole (weep hole) at the bottom for gases trapped under the solder to escape. If the terminal does not have a weep hole, attention must be given during the soldering operation to allow gas to escape from the top opening.

A connector pin is soldered using a conventional heated iron or a resistive soldering unit. A resistive unit normally produces the best results because of localized heat. It permits work to be done in close confines such as when making a multilead cable using cannon plugs.

The strength of the terminal is gained by placing the lead all the way to the bottom of the cup and having the entire tinned lead centered at the back of the cup (fig. 2–17). The insulation clearance is visible clearance as a minimum to two-wire diameters including insulation as a maximum.

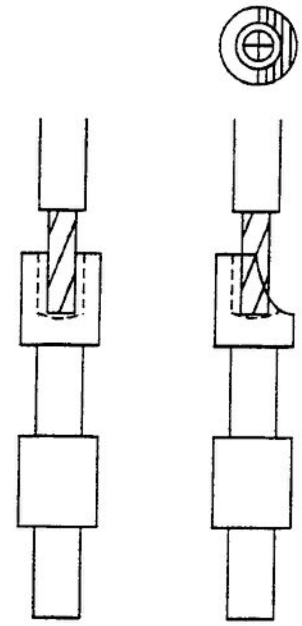


Figure 2–17. Lead in connector pin.

When a connector pin's cup does not have a weep hole, you force gas out by pushing the lead against the back of the cup as soon as the solder melts. Then move it to an upright position as shown by the arrows in figure 2–18, while holding the cut end against the back of the cup. This motion causes the molten solder to move in a way that forces the gas up and out the front.

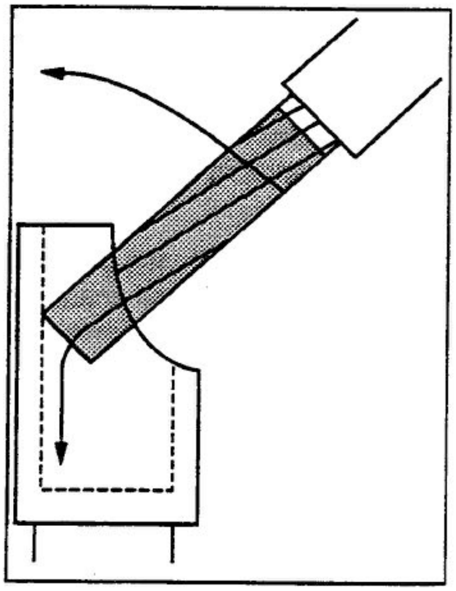


Figure 2–18. Inserting lead into connector pin with no weep hole.

The lip of the cut out portion of the cup is tinned. Do this by pivoting the lead in the cup while holding the cut end in place, causing the solder to spill out on the lip. A movement of the lead like the path in figure 2–19 accomplishes this.

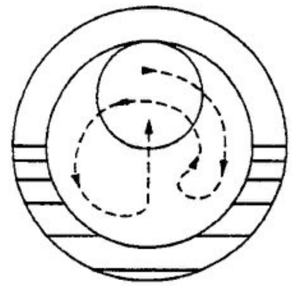


Figure 2–19. Tinning lip of connector pin.

The maximum amount of solder is illustrated by the dashed line in figure 2–20. Solder extending to the right of the dashed line is excessive. Minimum solder is seen as the 80 percent line on the figure. There is enough solder so that individual strands start to emerge out of the solder fillet at this line. Strands are not visible below this point.

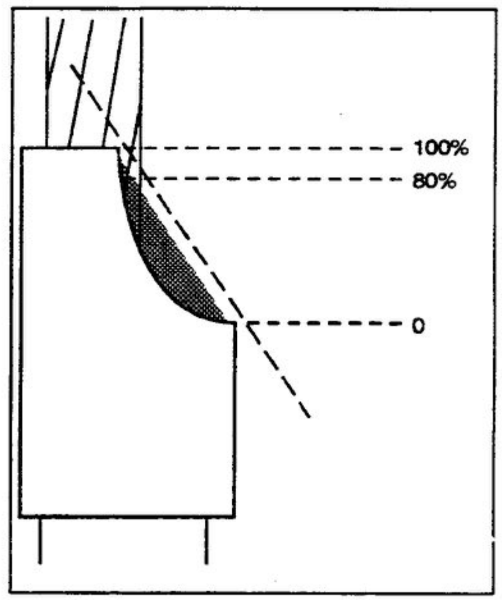


Figure 2–20. Correct solder for connector pin.

Connector pin terminals are very useful when building multipin connectors. Use care when creating them to ensure no gases are trapped inside the solder. Regardless of the type of terminal connection you create, all solder connections must be carefully inspected to ensure they meet specifications.

Solder connection inspections. Inspect the soldered connections after cleaning. Acceptable solder connections have a shiny, bright look with no pits or holes, a good concave fillet between the wire and terminal, and no excess solder. In all applications, except solder cups and connector pins, the contour of the wire is visible and the end of the wire does not extend beyond terminal dimensions. In solder cup applications, the contour of the wire is visible from the insulation termination to the point of entry in the cup. Figures 2–21 and 2–22 show typical acceptable and unacceptable solder connections for terminals and are used as visual workmanship standards. A magnifying glass not exceeding 7X is used for inspection. Study these two illustrations closely so you know the standards for acceptable and unacceptable work.

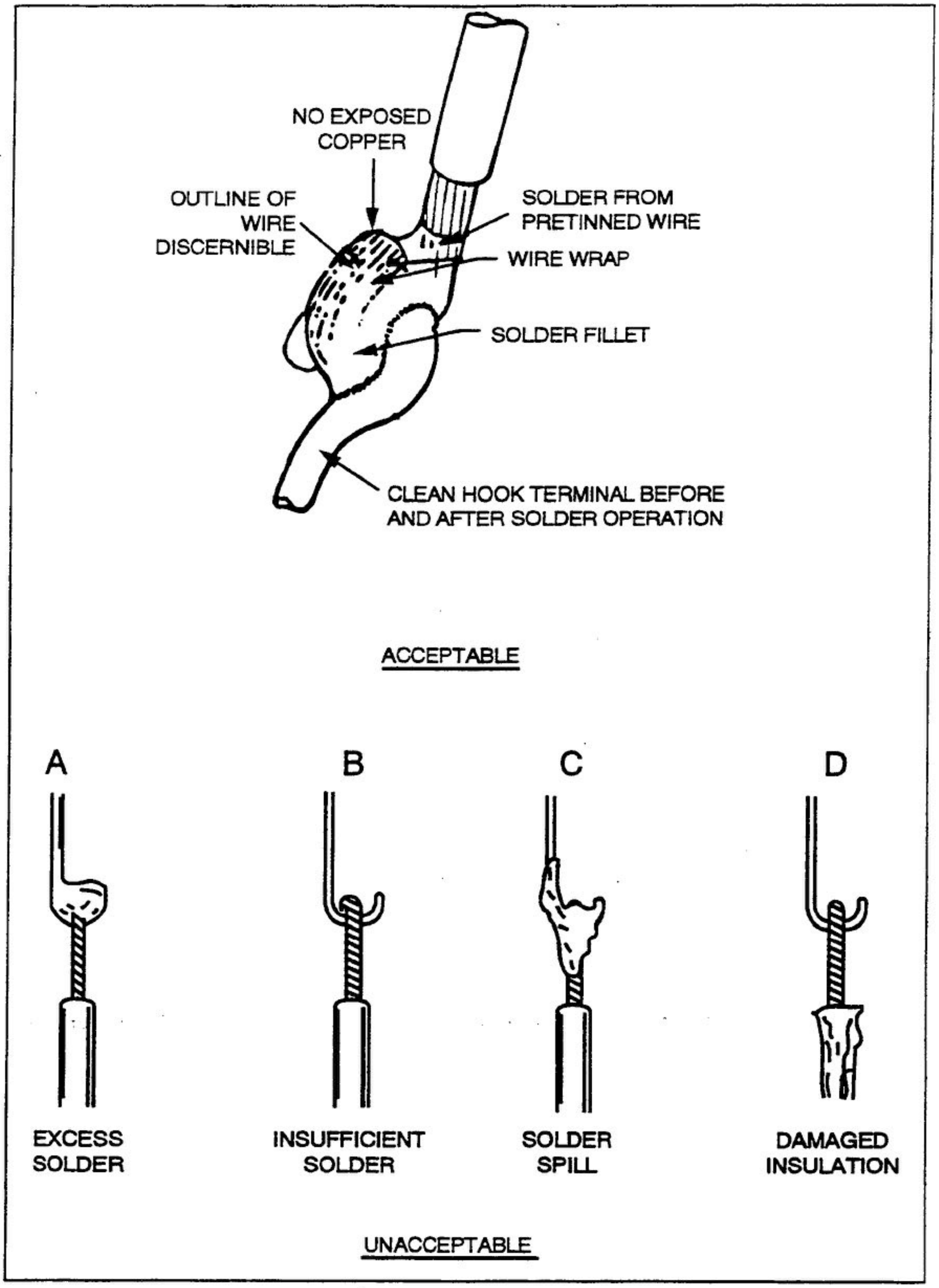


Figure 2–21. Hook terminal solder connections.

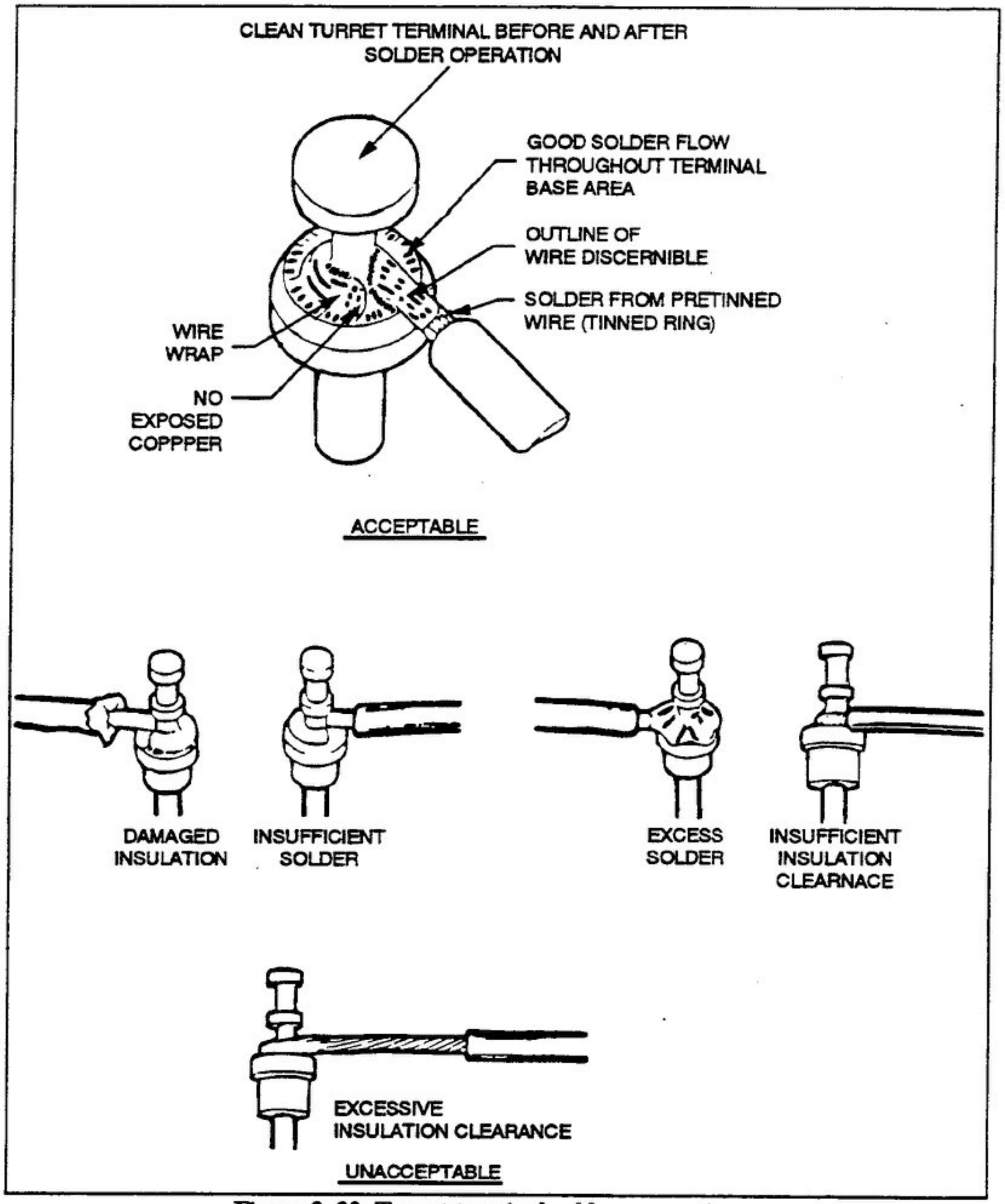


Figure 2–22. Turret terminal solder connections.

Remember to check all solder joints closely. The time and effort you spend here can save you lots of frustration and work later.

The soldering process may seem complicated, but it's not too difficult with a little practice and experience. Always bear in mind the reasons for creating a soldered connection. Choose your materials carefully to ensure you use the proper soldering iron and tip for the particular task. Prepare all wire leads correctly and use the best soldering technique for the job at hand. Finally, whether you create a turret, hook, bifurcated or connector pin terminal connection, remember to inspect it closely to ensure it will perform as desired.

Sometimes, as with the case of distribution frames, soldered connections may not be required. Our next section of this volume deals with the techniques used to create these "solderless" connections.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

203. What do you do before the soldering process begins?

1. What soldering iron tip cannot be reshaped?

2. What soldering iron tip easily corrodes?

3. What soldering iron tip is designed to be temperature controlling?

4. What is the relationship between the AWG number of a wire and its physical size?

5. What is the minimum and maximum insulation clearance for a soldered wire?

6. What does wire tinning provide?

7. What part of a stranded wire is tinned?

8. What is the distance between a wire's insulation and the beginning of the tinned portion?

204. The reasons for soldering a connection and the proper soldering techniques to use

1. State two important criteria for a properly connected solder joint.

2. When soldering a connection, what shape does the solder fillet make between the wire and terminal?

3. What is the purpose of a heat sink?

4. What is meant by "completely wetted"?

205. Turret, hook, bifurcated, and connector pin terminals

1. How many leads can be soldered individually to a turret terminal?

2. What factor controls the number of leads that can be soldered to a side-entry bifurcated terminal?

3. In a top-entry bifurcated terminal, what determines the strength of the solder connection?

4. What is the function of the weep hole in a connector pin cup?

5. What soldering system provides the best results for connector pin terminals?

6. In a solder cup application, where is the contour of the wire visible?

2–2. Solderless Connections in Distribution Frames

In the past, soldered connections were the norm for connections in a communications facility. Today, the soldered connection has been replaced by solderless connections where possible. Commercial companies use solderless connections extensively because they provide reliable service and are easy to maintain. The military is following suit and is replacing soldered connections when facility upgrade projects are implemented. The two solderless connections you'll probably use are *wirewrap* and *punch-on.* Since we encounter these primarily through our association with distribution frames, let's recharge our brain cells with a review of the various types and their components.

206. Distribution frames

In this section, we survey the various types of distribution frames and what we expect to find in them. They are a very important part of technical control facilities and must be wired in a specific manner that avoids confusion. Otherwise, a message from a secret listening post might be connected to a not so secret listening post such as a news wire circuit! How would you like to explain *that* to the boss?

First, what is a distribution frame? The term is defined as a structure for terminating the permanent wires of a communications building (e.g., systems control facilities and commercial telephone central offices). In other words, a distribution frame is a device used not only in our work centers but in many other locations as well to route circuits through a common point to minimize confusion and frustration. Can you imagine the confusion if circuits were wired randomly throughout a communications building? It would take hours or days to find the right wire. The distribution frames make it easier for the systems controller to keep accurate circuit records that are vital when adding or removing circuits and during fault isolation.

All circuits entering, leaving or passing through a Defense Communications System (DCS) station are routed through a distribution frame such as the one shown in figure 2–23. There may be more than one distribution frame in a systems control facility, but that will depend on the types of circuits in the facility and their complexity.

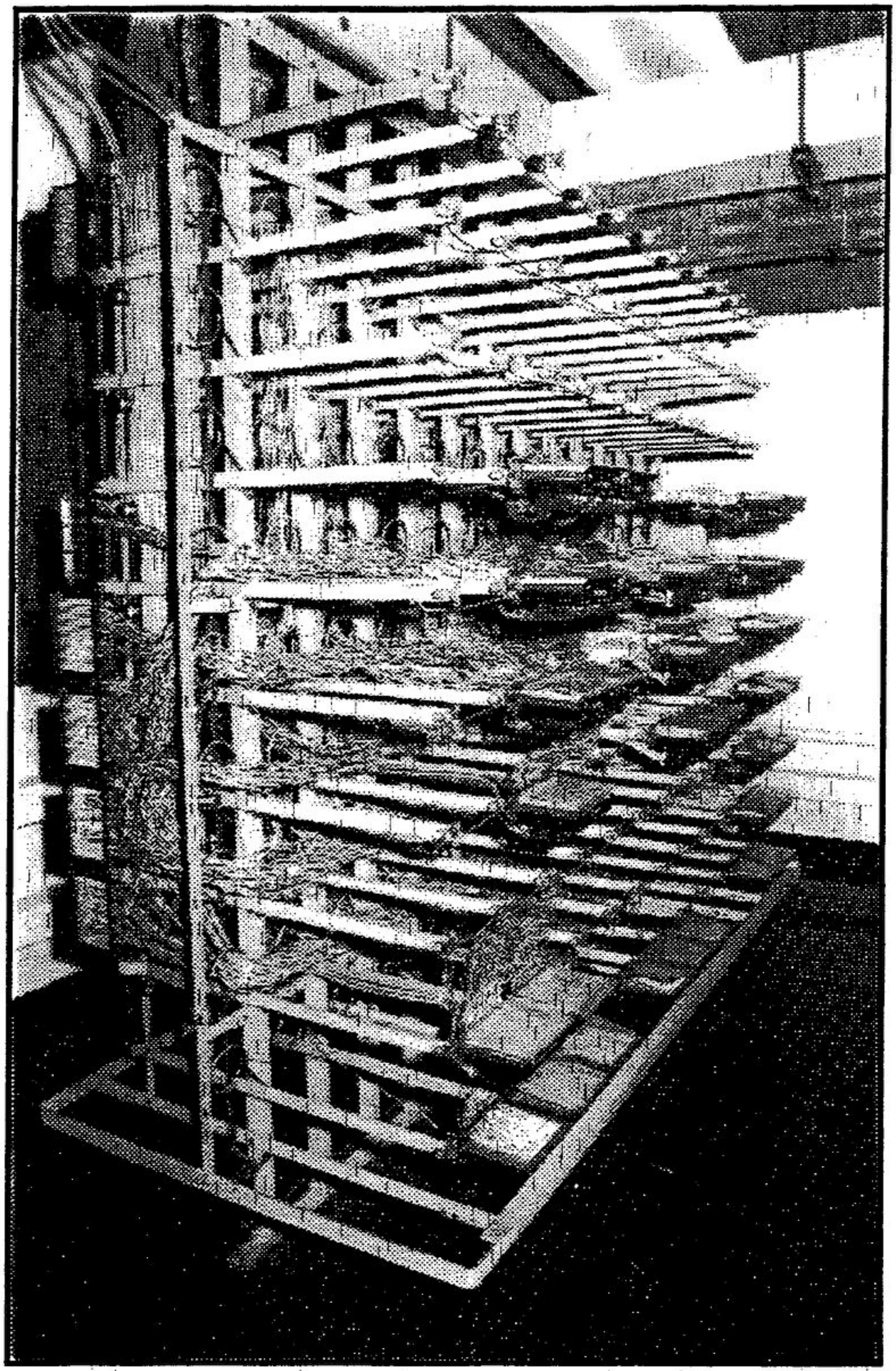


Figure 2–23. Typical floor-type distribution frame.

As a systems controller, you are concerned with station wiring regardless of where you are assigned. Even the smallest station requires wiring to connect the equipment or circuit components together. In the past, the systems controller did little of the actual connecting, but this is no longer true. Some stations now require you to do most, if not all, wiring in a facility. With this trend in mind, distribution frame wiring is more important now than ever before.

Types of distribution frames. There are various types of distribution frames in a DCS complex. They are distinguishable on the basis of how each is used. The names used to describe the various frames are main distribution frame, intermediate distribution frame, combined distribution frame, red distribution frame, and black distribution frame.

The main distribution frame (MDF) as the name indicates, is the *primary* distribution frame in a facility. This means there will likely be other frames in the complex. The MDF is the primary entrance/exit to and from the facility.

Outside lines are terminated on one side of the frame through protective devices. The other side connects all in-station equipment carrying circuits to be connected to outside lines.

The intermediate distribution frame (IDF) is physically located near the equipment in a particular area. These IDFs may be located in the systems control facility or close to a subscriber. For example, a weather facility would have its equipment connected to an IDF with in-house cables going to the systems control facility. There could be any number of IDFs at a facility depending on the number of subscribers requiring connectivity to the systems control facility. In many cases, the facility will have an IDF positioned at an *intermediate* point (in the systems control room) between a main distribution frame and the systems control patching facilities. A traditional IDF may look like the one shown in figure 2–23, but some may look like the one in figure 2–24. This IDF uses a connection method known as *punch-on* which will be discussed later in more detail. But for now, just remember that IDFs vary in size, shape, and design.

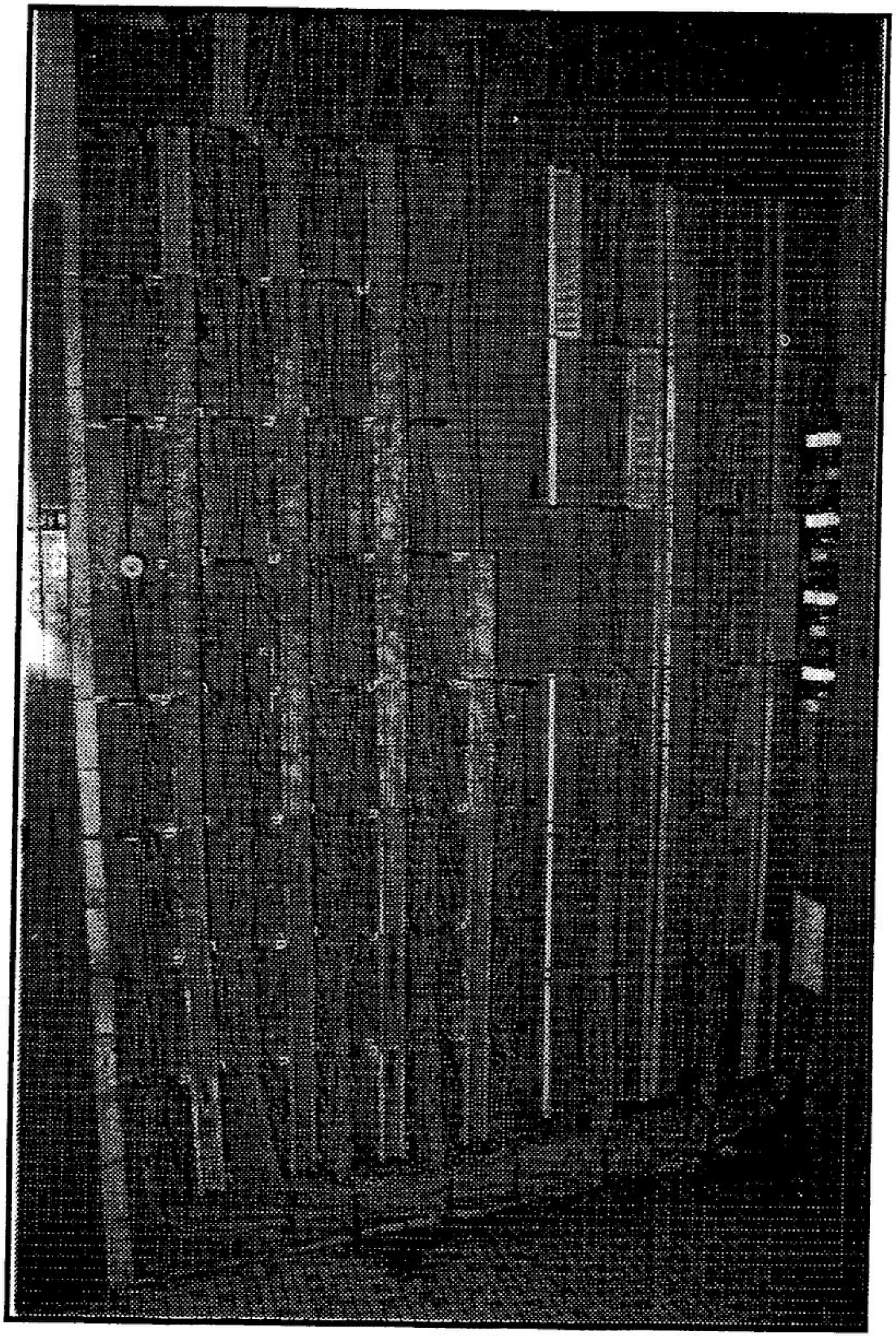


Figure 2–24. Punch-on connector IDF.

The combined distribution frame (CDF) combines the functions as a main distribution frame and an intermediate distribution frame. Part of this frame connects all outside lines entering the station. Another part connects various electronic devices and other equipment located within the station. This arrangement permits the association of any outside line with any desired terminal equipment.

The red distribution frame is used to make connections between red circuit patching facilities and equipment. This frame is used for clear text classified data which is encrypted before going to any other frame, and eventually out of the station. Wiring that terminates input/output equipment is connected to the vertical side of the red distribution frame. Wire connections for the unencrypted side of cryptographic devices, battery isolation relays, red circuit control, and switching and monitoring devices are made on the same portion. The horizontal side of the red distribution frame is used to connect red patching facilities and the positive and negative rectifiers that furnish battery.

The black distribution frame is used to make connections between black circuits, patching facilities, lines and channels, and equipment. The black distribution frame has the same configuration as the red distribution frame except that no clear text classified data is found here. At many stations, the red distribution frame is much smaller and is sometimes enclosed in a cabinet. The horizontal side of the black distribution frame is used to connect analog and digital patching facilities and the positive and negative battery supplies. The vertical side is used to connect all landlines (both analog and DC), VF channels derived from radio media, encrypted side of cryptographic devices, battery isolation relays, and any black circuit control, switching or monitoring devices used in the technical control facility.

Distribution frame components. In addition to the metal frame structure, a distribution frame consists of terminal boards and wire guides. The terminal boards are used to make the connection to whatever equipment is needed while the wire guides keep the distribution frame neat and orderly. Figure 2–25 shows a small section of a floor-type distribution frame and where each part is situated.

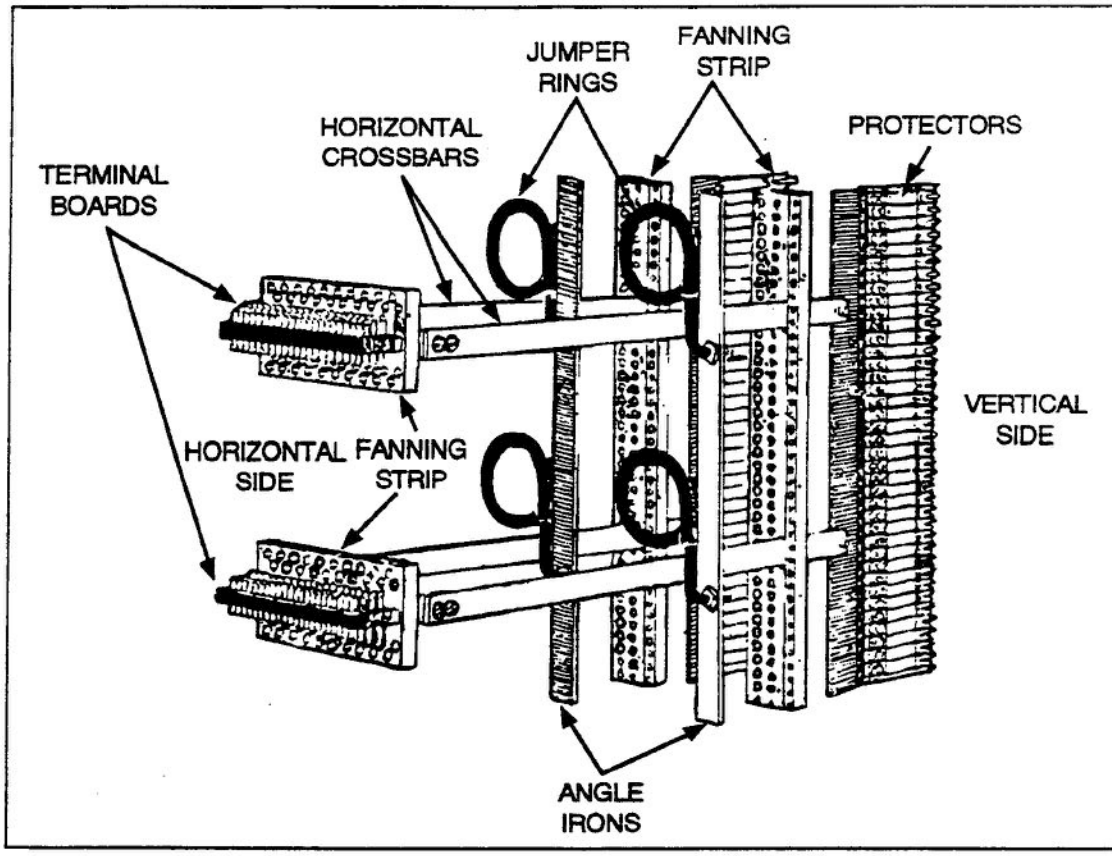


Figure 2–25. Sections of floor-type distribution frame.

Terminal boards are insulated bases or slabs provided specifically to mount a group of wiring terminals as shown in figure 2–26. Wood, ceramic, and plastic are used in their construction. The two parts of a terminal board are the wiring terminal support and a mounting board which also serves as a wire guide. The terminal boards are secured to the metal frame structure by screws so they may be added or removed as required.

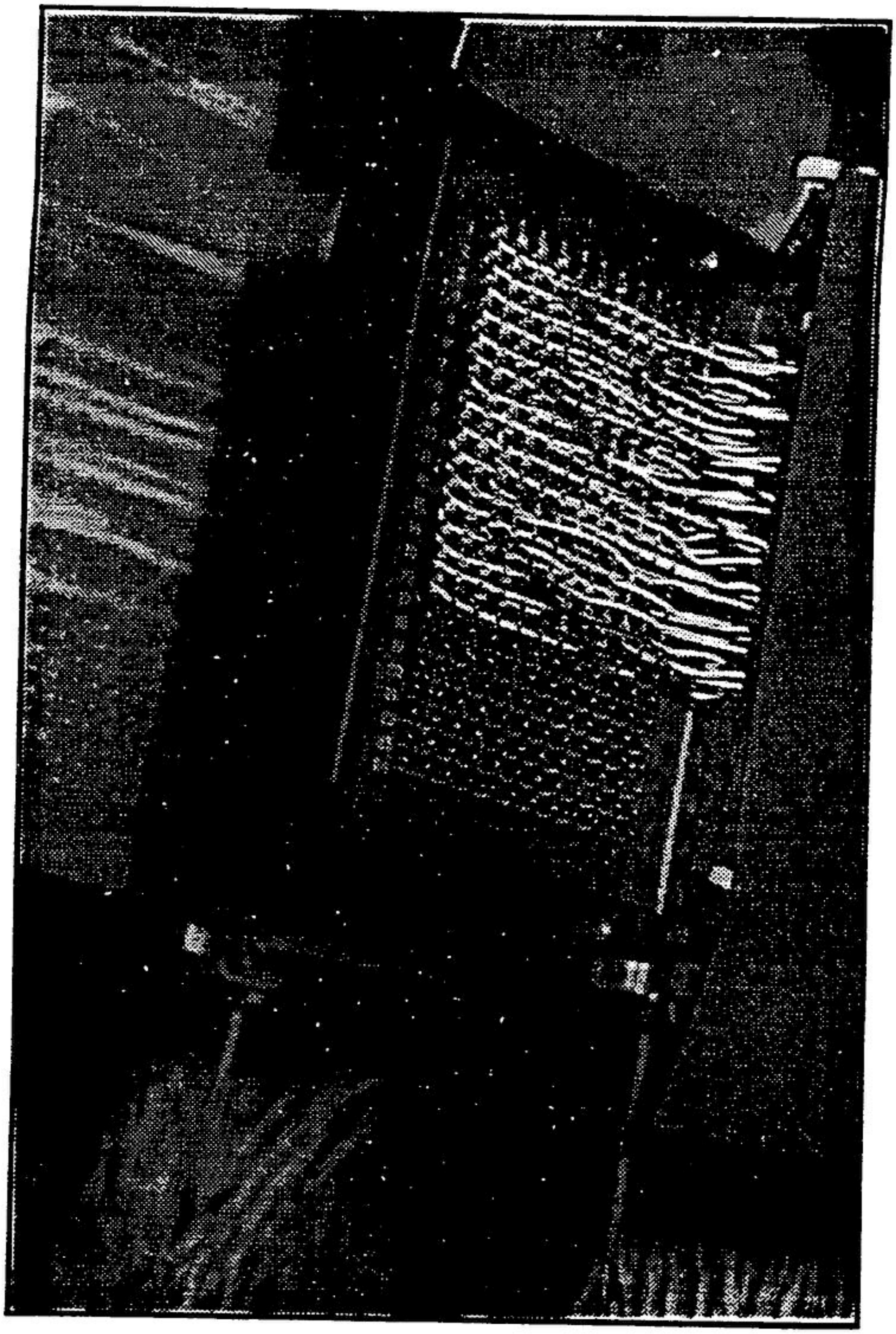


Figure 2–26. Terminal board.

All of the terminal boards on one side of a distribution frame are positioned vertically. These terminal boards are called vertical terminal boards. The other side of a distribution frame has terminal boards positioned horizontally. They are called horizontal terminal boards. On the terminal boards, there are insulated terminals to which two or more wires may be connected.

The terminals (called tie-points) are usually different lengths, with the longer ones positioned toward the rear to make wiring and soldering easier. Figure 2–27 is a side view of a horizontal terminal board and illustrates the length of each tie point. Notice that the notched terminals on this terminal board face toward the front. These flat metal strips are notched to hold the conductors in place and to permit a soldered connection. Figure 2–28 is a terminal board that uses a solderless connection known as a *wirewrap*. Notice that the terminals are angled away from the frame. This is very helpful in connecting the wires, because the terminals are pointing toward you. The importance of this will be readily apparent to you when we cover wire wrapping.

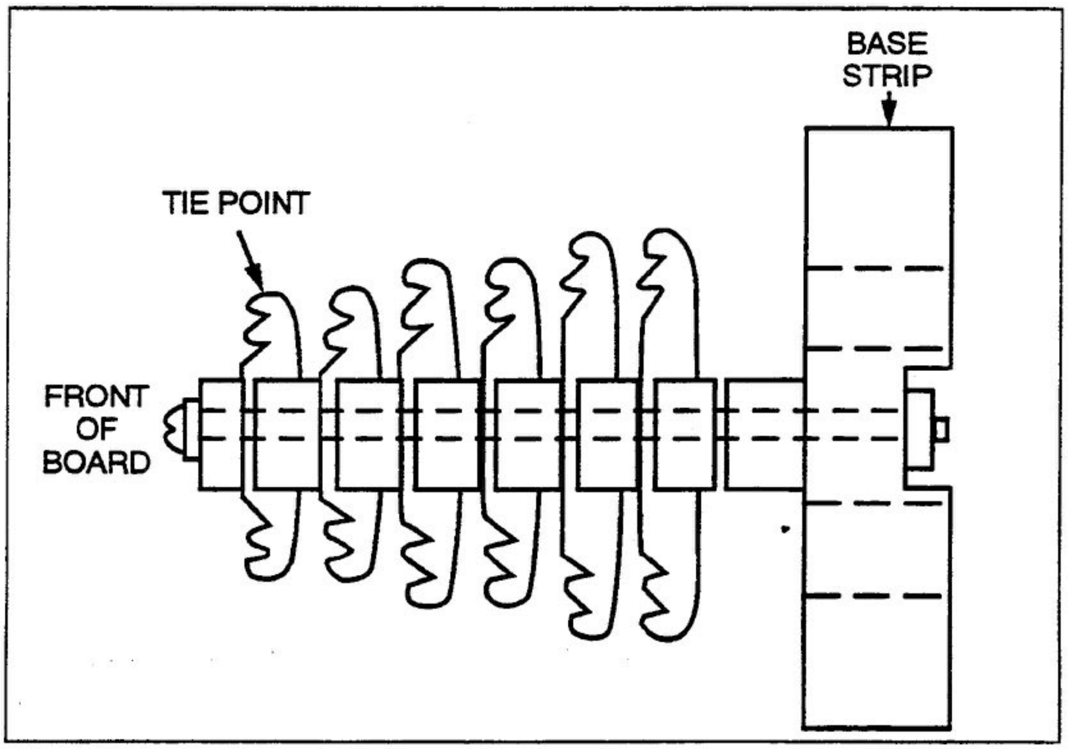


Figure 2–27. Notched terminal board (side view).

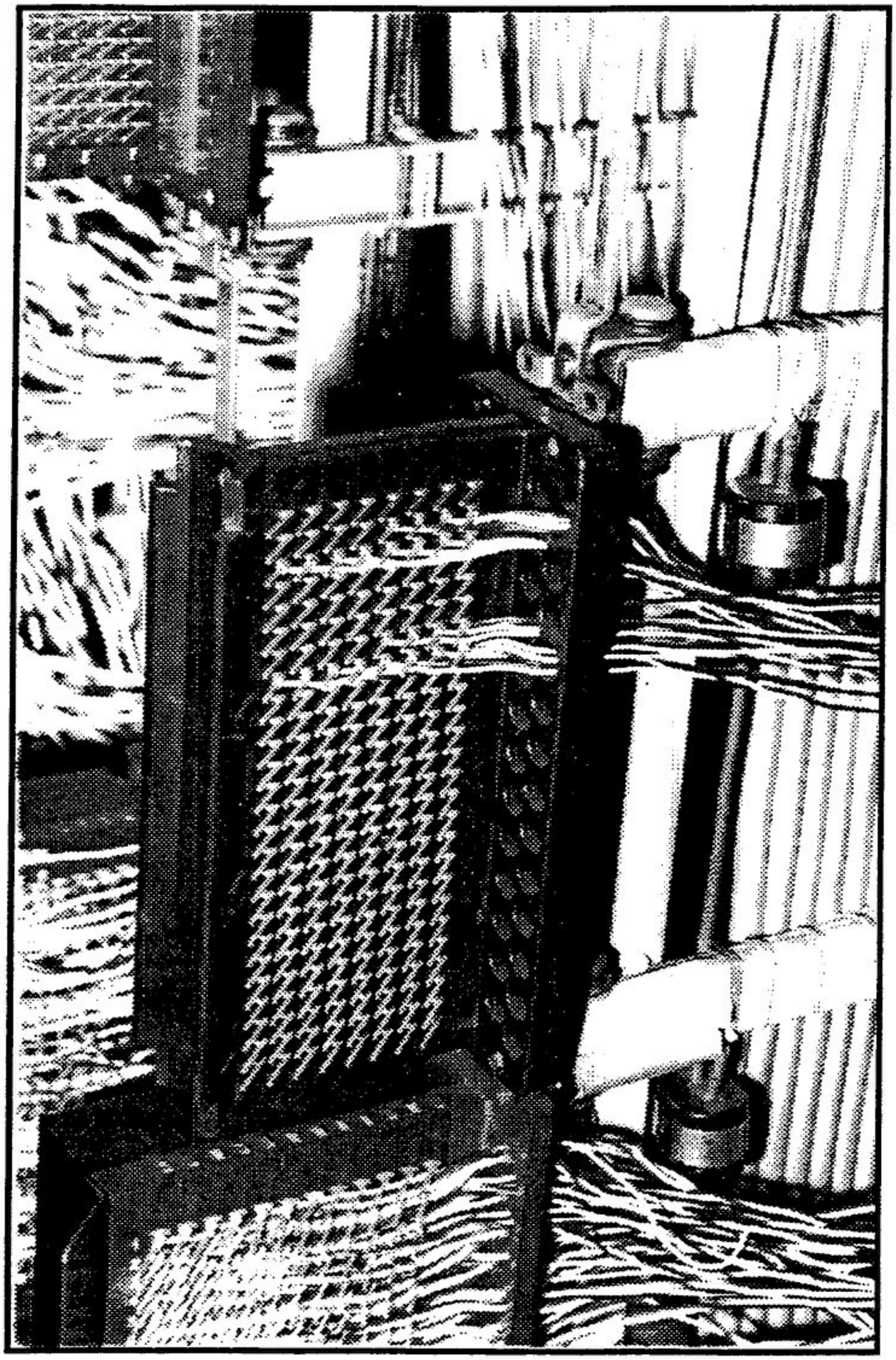


Figure 2–28. Wire-wrap terminal board.

Wire guides. The two types of wire guides are jumper rings and fanning strips. Their location is illustrated in figure 2–25. Jumper rings are heavy metal loops between the vertical and horizontal sides to guide cross-connecting wires. Fanning strips are wooden guides through which a number of small holes have been drilled. They are positioned close to the terminal boards or protectors to guide wires to these devices. Fanning strips associated with the cable protectors are usually one continuous guide reaching the entire height of the vertical side of the frame. The other fanning strips are the same length as the terminal board and are considered part of it.

Permanent wiring is on the left side of the vertical terminal boards and the bottom of the horizontal boards. As the name implies, permanent wiring is fixed permanently to the frame. This wiring connects outside cables, multiplexing equipment, teletype equipment, COMSEC equipment, battery taps, and patch panels to the frame. Patch panels, battery and ground taps, are wired to the bottom side of the horizontal boards. All other equipment is wired to the left side of the vertical boards. Heat coils serve as the vertical terminal boards for landline connections. They are protective devices that, when heated above a predetermined temperature, allow a mechanical device to move, opening the circuit. Figure 2–29 shows a simplified view of the permanent and temporary wiring configurations.

Temporary wiring. Cross connections (jumpers) are wired from the right side of the vertical boards to the top of the horizontal boards. These jumpers are loose connections (an individual wire or twisted pair) so they can easily be changed to suit the needs of the station. Jumpers make it possible to change the routing of a circuit without having to open a cable. The reperforator in figure 2–29 can be wired to appear at any patch panel location by changing the temporary wiring from one tie point to another.

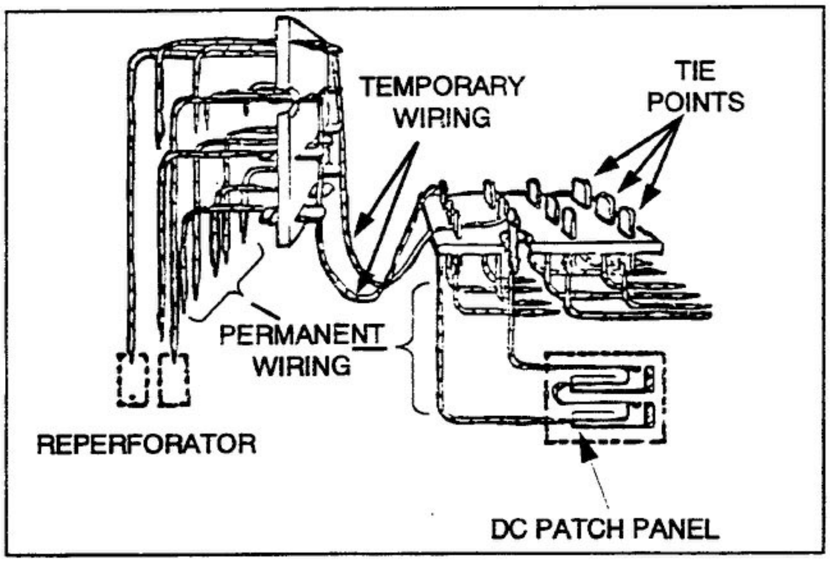


Figure 2–29. Permanent and temporary wiring configuration.

As was noted earlier, wires were soldered to distribution frame terminals in the past. Now most frames use solderless connectors. These connections provide reliable service to the user and have proven their value to the systems controller.

207. All about wire wrapping

A wire-wrapped termination is a closely wrapped wire, under tension around a specially designed terminal. This connection provides the basic requirements of a mechanical connection necessary for termination. And although wire wrapping is mechanical, it is soldered as conditions dictate. This type of connection is accomplished with the aid of a wire-wrapping tool.

Wire-wrapping tools. The three types of wire-wrapping tools are the electrically driven, mechanically operated, and hand wrapped (fig. 2–30). All are used in conjunction with a bit and sleeve to wrap a number of turns of wire around the terminal.

Figure 2–30. Wire-wrapping tools.

The wrapping tool bit is formed of metal containing an axial hole and a slot as shown in figure 2–31. The slot is on the outer surface of the bit and receives the stripped portion of the wire. The center hole (axial hole) accepts the terminals that the wire is to be terminated to. Refer again to figure 2–30.

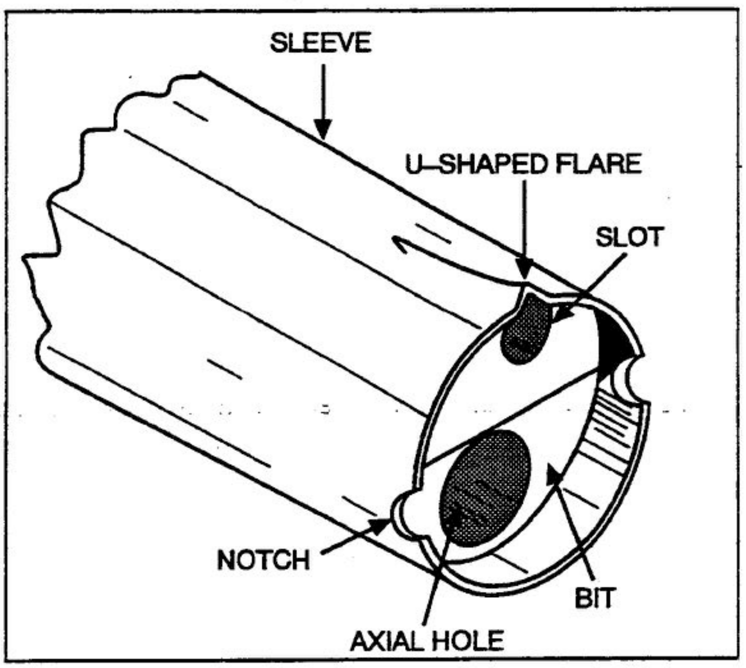


Figure 2–31. Wire-wrap tool bit.

The bit rotates during operation while the sleeve remains fixed. The two notches of the sleeve located on one end are for anchoring the insulated portion of the wire (fig. 2–31). This prevents the wire from slipping during operation. On the same end of the bit is a U-shaped flare. This flare guides the wire into the slot of the bit. The wrapping tool is operated by rotating the bit in the fixed sleeve.

The electric wire-wrapping tool (fig. 2–30,A) has a pistol grip and trigger. The trigger starts the electric motor that turns the wrapping bit causing it to rotate in the fixed sleeve, thus wrapping the wire. The tool is easy to use because the electric motor does most of the work. The tool looks and operates like an electric drill and can perform more wraps in a shorter period of time than other wire-wrapping tools.

The mechanical wire-wrapping tool (fig. 2–30,B) has a movable handle that drives the wrapping mechanism when squeezed. The bit rotates within the sleeve and wraps the wire. This tool has two advantages over the electrically driven tool. It's portable since it does not require a power source and is less expensive than the electric tool. However, it is harder to work with for long periods of time.

The hand-operated wire-wrapping tool (fig. 2–30,C) is a long metal rod with one end constructed like the bit and sleeve of the mechanical tool and has a grip for hand turning. The tool is used like a screwdriver and is a backup for the other tools.

The wire wrapping procedure is quick and easy but some guidelines must be observed for good results. We use the electric tool for our example, but the procedure remains basically the same using any type of tool. The process starts by putting the conductors through the fanning strips in the terminal board. Line up the tracer color code to the tip terminal and the basic color code to the ring terminal. Untwist the wires back to the fanning strip, and pull the wire through allowing 3 inches of slack for short runs and 4 inches for long runs. The slack is used in the future if the wire is transferred to another terminal and is helpful when tracing wires. Place it under the proper terminal and bend it slightly, being careful not to crush the synthetic insulation. Remove the insulation from the bend forward using wire strippers and cut the excess bare wire, leaving 1 1/4 inches to 1 1/2 inches.

Now the wire is prepared and in place to be wrapped. Bring the wire-wrapping tool up to the terminal and insert the shiner portion of the wire into the slot (fig. 2–32). Be sure the wire is fully inserted and not pulled away when the operation starts. Now bend the wire back through the notch of the sleeve. The insulation is seated in the notch of the sleeve (fig. 2–33). Place the tool over the terminal allowing space on the terminal for five wraps (fig. 2–34). Be careful not to force the terminal into the hole of the bit or you may bend the terminal.

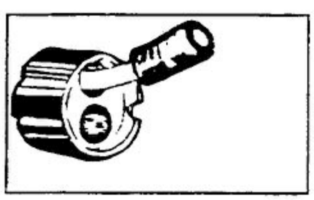


Figure 2–32. Inserting the wire.

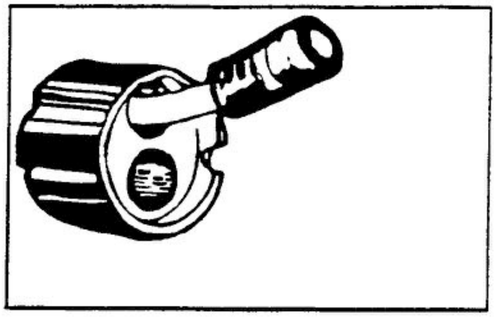


Figure 2–33. Anchoring the wire.

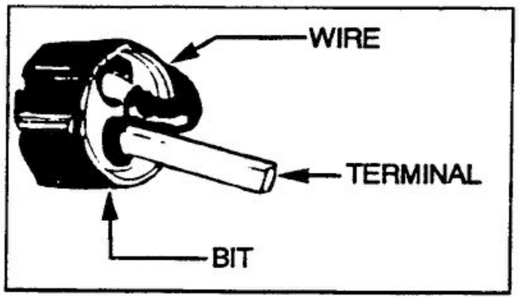


Figure 2–34. Tool and terminal positioning.

Ready, aim, *fire!* Holding the tool firmly while the bit turns, allow the tool to back off from the terminal by itself. It is important that you do NOT pull the tool off the terminal during the wrapping operation. Wait until the wrap has been completed (fig. 2–35). The mechanical tool is held even more firmly than the electric tool because it tends to pull away from the terminal quicker. This causes the wrap to be uneven or not have enough wraps around the terminal.

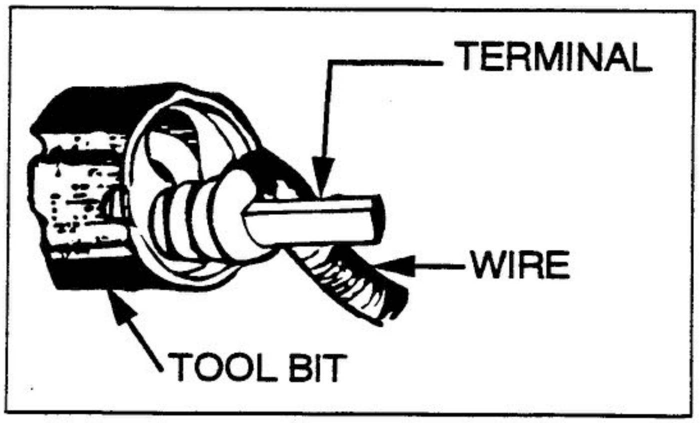


Figure 2–35. Wrapping cycle.

Remove the tool and inspect your work! Again, avoid bending the terminal by carefully removing the tool. The finished termination looks like the one in figure 2–36. Nothing to it, right? Figure 2–37 shows examples of acceptable and unacceptable work. Having done the first one okay, connect the remaining conductors using the same procedure. The entire process is illustrated again in figure 2–38.

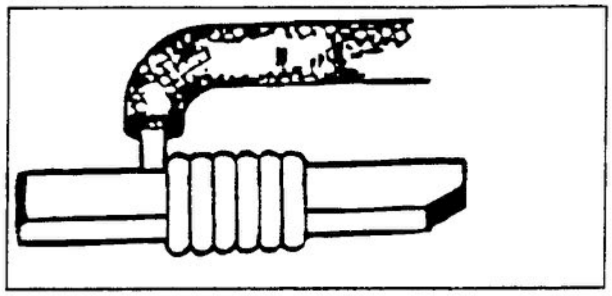


Figure 2–36. Completed wire-wrap connection.

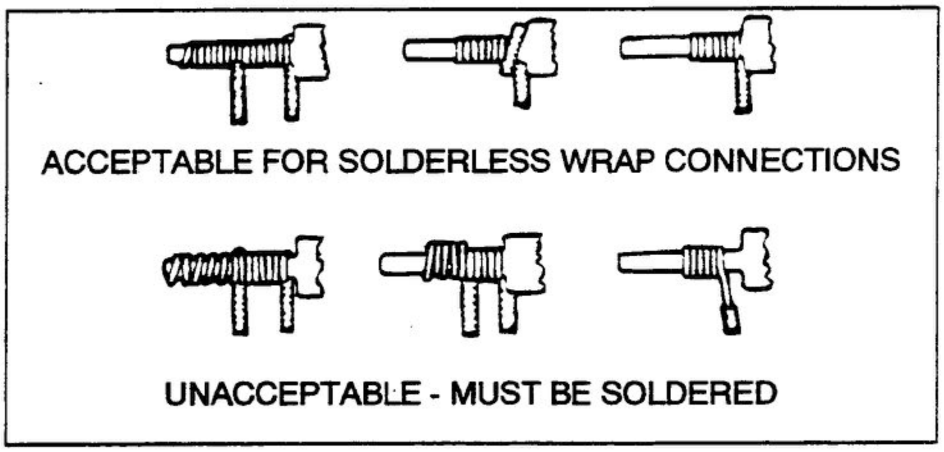


Figure 2–37. Wire-wrap connections—acceptable and unacceptable.

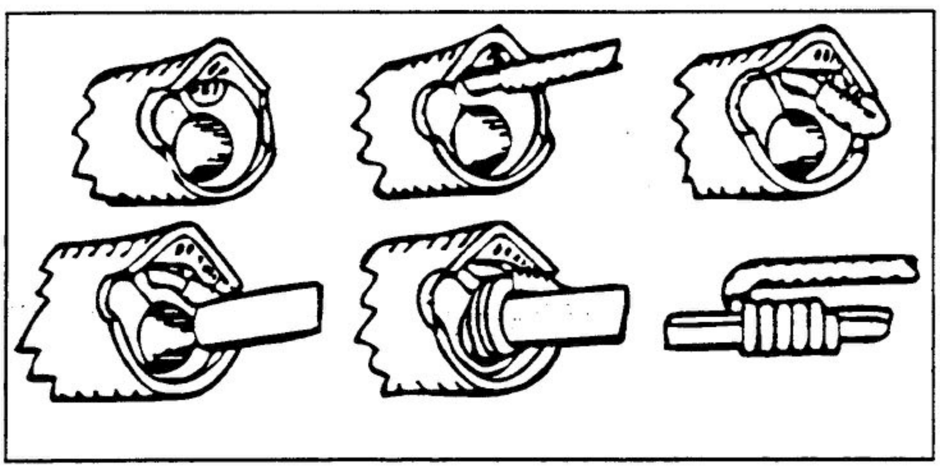


Figure 2–38. Wire-wrapping procedure.

For a termination to be considered a solderless connection, it requires a minimum of five complete wraps. Generally, a 1 1/4- to 1 1/2-inch shiner (bare wire) length is sufficient for a five-wrap termination. However, those wrapped connections that have been predetermined to be soldered require only 1 1/4 to 3 wraps which can be obtained by using a 3/4-inch shiner.

The removal of wire wraps is done with an unwrapping tool, longnose pliers or by hand. The unwrapping tool is like a drill bit. It is placed over the terminal, against the wire, and rotated while keeping a slight pressure against the wire. The wrapped wire will unravel. If using longnose pliers, grip the end of the wire and unwind the wrap. If there is sufficient slack, unwrap the wire by hand. Once the wire is removed, do not try to reuse it. Carefully cut off the used portion of the wire with wire cutters and strip a new portion of the wire. Remember, a used wire is slightly damaged from being pressed tightly against the terminal. Reusing damaged wire wastes time and you're asking for trouble. Take the time and do it right and prevent future problems.

208. Punch-on connections

Another solderless connector is known as *punch-on.* It has been used and tested in the commercial world for a number of years. Their success led to acceptance by the military. The military has found punch-on to be valuable in a number of situations.

Advantages. Punch-on terminals have a number of advantages over other types of connections. They take up little space since the connector blocks are mounted on a wall. This frees up space for other equipment. Take another look at figure 2–24. This is a distribution frame using punch-on connectors. As you see, a number of connector blocks can be mounted on the wall in a small space.

With budget reductions, we are consolidating in existing buildings as much as possible. These connector blocks open up floor space for new systems without constructing new buildings. This saves money for the military, so look for this terminal to be used more and more.

Another advantage is obvious. The connector blocks are facing you and are easy to reach. Examine the *type 66* connector block in figure 2–39. It is a typical punch-on connector block, but there are other types in use. This block has 50 connector pins arranged vertically and 4 horizontally. Permanent wiring is the two rows on the left and temporary wiring is the two on the right. Sound familiar? Yes, it's just like the vertical terminal boards discussed earlier. The other advantage of this connector is that the wires are easily terminated.

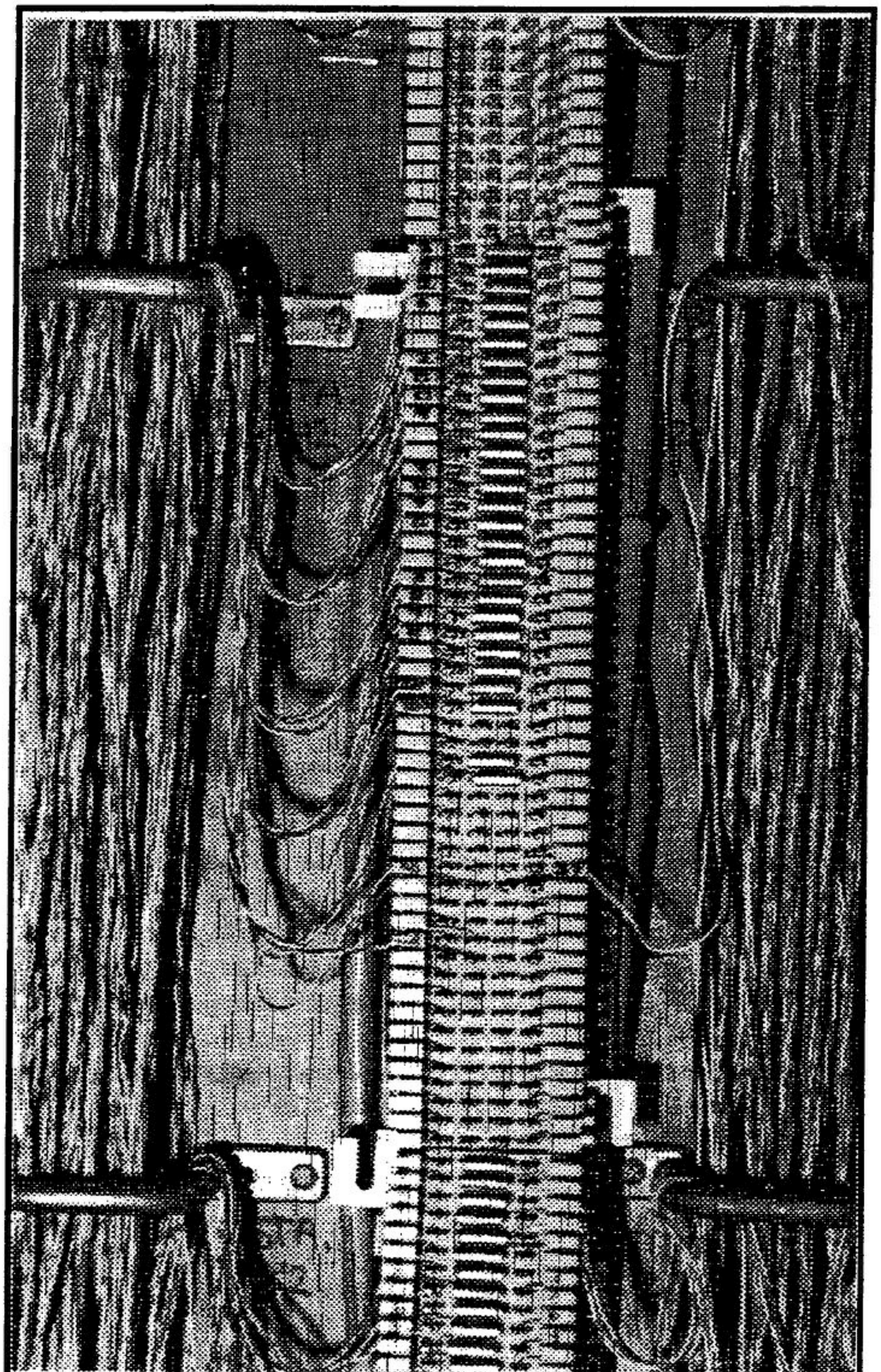


Figure 2–39. Punch-on connector block.

Terminations on the type 66 connector blocks are made with the 714B quick-connect tool (fig. 2–40). The tool has a plastic handle attached to a reversible steel blade. One end of the blade is used for conductor seating and the other end is for seating the conductor and cutting the wire. The tool is small enough to put in your pocket and is easy to use.

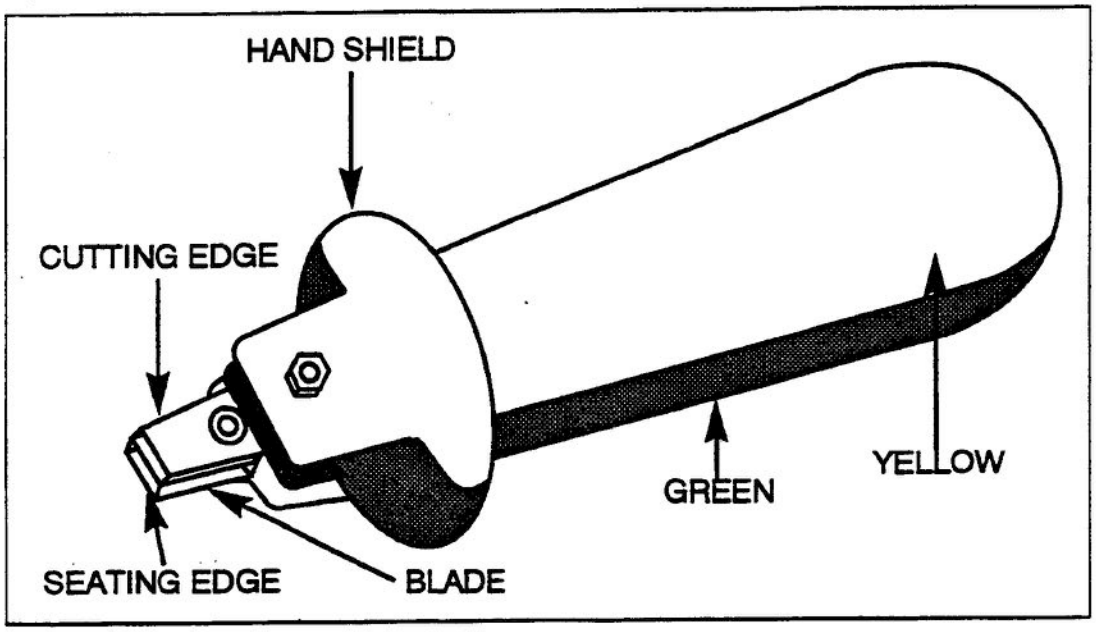


Figure 2–40. 714B quick-connect tool.

Looping termination. In some instances, you may not want to cut the wire when connecting it to the terminal. There are times when the wire needs to be looped through the terminal then routed somewhere else. To do this, place the conductor wire in the hook of the terminal and place the seating end of the 714B tool over the terminal (fig. 2–41). Press the tool toward the block until the wire is seated (fig. 2–42). The terminals are designed to separate just enough to cut through the wire insulation and allow the wire to sit between them. Now the wire is being pinched between the terminals but is not cut, allowing you to route it elsewhere.

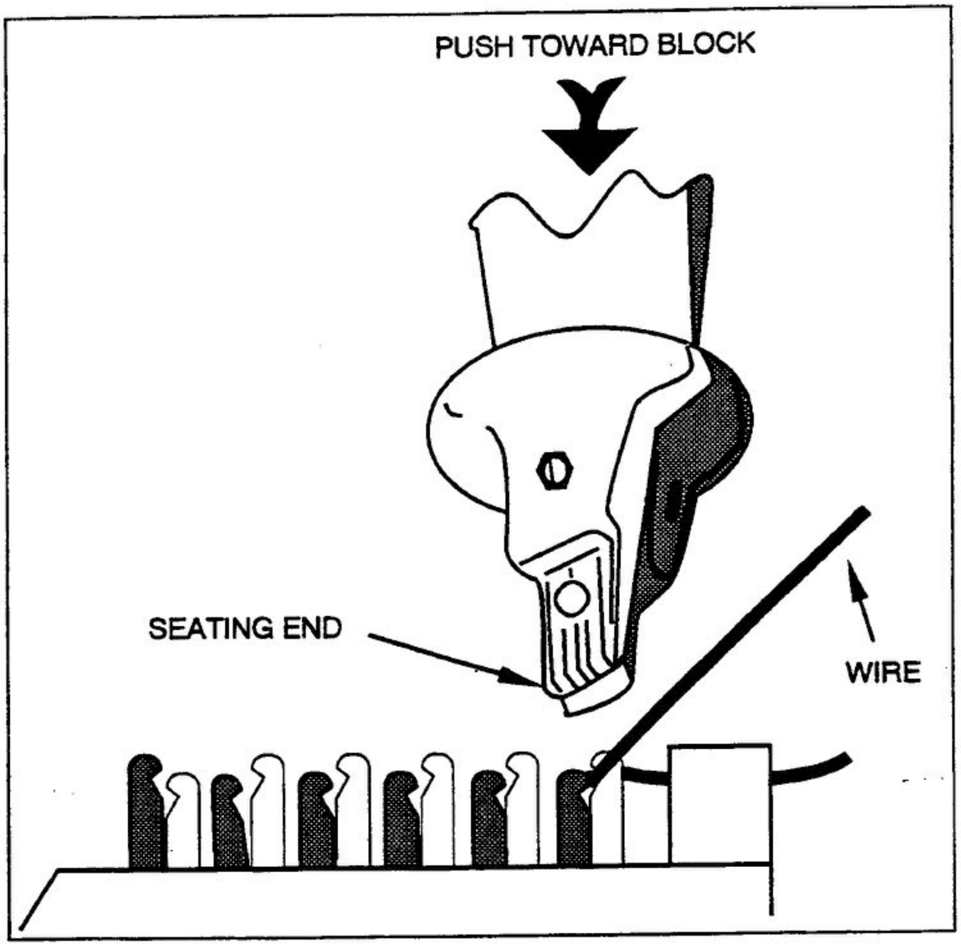


Figure 2–41. Preparing a looping termination.

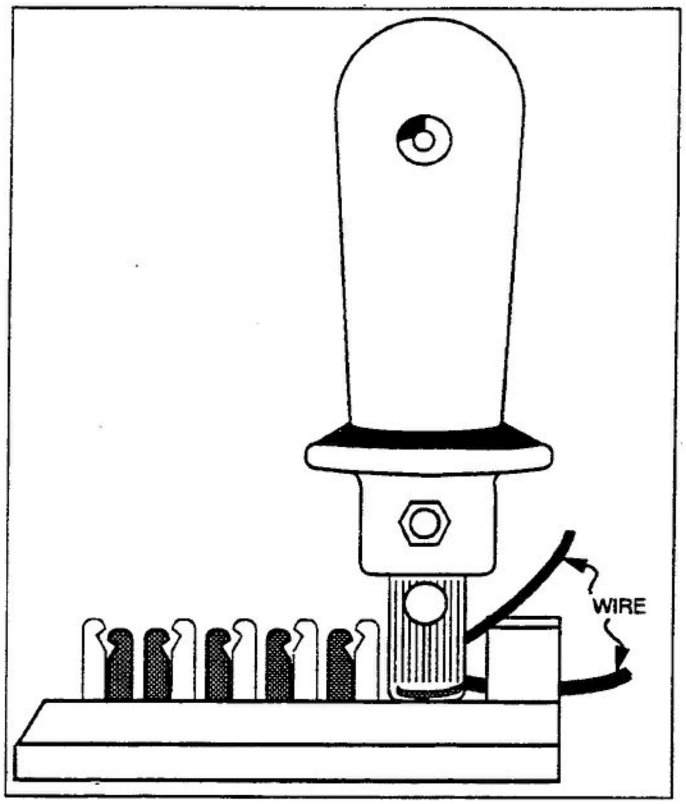


Figure 2–42. Looping termination completed.

Ending termination. If a wire needs to be connected to only one terminal, the cutting edge of the 714B tool is used. Remove the screw below the hand shield, reverse the tool edge, and reinsert the screw. Again, place the conductor wire in the terminal hook with about 3 inches of slack. Place the 714B tool over the terminal with the cutting edge positioned over the scrap end of the wire as shown in figure 2–43. If the tool is reversed, you'll have a piece of scrap wire connected to the terminal, which is probably not what you had in mind. Press the tool toward the block until the wire is cut against the face of the block (fig. 2–44). The seating part of the tool pushes the wire between the terminals while the cutting edge cuts the scrap end of the wire.

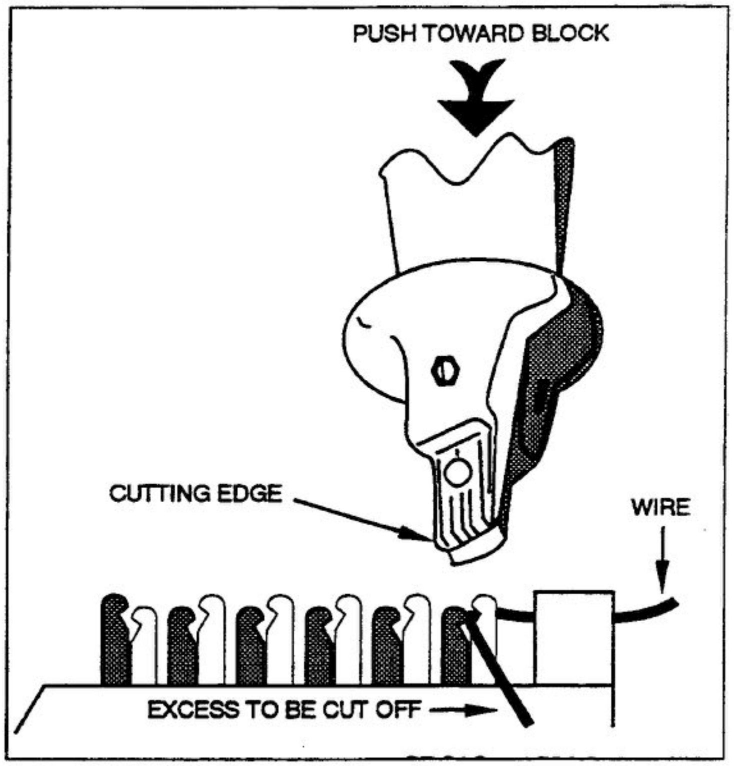


Figure 2–43. Preparing an ending termination.

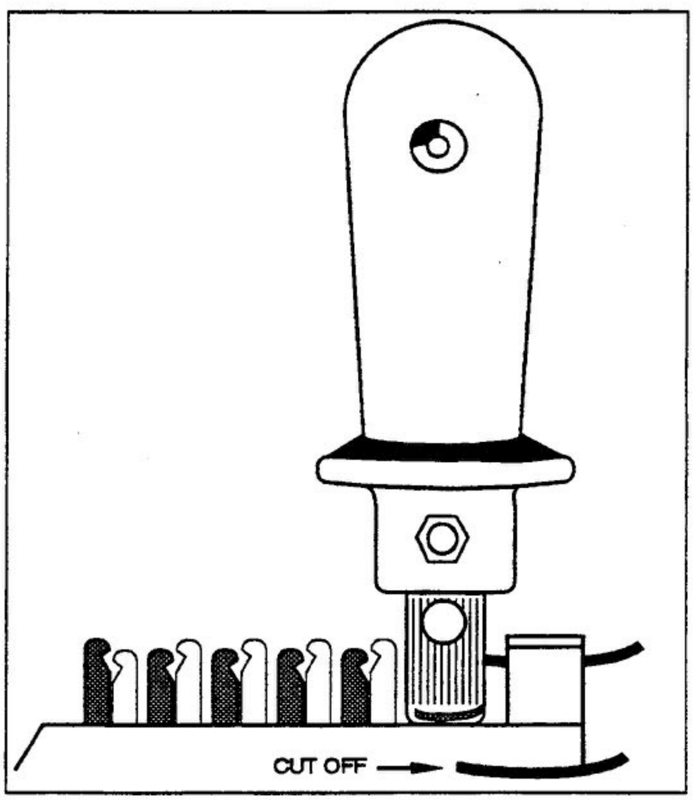


Figure 2–44. Ending termination completed.

As you can see, creating solderless connections on distribution frames is not difficult but like anything else, practice makes perfect. After some practice, you'll find the terminations are quick and easy. These connectors provide reliable service to you and your subscribers. And as you know, better service to the subscriber saves *you* work.

In Unit 2 we've discussed what needs to be done before the soldering process begins, the reasons for creating a solder connection, and some soldering techniques to use. We also discussed many of the types of connector terminals you'll use in making these solder connections. We then discussed how sometimes solderless connections may be appropriate to use instead, as in the case of distribution frames. The two types of methods for creating these connections were described as wire-wrapping and punch-on connections. Not all connections you'll be required to make will be on distribution frames or terminal boards. You may be called upon to exercise your talents for creating electrical equipment connectors. But that's ahead in Unit 3. For now, complete the following self-test questions and unit review exercises before moving on.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

206. Distribution frames

1. All communications entering, leaving, or passing through a DCS station are routed through what component?

2. Why is it important to keep accurate distribution frame circuit records?

3. What frame combines the functions of the main distribution frame and the intermediate distribution frame?

4. What distribution frame is used for clear text classified data?

5. What are two types of wire guides?

6. Where in a distribution frame would you find the permanent wiring for patch panels, battery, and ground taps?

207. All about wire wrapping

1. What is an axial hole?

2. What are the three wire-wrapping tools?

3. What is the result of pulling the tool back off the terminal during the wrapping operation?

4. How long is the shiner on a five-wrap termination?

5. How is a wire-wrapped connection removed from a terminal?

208. Punch-on connections

1. What led the military to accept the punch-on connector?

2. What are the advantages of the punch-on connector?

3. What tool is used for punch-on connectors?

4. What are the two terminations possible on the punch-on connector block?

5. How many terminals are on the type 66 connection block?

Answers to Self-Test Questions

203

1. Plated.
2. Unplated.
3. Plated.
4. Inverse—the larger the AWG, the smaller the wire.
5. Minimum is one-wire diameter and maximum is twice the minimum.
6. Rapid heat transfer during the soldering operation.
7. All the stranded wire coming in contact with the area to be soldered.
8. About 0.02 inch.

204

1. Wire contacts terminal, and contour of wire visible under a thin coat of solder.
2. Concave.
3. Prevents insulation damage and keeps heat away from thermally sensitive devices.
4. Fused in a smooth continuous blend.

205

1. Four.
2. Any number can be used if the last lead does not protrude above the forks.
3. Snugness of the fit of the lead between the forks.
4. Permits gases to escape.
5. Resistive soldering unit.
6. From the insulation termination to the cup entry point.

206

1. Distribution frame.
2. To accurately add, remove or fault isolate circuits.
3. Combined distribution frame.
4. Red distribution frame.
5. Jumper rings and fanning strips.
6. Bottom of the horizontal terminal board.

207

1. The hole in the end of the wire-wrapping tool bit that accepts the terminal to be wrapped.
2. Electrical, mechanical, and hand wrap.
3. It causes the wrap to be uneven and not have enough wraps around the terminal.
4. 1 1/4 to 1 1/2 inches.
5. With an unwrapping tool, longnose pliers, or by hand.

208

1. The success achieved by the commercial world.
2. a. They require less space; b. Easy access to connector blocks; c. The ease at which wires can be terminated.
3. 714B quick-connect tool.
4. Looping termination and ending termination.
5. 200 (50 *X* 4).

Do the Unit Review Exercises (URE) before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

14. (203) The correct procedures for cleaning a plated soldering tip are
    a. after cooling, file with a flat, fine, single-cut file.
    b. while hot, apply solder to the tip and wipe with a tissue.
    c. none. Plated tips cannot be cleaned and must be replaced.
    d. after cooling, submerge in solvent and scrub with a wire brush.

15. (203) The first step taken to redress an unplated soldering iron tip is to
    a. remove the tip from the soldering iron.
    b. file the tip to the required shape.
    c. clean the tip with a wire brush.
    d. clean the barrel.

16. (203) What wire lead *must* be rigidly secured between soldered connections?
    a. Stranded hookup wire longer than 1 inch.
    b. Solid hookup wire longer than 1 inch.
    c. Stranded hookup wire of any length.
    d. Solid hookup wire of any length.

17. (203) What type of wire is primarily used for circuit wiring within technical control facilities?
    a. Solid.
    b. Braided.
    c. Stranded.
    d. Rosin-core.

18. (203) To properly tin a wire lead end, solder *must* be applied
    a. to mate flush with the wire insulation.
    b. so it flows underneath the wire insulation.
    c. evenly all the way around the wire lead end.
    d. to cover only half the diameter of the wire lead end.

19. (204) A properly soldered connection will provide
    a. a light covering to allow the connection to breathe.
    b. an airtight covering to prevent corrosion.
    c. an increase in its electrical resistance.
    d. an increase in its mechanical stress.

20. (204) An important step in soldering a wire lead to a terminal is to make sure the solder
    a. does not cover the entire wire lead end.
    b. leaves the contour of the wire visible beneath it.
    c. forms a convex fillet on each side of the wire lead end.
    d. blends smoothly into the terminal's surface but does not create a feathered edge.

21. (204) At what point during the soldering process is a heat sink removed?
    a. Before the solder solidifies.
    b. After the solder joint has cooled.
    c. Before the solder joint has cooled.
    d. Immediately after flux has been applied.

22. (204) A correct step in making a solder connection is to
    a. apply the cold soldering iron tip to the connection and let it heat up.
    b. melt solder on the soldering iron tip and let the solder flow onto the connection.
    c. keep the soldering iron tip in contact with the connection until the solder leaves an even coating of flux residue on the connection.
    d. keep the soldering iron tip in contact with the connection until the solder has completely wetted with the wire and terminal surfaces.

23. (205) What locations on a turret terminal are used when connecting only two wire leads?
    a. The top of the bottom base and the top of the center base.
    b. The top of the bottom base and the bottom of the top base.
    c. The top of the center base and the bottom of the center base.
    d. The bottom of the top base and the bottom of the bottom base.

24. (205) How many wire leads can be soldered to a turret connector terminal?
   a. One.
   b. Two.
   c. Three.
   d. Four.

25. (205) Properly connected wire leads on a turret terminal have bends that are between
   a. 0° and 90°.
   b. 90° and 180°.
   c. 180° and 270°.
   d. 270° and 360°.

26. (205) Where on a hook terminal is a single-wire lead connected?
   a. The shank portion of the terminal.
   b. The end of the hook portion of the terminal.
   c. The exact center of the curved portion of the terminal.
   d. Anywhere above the insulated portion of the terminal.

27. (205) How many wire leads can be connected to a bifurcated connector terminal if the top-entry method is used?
   a. One.
   b. Two.
   c. Three.
   d. Unlimited, if leads are not shorted together.

28. (205) What type of electric connector terminal is used to create multiple-lead cables?
   a. Hook.
   b. Turret.
   c. Bifurcated.
   d. Connector pin.

29. (205) The purpose of the "weep hole" in some connector pin terminals is to
   a. allow excess solder to seep out.
   b. promote quick cooling of the solder.
   c. allow gases trapped under the solder to escape.
   d. allow visual inspection of the soldered connection.

30. (205) Acceptable solder connections have the appearance of
    a. no excess solder.
    b. a shiny look with no pits or holes.
    c. a good concave fillet between the wire and terminal.
    d. All of the above.

31. (205) A properly soldered hook or turret terminal is one in which the connection has
    a. very few pits or holes.
    b. a visible wire contour.
    c. a smooth, flat, and dull appearance.
    d. a good convex fillet between the wire and terminal.

32. (205) What is the final step in the soldering process?
    a. Inspecting.
    b. Adjusting.
    c. Soldering.
    d. Cleaning.

33. (206) Which type of distribution frame serves as the primary entrance/exit for communications lines entering and leaving a facility?
    a. Red.
    b. Main.
    c. Black.
    d. Intermediate.

34. (206) Combined distribution frames encompass the functions of a main distribution frame and
    a. an intermediate distribution frame.
    b. a black distribution frame.
    c. a red distribution frame.
    d. All the above.

35. (206) Patch panels containing clear text classified data circuits are connected with local equipment using
    a. an intermediate distribution frame.
    b. a combined distribution frame.
    c. a black distribution frame.
    d. a red distribution frame.

36. (206) Which type of distribution frame is used to connect unclassified data circuits and local equipment?
    a. Combined.
    b. Black.
    c. Main.
    d. Red.

37. (206) Distribution frame construction consists of a metal frame structure, terminal boards, and
    a. wire guides.
    b. alarm panels.
    c. patching matrices.
    d. circuit conditioning equipment.

38. (206) Within distribution frames, permanent wiring is connected to the
    a. right side of vertical terminal boards and the bottom of horizontal terminal boards.
    b. left side of vertical terminal boards and the bottom of horizontal terminal boards.
    c. right side of vertical terminal boards and the top of horizontal terminal boards.
    d. left side of vertical terminal boards and the top of horizontal terminal boards.

39. (206) Within distribution frames, temporary wiring is connected to the
    a. right side of vertical terminal boards and the bottom of horizontal terminal boards.
    b. left side of vertical terminal boards and the bottom of horizontal terminal boards.
    c. right side of vertical terminal boards and the top of horizontal terminal boards.
    d. left side of vertical terminal boards and the top of horizontal terminal boards.

40. (206) Which of the following are tied to the top of the horizontal blocks on a main distribution frame?
    a. Battery taps.
    b. Outside lines.
    c. Cross connections.
    d. In-station equipment.

41. (207) What length of shiner is required for a wire lead being prepared for a wirewrap terminal connection?
    a. 1 inch.
    b. 1 1/4 to 1 1/2 inch.
    c. 2 inches.
    d. 3 inches.

42. (207) When creating a wirewrapped terminal connection, what is done with the wire lead after it is stripped of insulation?
    a. It is tinned and inserted into the wirewrap bit.
    b. The shiner portion is inserted into the slot of the wirewrap bit.
    c. The shiner portion is inserted into the axial hole of the wirewrap bit.
    d. It is placed around the terminal end and wound with the wirewrap tool.

43. (207) For a wirewrapped termination to be considered an efficient solderless connection, you must wrap the wire lead at *least*
    a. once around the terminal connector.
    b. three times around the terminal connector.
    c. five times around the terminal connector.
    d. seven times around the terminal connector.

44. (208) Which of these is *not* an advantage of the punch-on terminal block?
    a. The termination process is easy.
    b. The connector blocks are easy to get to.
    c. They require less wiring than other types.
    d. The design allows for more equipment in a small area.

45. (208) What tool(s) are required to complete a punch-on terminal connection?
    a. 714B quick-connect tool only.
    b. Soldering iron and wire strippers.
    c. 714B quick-connect tool and wire strippers.
    d. 714B quick-connect tool and soldering iron.

46. (208) Which of the following is *not* a procedural step for creating a punch-on looping termination?
    a. Place the conductor wire in the hook of the connector block terminal.
    b. Place the seating end of the quick-connect tool over the terminal.
    c. Press the tool toward the connector block until the wire is seated.
    d. Remove the scrap end of the wire.

Please read the unit menu for Unit 3 and continue. →

Unit 3. Electrical Connectors

Page

ELECTRICAL connectors are often an overlooked component in electrical paths. This is a natural tendency since a properly operating connector is electrically "invisible." That is, it performs its task of completing a circuit without the circuit being aware of its presence.

The purpose of this unit is to give you a ready reference of basic information on the physical, electrical, and environmental requirements that are met by commercially available connectors. You'll recognize many of the electrical connectors listed from the coaxial, multiconductor, and ribbon cables you know about and have used. When you understand how they are designed and constructed, cable fabrication and repair is easy.

Preparation of this unit was aided through the cooperation and courtesy of Howard W. Sams and Company, publishers of the *Applications Handbook for Electrical Connectors* by John D. Lenk, ©1966. Permission to use textual information and illustrations from Howard W. Sams and Company is gratefully acknowledged.

3–1. Design Considerations and Connector Components

Many of the basic design considerations for electrical connectors are obvious. For example, if 100 interconnections are required, the connector has at least a total of 100 contacts. The contacts are spaced far enough apart to withstand the applied voltages. They are large enough to carry the required current load and rugged enough to maintain continuity after numerous pluggings and unpluggings. The connector insulators *remain* insulators despite exposure to heat, cold, vibration, and other environmental conditions. A coupling device holds the mated parts of the connector together under adverse conditions but in some requirements, it must be capable of instant disconnection.

The three considerations when selecting an electrical connector are electrical characteristics, mechanical characteristics, and environmental requirements. A fourth factor is cost; but if properly selected, the cost of an electrical connector depends on the other three factors.

The three basic considerations are discussed in detail in later sections. Before going into detail, let's discuss each of the considerations in general terms. Also, some general "rules of thumb" and tables used for the selection of connectors are provided. A careful study of these rules and tables shows about 90 percent of connector problems can be solved with existing connectors and these connectors are available from a number of manufacturers. The rules and tables also establish what can be considered a "special" or "problem" connector.

209. The considerations of connectors

The three considerations of connectors are electrical, mechanical, and environmental.

Electrical considerations. If the electrical requirements for a particular connector are within the limits specified in table 3–1, it is probably safe to use a connector having the necessary number of contacts and mechanical characteristics. This table lists the electrical characteristics common to most commercially available connectors. While it is true that many of them are built to exceed these values, the characteristics should be specified when ordering a connector.

Voltage Range	**10 to 300 volts**
Contact Current	**1 to 7.5 amperes**
Frequency	DC to 50kHz
Insulation Resistance	5000 megohms

Table 3–1. Electrical parameters (at sea level) common to connectors.
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The size of a connector depends on the number of contacts, the current per contact, and the voltage. As current requirements increase, you need to use larger contacts (contact size usually follows the size of the wires to be connected to the contact). As voltage increases, you need to allow additional spaces between contacts to prevent arcing. Additional spacing means that fewer contacts can occupy a given space.

Miniature connectors are available with up to approximately 55 contacts and subminiature connectors have up to 50 (5-ampere) contacts. These miniature and subminiature connectors are often built to withstand test voltages of 1,200 to 3,000 volts. Proportionally larger numbers of contacts, current ratings, and voltage ratings are available on standard size connectors.

The three electrical conditions calling for particular care in selecting an electrical connector are low-power signals, high-voltages, and high-power signals.

Low-power signals, in particular the combination of low voltage and low power, are the main cause of difficulty in maintaining good electrical continuity between contacts. Even non-oxide-forming, gold-finished contacts are susceptible to contamination. If the voltage or current is not sufficient to break down the contamination, electrical continuity is lost. The only way to get suitable mechanical contact is by a wiping action that occurs when the connector halves are mated. The contact problem is usually aggravated when voltages are below 0.1 volt.

High voltage. Any voltage above the minimum *flashover* voltage for dry air (about 300 volts) dictates that a sufficient air gap be furnished to sustain the voltage without breakdown. The exclusion of air as the dielectric (effected by sealing the connector to create a vacuum) permits closer spacing of contacts. This results in a smaller connector than otherwise would be possible and is particularly important in operation at high altitudes.

High-power signals call for connectors of appreciable size. The large size is necessary to handle the large contacts needed for high currents, plus the large air gaps needed for high voltages.

It is not normally the responsibility of the person selecting a connector to calculate the current, voltage, and power capabilities of that connector. This is the job of the connector manufacturer's design group and it has already been done. However, the person making the selection must check that the characteristics of the connector are equal to or exceed those of the required connector or specify the exact requirements when ordering a connector.

Mechanical considerations. Connectors can be grouped by shape, type, or function. The two basic shapes are circular and rectangular.

Circular connectors lend themselves to cord or cable applications. They offer a variety of coupling means including standard screw threads, acme screw threads, bayonetlock, and latchlock coupling. Circular connectors are generally easier to produce and therefore, less expensive than rectangular connectors with corresponding characteristics.

Rectangular connectors lend themselves to rack-panel applications where a number of removable panels of electronic equipment are mounted in a stationary rack. In this case, the connector need not have any coupling mechanism to hold the mating portions together. Half of the connector is mounted on the rack, the other half on the panel. The connector is automatically mated when the panel is slid into position. One of the major advantages of rectangular connectors is saving space. This is especially true when several connectors must be mounted close together.

Because of the wide variety of connectors available, it is not feasible to set up any rules of thumb regarding mechanical considerations. It must be pointed out that certain types of connectors, such as environmental resistant, rack panel, hermetically sealed, and RF coaxial, may overlap each other. Thus, it is possible to order an environmental resistant, rack panel connector with RF coaxial contacts.

The environmental considerations most likely to affect connector operation are temperature, altitude, moisture, and vibration. If the environmental requirements for a particular connector are within the limits specified in table 3–2, it is reasonably safe to use any connector having the necessary electrical and mechanical characteristics. The table sums up the value of some environmental conditions that are common to most commercially available connectors.

Temperature	-65F to +250F
Altitude	to 10,000 feet
Moisture	to 50% relative
Vibration	10 to 2000 cycles per second at 10g max

Table 3–2. Environmental parameters common to connectors.
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Temperature affects connectors in three ways. It deteriorates materials, the electrical resistance of conductors increases as temperature increases, and the electrical resistance of insulators (particularly air) decreases as temperature increases.

Altitude directly affects the insulating quality of air. As the altitude increases, air becomes a less efficient insulator. This condition begins to be significant above 10,000 feet and becomes critical above 35,000 feet. However, voltages below the minimum breakdown voltage for air are not significant at any altitude unless superimposed ionization (boiling-off of ions from the surface of contacts and insulators) is severe.

The adverse effects of altitude are avoided by excluding air as a dielectric or retaining sea level pressure around the contacts. This is accomplished by sealing both the rear and mating face of the connector with resilient (rubber-like) materials. When connectors are sealed in this manner, their size can be kept within reasonable limits while avoiding voltage breakdown at high altitudes.

Moisture is an enemy of connectors and should always be avoided or combated. Although leakage power dissipated through moisture quickly dries a connector, this effect should be avoided. Sealing mated connectors to keep moisture out is sometimes a mandatory feature. It nearly always involves resilient materials.

Vibration. Military specifications require that connectors to be used where vibration is severe have insulators of resilient material rather than of the hard plastic material used in standard (nonenvironmental) connectors. Resilient insulators of such materials as polychloroprene or silicone rubber can be selected for applications where severe vibration is expected.

210. Electrical connector insulating materials and shells

The three basic components in any connector are the insulator, shell, and contacts (fig. 3–1). Many types of insulators, shells, and contacts are used in today's equipment, but generally the three components are matched in a combination to do a specific job. In many cases it is possible to interchange one or more of the basic components to accommodate special needs. For example, more than one type of shell can be used with a given insulator contact configuration. Also, some insulators accept more than one type of contact. As opposed to understanding how the characteristics of components are combined, it is necessary for you to understand the characteristics of the individual components so you are able to make intelligent selections of connectors for a specific purpose. For example, the normal function of a shell is to house and protect the insulator and contacts. In special applications, a shell also acts in conjunction with the insulator as a moisture seal or serves to maintain pressurization of the major component where the connector is used.

For these reasons, we are going to discuss both insulators and shells with a description of the accessories available (most connector accessories are related directly to the shell). Because of the special nature of contacts, they are discussed in a separate lesson.

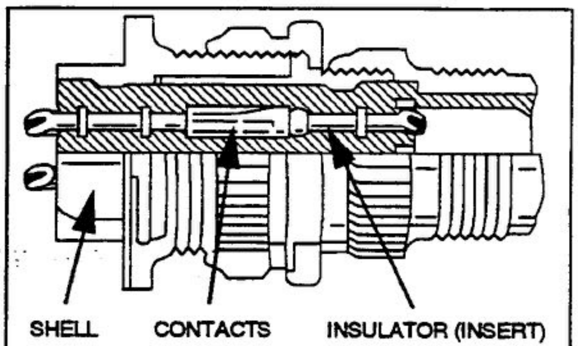

Figure 3–1. Basic connector components. (©1966, Reproduced with permission of Howard W. Sams & Co.)

Insulators. The basic function of an insulator (*insert*) is to hold the contacts and insulate them from each other. In certain applications such as connectors without shells and most microminiature connectors, the insulator also forms the body of the connector. One important factor to consider when selecting insulators is the type of material from which they are made.

Materials. Insulator materials are chosen primarily for their dielectric strength (insulating ability). The next important considerations are physical strength and weight. In special applications where the connector becomes part of a pressurization system or is designed for moisture resistance, insulator materials are chosen accordingly. The most common materials for connector insulators are phenolics (for fabricated insulators), melamine (for molded insulators), resilient silicone or polychloroprene (for moisture resistance), nylon (for high-voltage applications), and glass or asbestos filled diallylphthalate (for a single-piece insulator).

Insulation resistance and breakdown. Insulators are rated for their electrical resistance (at a given voltage) and/or their ability to withstand breakdown when specified voltages are applied. This resistance factor is usually expressed in megohms (millions of ohms) and indicates the amount of resistance offered to voltages on adjacent contacts or from the contacts to the shell. The breakdown factor is usually expressed as a maximum voltage figure. If this voltage is exceeded, the insulator material could break down permanently and provide a conducting path between contacts. This is not to be confused with "flashover voltage" which is determined primarily by the spacing between contacts.

Insulation temperature factor. Since insulators are not made of metal as are the contacts and shell, they cannot withstand the same temperature extremes. Consequently, the temperature range of an insulator determines the temperature range of the entire connector. High temperatures cause insulation material to break down faster.

Two-piece insulators. Some connectors have two-piece insulators (fig. 3–2). The insulator is split in two halves with the contacts held between the halves by means of a shoulder or ridge on the contact. The insulator halves are held together by the shell or in the case of connectors without shells, by screws and spacers. When assembled, the contacts are placed between the insulator halves, the halves are pressed together and secured in place with the shell or attaching hardware.

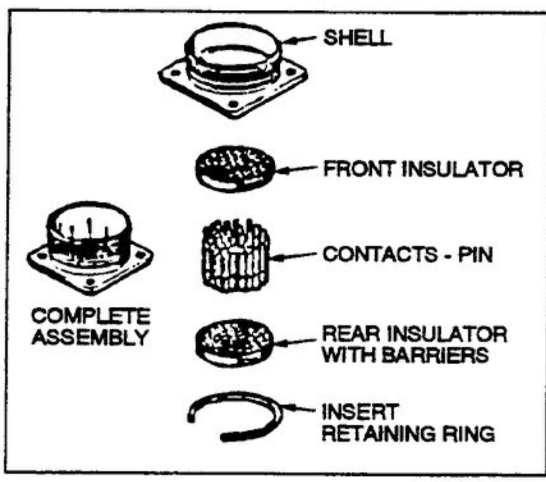

Figure 3–2. Connectors with two-piece insulators.
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One-piece insulators. Many connectors have insulators molded as one piece (fig. 3–3). These insulators are usually molded in block form instead of being fabricated in split or laminated form. However, there are one-piece insulators that can be used with removable contacts, including snap-in contacts. The one-piece insulators are held in the shell by retaining flanges or by attaching screws or a combination of both.

Hermetic seal insulators. For a true hermetic seal to accommodate extreme pressure or moistureproofing applications, the insulators must be of one-piece construction with the contacts permanently molded in place as shown in figure 3–4. Such insulators are usually made of special material such as compression glass. The insulators are also permanently molded and sealed to the shell.

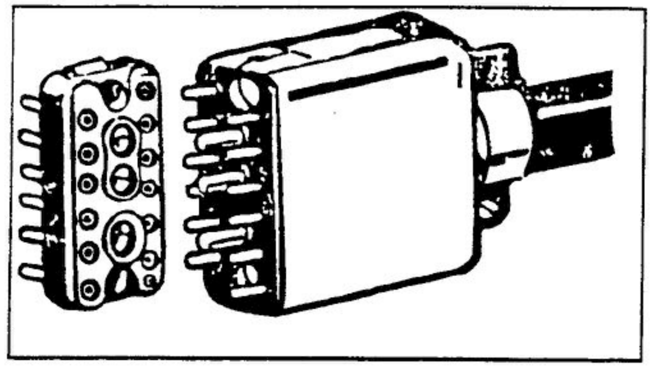

Figure 3–3. Connector with one-piece insulator. (©1966, Reproduced with permission of Howard W. Sams & Co.)

As you can see, a lot of thought is put into the designing of insulators to ensure they offer proper resistance and temperature sensitivity as well as those with special properties such as moistureproofing. Like insulators, connector shells also have a variety of designs and purposes.

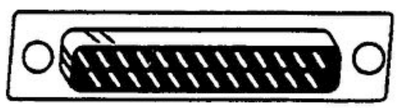

Figure 3–4. One-piece insulator with hermetically sealed contacts. (©1966, Reproduced with permission of Howard W. Sams & Co.)

Shells. The functions of a shell are to house and protect the insulator and contacts, provide mounting facilities for the connector, and in special cases, provide such features as quick-disconnect, pressurization, potting, moistureproofing, locking of the connectors, and engagement of the mating halves. In the case of circular connectors, shells must also provide a means for coupling for cable support (for the plug half) and for mounting the receptacle half. Most shells are also designed to provide electrical polarization.

Polarization is any means used to prevent mismatching or cross plugging should the connector halves be inverted before insertion. Shells or accessories associated with shells are often used for polarizing connectors. In older types of connectors, polarization was accomplished solely by arrangement of the contacts. Modern connectors have additional means for polarization. These vary with the type of connector or its shape.

With rectangular connectors, many shells are provided with (or have provisions for) polarizing pins or posts as shown in figure 3–5. These pins, mounted on half of the connector shell, mate with keyways on the opposite half. The pins and keys can be arranged in various combinations so only the proper mating halves engage before the contacts engage. This type of arrangement is of particular importance where polarization is a special problem. For example, assume the design calls for two or more subassemblies of identical outward appearance and similar electrical characteristics in the same major assembly or equipment. Unless polarizing pins are used, it would be necessary to have radically different contact arrangements to ensure that the subassemblies are not accidentally interchanged. Even with different contact arrangements, the contacts would be subject to possible damage by an accidental interchange of the subassemblies. Polarizing pins prevent both of these conditions. They also serve as guide pins.

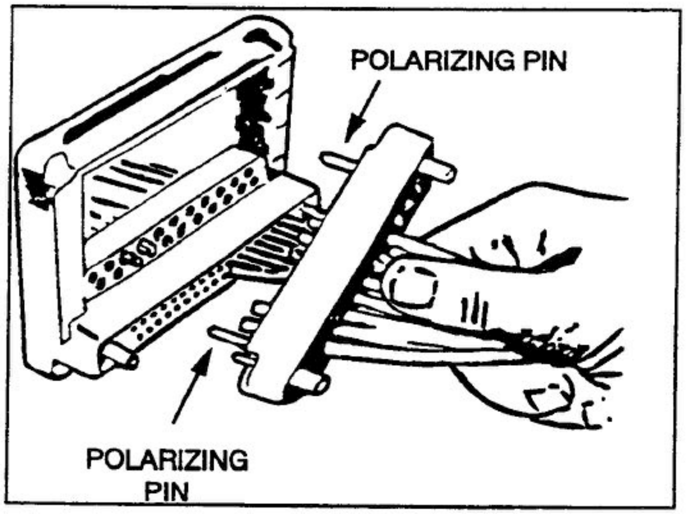

Figure 3–5. Polarization pins ensure proper mating of connector halves. (©1966, Reproduced with permission of Howard W. Sams & Co.)

Some rectangular connectors that are not provided with polarizing pins can be polarized by means of guide pin plates. These plates—male and female halves—are available as accessories for standard shell connectors. Normally, the male plates are provided with float-mounted guide pins while female plates have mating holes for the pins and non-float mounting holes. The standard connector halves are mounted directly onto the corresponding plates that are attached to the equipment mounting surfaces. The use of guide plates provides both polarizing and the float-mount action necessary for satisfactory rack-and-panel operation (rectangular connectors are often used here).

Polarization of circular connectors is accomplished using polarizing keys or bosses that mate with grooves on corresponding halves of the connector as shown in figure 3–6. These are usually located on the barrel portion of the connector shell. Only one groove is normally needed. Contact arrangement is also used for polarization as is positioning of the insert within the shell. Besides polarization, certain types of connector shells also offer the advantage of protection against moisture seepage.

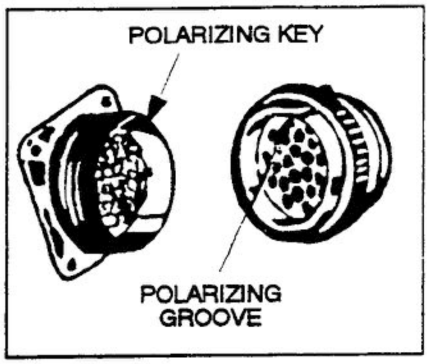

Figure 3–6. Circular connector polarized with key and groove.
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Moistureproofing in many connectors serves two separate purposes. It provides a moisture seal between the connector and the equipment. This is usually accomplished with a gasket or grommet between the shell and mating surface. Also, it provides a moisture seal between the insulator and shell as well as around the wires entering the insulator (fig. 3–7). A separate tooled grommet that mates against the insulator and a grommet retainer that fits over the grommet, is tightened onto the shell with locking screws. When the screws are tightened, the grommet retainer presses on the resilient grommet sealing the wires and shell against moisture.

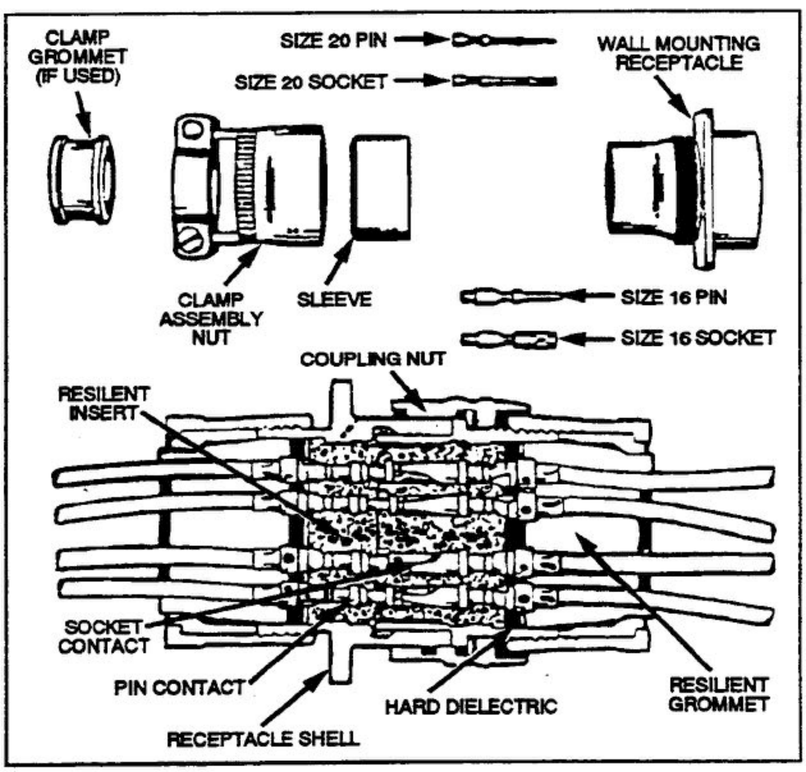

Figure 3–7. Methods of moistureproofing.
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Pressurization. Special connectors are available that provide pressurization of the major component and prevent leakage past the connector as well as to withstand pressure differentials inside and outside the component. This is accomplished using the sealing methods previously described or by using hermetic seal insulators and shells with large mounting flanges welded to the mounting surface.

Shell shape and construction. Most noncircular connector shells are rectangular in shape with chamfered mating edges to ensure easy alignment. Some shells have a keystone shape or a slanting corner for polarization as shown in figure 3–8.

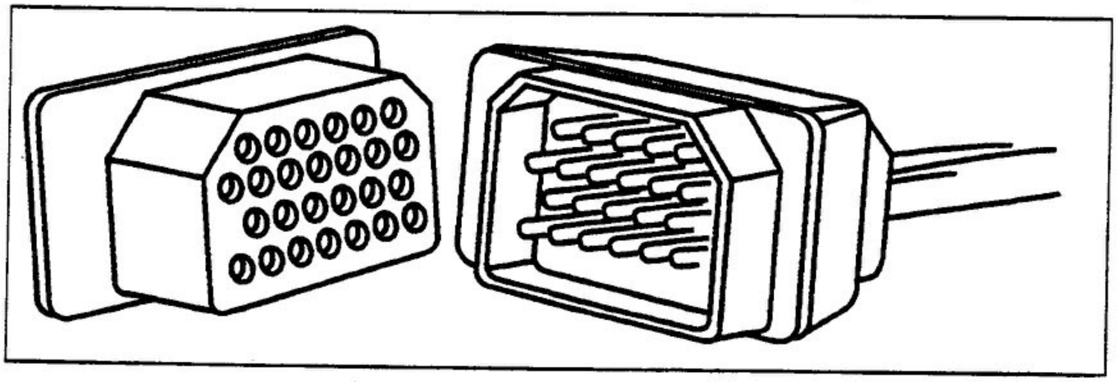

Figure 3–8. Polarization by means of special-shaped shells.
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Although not all circular connectors are identical in construction, most have certain parts in common (fig. 3–9). One-half of a typical circular connector shell consists of a barrel (holding the insulator or insert), a coupling nut (knurled on the outside for easy turning and threaded on the inside to mate with the threads on the opposite half), an endbell, and possibly a grommet, ferrule, and sealing washers or O-rings. The opposite half of a typical circular connector shell has a mounting flange but does not have the endbell, grommet, and ferrule. The assembly of the shell, including assembly of the insulator and contacts within the shell is described in the last section of this unit. Both rectangular and circular connectors can be adapted for special purposes by adding certain accessories during their construction.

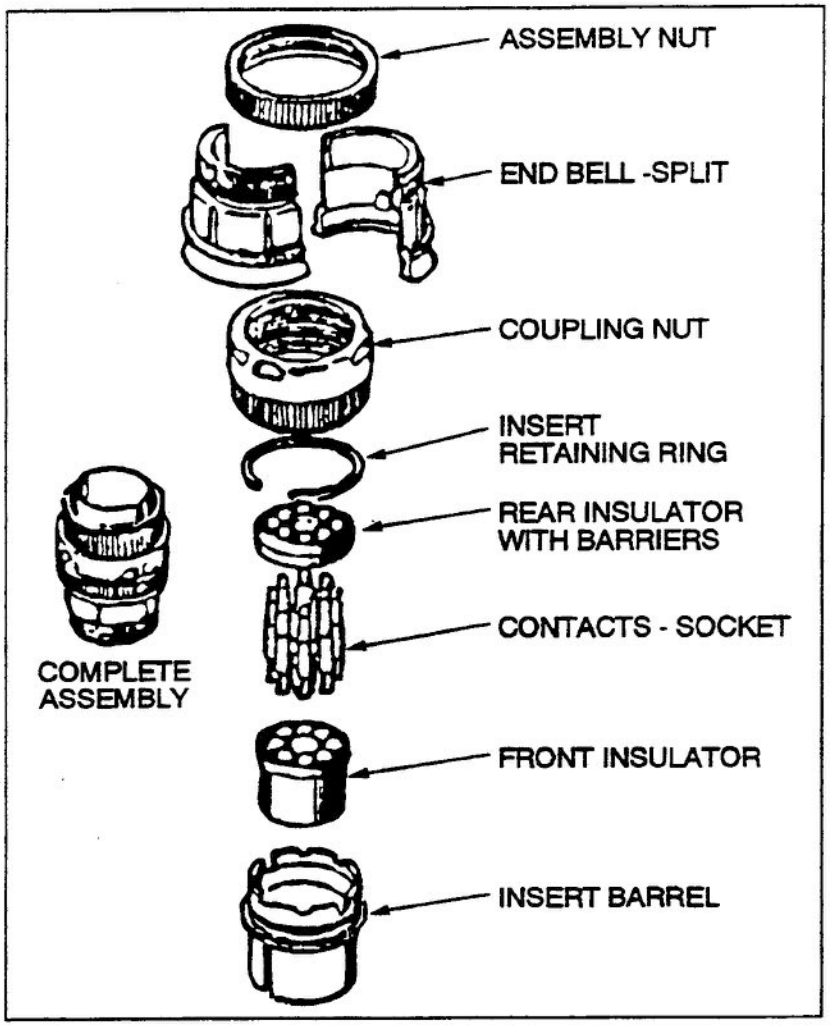

Figure 3–9. Typical circular connector.
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Connector accessories. There are a number of accessories available for use with both rectangular and circular connectors. Most of these accessories are used to adapt connectors to some specific purpose or to protect the connector from external conditions. Such accessories include locking screws and engaging devices for rectangular connectors, cable clamps, junction shells, dummy receptacles, bonding rings, telescoping bushings, and dust caps. It is impractical to describe every accessory available for every type of connector. However, we'll cover locking screws and engaging devices.

Locking screws. When rectangular connectors are used in rack-and-panel applications, the mating halves are usually held together by friction alone. However in applications such as cable-to-cable, it may be necessary to lock the two halves together by external means. Shells with locking screws are provided for this purpose. These screws are attached to half of the shell and they mate with corresponding nuts on the opposite half (fig. 3–10). The contacts are usually engaged part way by insertion in the normal manner, then the locking screws are tightened.

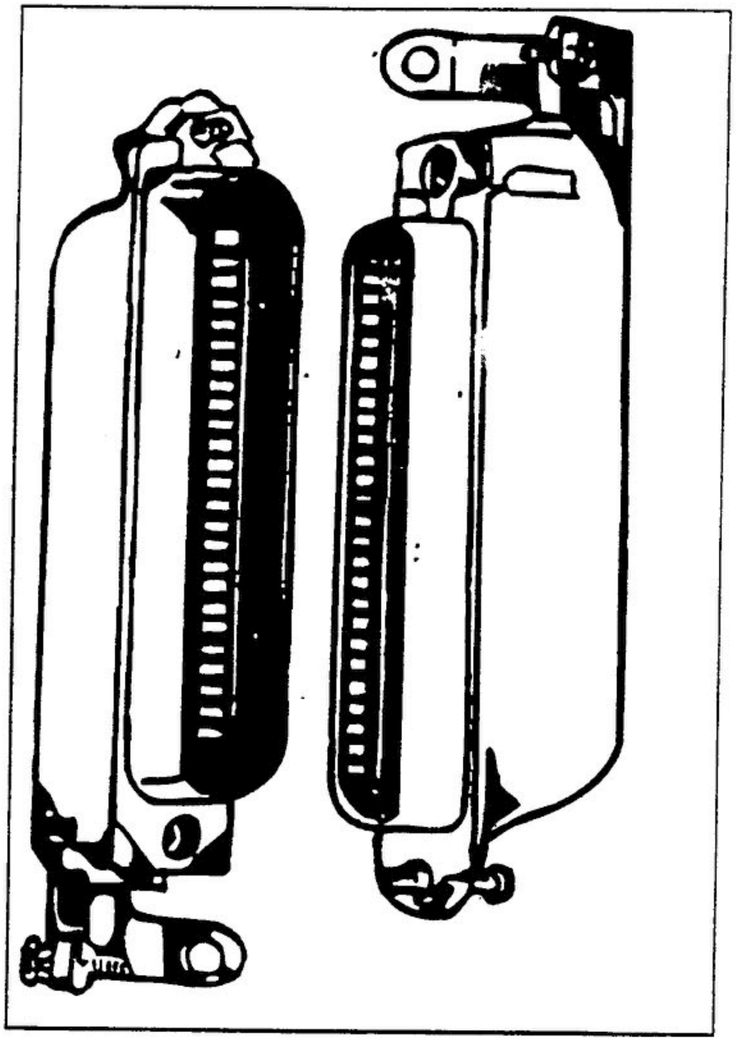

Figure 3–10. Connector shells with locking screws.
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Engaging devices. Instead of locking screws, shells may have engaging screws or engaging drive mechanisms serving the dual purposes of engaging and locking the mating halves in place. These are well suited for instrument panel application. Such engaging devices come in a variety of configurations: straight screws with large wingnuts or knurled knobs for easy turning; right angle gear drives for applications where a straight drive would not be convenient; and latch mechanisms using a leverage action for quick engagement and disengagement as shown in figure 3–11.

We learned in this lesson that electrical connectors consist of three basic components. We've covered the first two—insulators and shells; now let's take a look at the last—*contacts*.

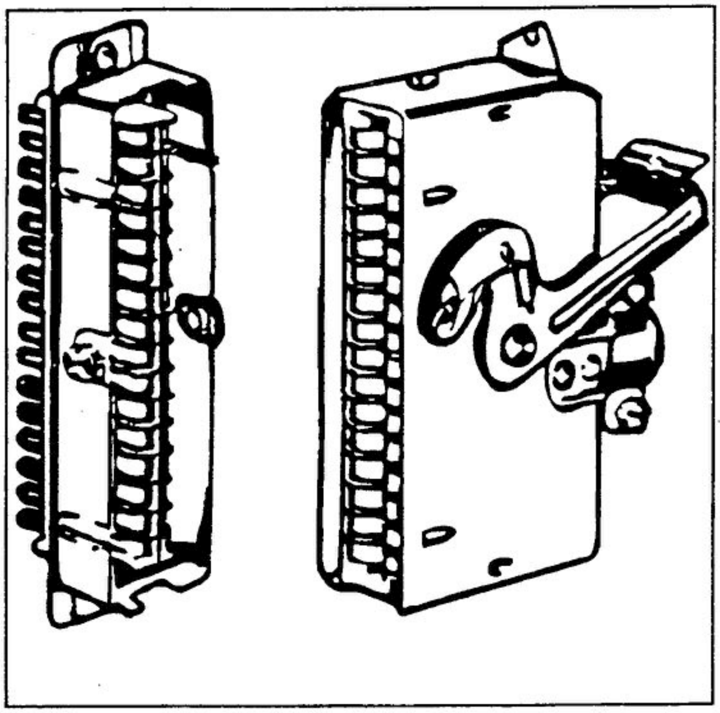

Figure 3–11. Connector shells with latch-type engaging mechanism.
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211. The characteristics of electrical connector contacts

At the heart of any connector are contacts. The contacts *are* the connector. All other elements such as insulators, sealing devices, shell, and coupling devices are supports placed around the contacts to protect them and see they function properly.

The two properties especially desired in contacts for electrical connectors are a maximum of conductivity between the pin and socket and a minimum of force required for engagement and disengagement. High conductivity is achieved by plating the pins and sockets with conductive, corrosion-resistant materials such as silver or gold and by providing a maximum area of contact between the pin and socket. Careful socket design and good alignment of pins and sockets keep engagement force to a minimum.

The characteristics of contacts are retention (how they are held in the insulator), engagement (the method of engaging the pin and socket surfaces together to provide maximum conductivity), and termination (how they are attached to the corresponding wires).

Contact retention. Let's look at some of the more commonly used methods of contact retention in an insulator.

Two-piece insulator. A simple method of retaining contacts is by means of a two-piece insulator (fig. 3–12). The shoulder of the contact fits into a recess in the rear insulator. This arrangement was used in early connectors and is still used in some connectors today.

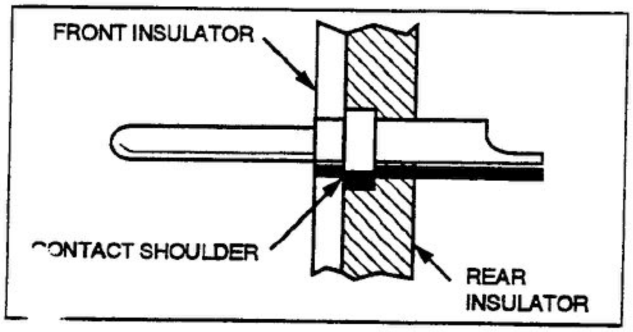

Figure 3–12. Contact retention by means of a two-piece insulator.
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One-piece resilient insulator. This method (fig. 3–13) is used where some measure of moisture protection is desired. Even if the moisture seal is effective, the contacts are not as rigid as with a hard insulator. This condition is overcome by special design of the insulator.

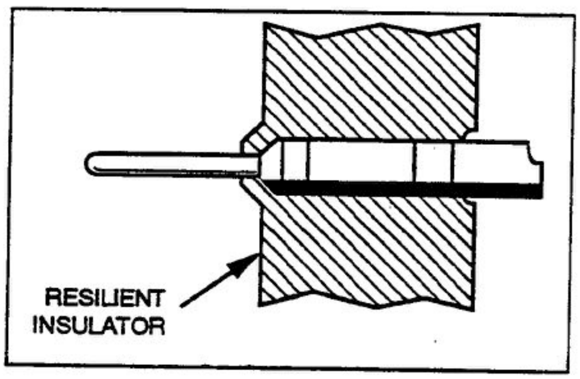

Figure 3–13. Contact retention by means of a one-piece resilient insulator.
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One-piece resilient insulator with 2° of hardness. Where the contacts must be held firm but a resilient insulator is desired to effect a moisture seal, it is possible to use an insulator that has varying degrees of hardness in front and back (fig. 3–14).

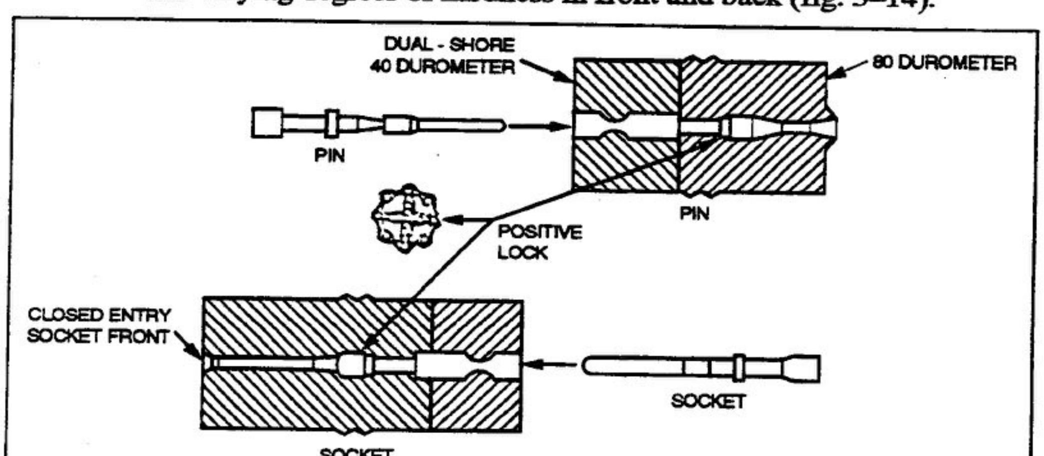

Figure 3–14. Contact retention by means of a one-piece resilient insulator with 2° of hardness.
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Two sections of the insulator can be molded together to form one continuous piece. This allows the rear of the insulator (sealing end) to be compressed by the endbell into a solid sealing mass around the conductors. However, the front (mating end) retains its hardness which is sufficient to hold the contacts firmly in place, but is resilient enough to allow them to be removed repeatedly. Thus, the contacts can be held in positive alignment and a continuous seal is maintained from front to back.

As shown in figure 3–14, each insulator includes a tough thermoplastic web consisting of ringlets molded in the same pattern as the contact layout. The web pattern is positioned and molded in place at the same time the two insulator halves are molded. When the contacts are inserted, the web pattern stops them at the proper preset depth and prevents the contacts from pushing all the way through the insulator.

The contact cavities in an insulator are molded with a close tolerance to get end-to-end sealing. When a contact is inserted from the back and snaps into place against the positive stop, the connector is both moisture resistant and pressurized. On the mating face of the pin insulator, the contact cavities have protruding rings around them and on the mating face of the socket insulator, molded recesses surround the cavities and complement the protruding rings of the pin insulator. These faces provide an extremely tight seal when held together with the coupling device on the connector. The recesses around the socket cavities also assist in guiding the pin contacts into the probeproof closed entry sockets.

Removable C-ring. This method of contact retention is similar to that of two piece insulators except that a removable C-ring or washer is used instead of a permanent contact shoulder (fig. 3–15). This allows the contact and wire to be pulled through the rear insulator for maintenance. To free the contact, the front and rear insulators must be separated slightly so the C-ring can be removed from the contact.

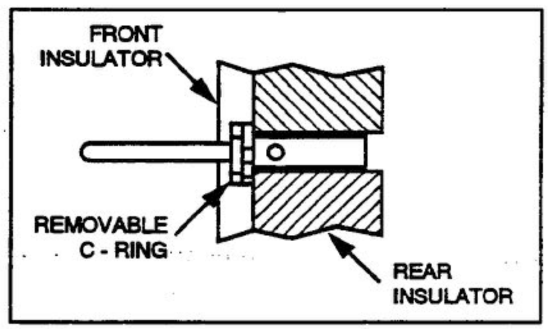

Figure 3–15. Contact retention by means of a removable C-ring.
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C-ring retention with one-piece insulator. Another method of contact retention consists of a stainless steel C-ring that is placed around the contact and expands against a shoulder in the insulator after insertion. This is the simplest of contact retention devices. When it is necessary to remove the contact, it is done with an impact tool. These tools fit around the front of the contact to force the contact out the back of the insulator. Such tools usually include a plunger used to strike the contact sharply once it is in place.

There are several advantages to this contact retention system. Since contact alignment is important in maintaining reliable mating characteristics, the C-ring system does not require a large space between the contact and the insulator. In systems where the contact release tool must slide between the contact and the insulator, there is a loss in alignment reliability because the contacts are not properly supported by the insulator at the engaging end. It is true that resilient insulators can be provided in the tool release system and such insulators are snug around the front of the contact. However, a resilient insulator lends little support to contact location or stability since it must be soft enough to allow the release tool to enter. A C-ring system ensures contact alignment for mating in hard, one-piece insulator construction.

Nonremovable contacts. When the electrical connector must provide a full hermetic seal or must withstand large pressure differentials, nonremovable contacts are used to prevent leakage.

In pressurized applications, the insulator is made of a hard and usually thick material (fig. 3–16). The contacts are molded into the insulator at initial fabrication and are never replaced. If one or more contacts are broken or seriously bent, the entire insulator must be replaced as a unit.

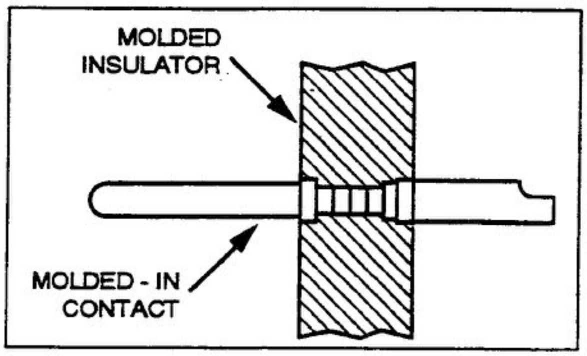

Figure 3–16. A nonremovable contact molded into the insulator.
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In full hermetic seal applications, the contacts are fused within a glass bead that is fused to the shell as shown in figure 3–17. The glass bead provides insulation for the contact. In the event of contact damage, the entire connector must be replaced. The materials of the contact, glass bead, and shell are selected to have approximately the same temperature coefficient of expansion so that all three materials will expand and contract at approximately the same rate. This prevents one material from expanding (or contracting) faster than the other materials, resulting in leakage between the contact and glass bead or between the bead and shell.

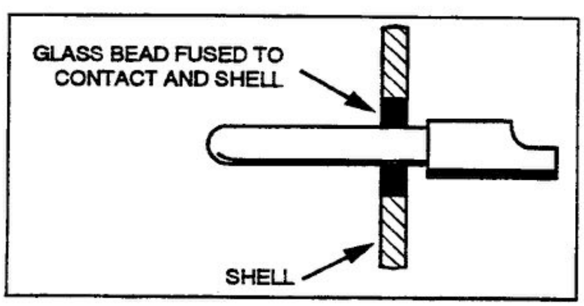

Figure 3–17. A contact fused within a glass bead for hermetic seal applications.
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Printed circuit board (PCB) contacts. Several types of contacts and contact retention systems have been developed for use with printed circuit boards (fig. 3–18). This contact, made of a flat material, is pushed through a slot in the insulator. The rear portion of the contact is then given a quarter twist to retain the contact. Recent developments in microminiature connectors have made them suitable for use with printed circuit boards. Secure contacts are a must for proper pin and socket alignment.

You may encounter many methods for contact retention, but all are designed to provide maximum conductivity. Another consideration for electrical contacts is their ability to maintain high reliability after numerous disconnections and reconnections.

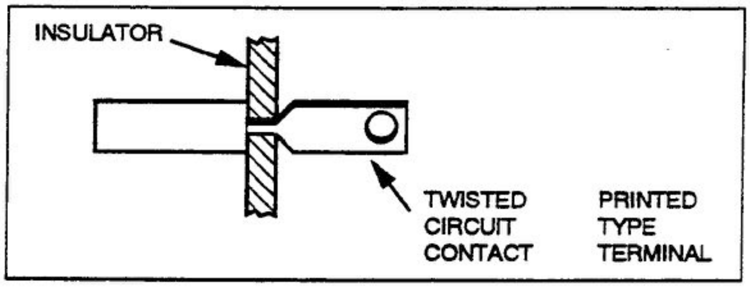

Figure 3–18. PCB contact retained by twisting the rear part of the contact.
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Contact engagement is determined primarily by the shape of the contact pins and sockets. These are typical contact shapes for both pins and sockets.

Contact pins. Figure 3–19 shows three types of pin contacts commonly in use. These contacts are identified by the shape of the end of the contact. The spherical type (A) is the most common, being used in most standard-sized connectors. The conical pin (B) is used primarily in miniature connectors. The flat pin (C) is used where the contact must carry very large currents.

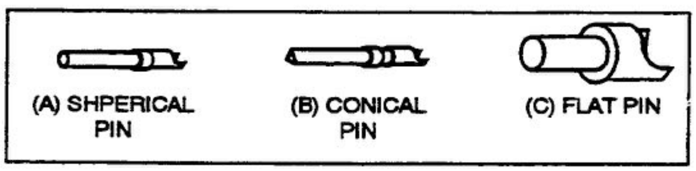

Figure 3–19. Three common types of pin contacts.
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Contact sockets. Figure 3–20 shows a "napkin ring" socket. This highly efficient design uses a beryllium copper spring formed around the contact for positive retention of the pin. As you see in the cross section, the spring pressing against two sides of the pin contact forces the pin against the opposite radius of the socket. This type of wraparound spring is used in many standard connector lines. A variation of the napkin ring spring for use with miniature contacts is shown in figure 3–21.

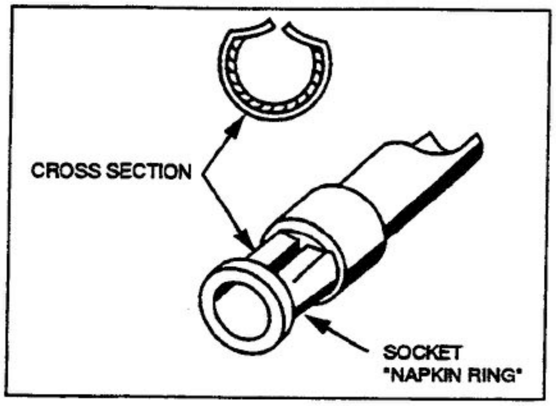

Figure 3–20. A "napkin ring" socket contact.
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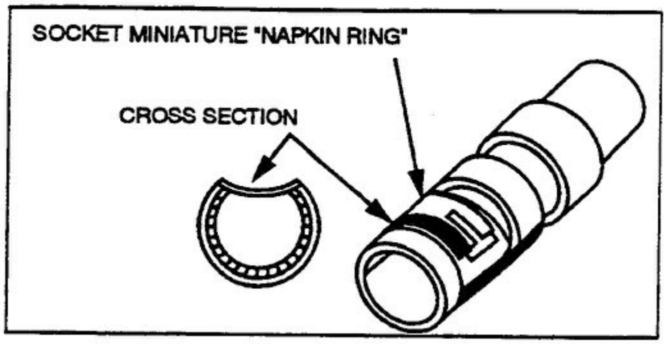

Figure 3–21. A variation of the "napkin ring" for use with miniature contacts.
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Radiofrequency circuitry requires the use of coaxial contacts. The socket half of a typical coaxial connector contact is shown in figure 3–22. The socket for the center conductor is contained within a Teflon insulating cone. Continuity for the outer braid of the coaxial cable is provided by the outer shell of the contact.

Good contact engagement is critical to electrical conductivity. Contact pins and sockets must be properly matched to the type of connection needed. How well wire leads are terminated into these contacts is equally important.

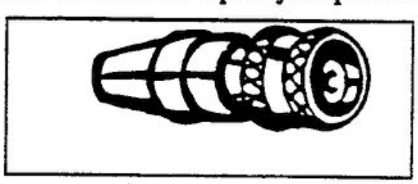

Figure 3–22. The socket half of a typical coaxial connector.
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Contact termination. There are a variety of ways for attaching wires to connector contacts. Until recently, soldering methods were used almost exclusively. In this method, the tip of the wire tinned with solder is inserted into a solder pot on the rear of the contact (fig. 3–23,A). Heat and solder are then applied to secure the joint. On most connectors having this type of contact, solder pots are prefilled with solder or are pretinned. Usually, there is an inspection hole on the contact so that the wiring can be viewed as it is inserted in the cup or pot.

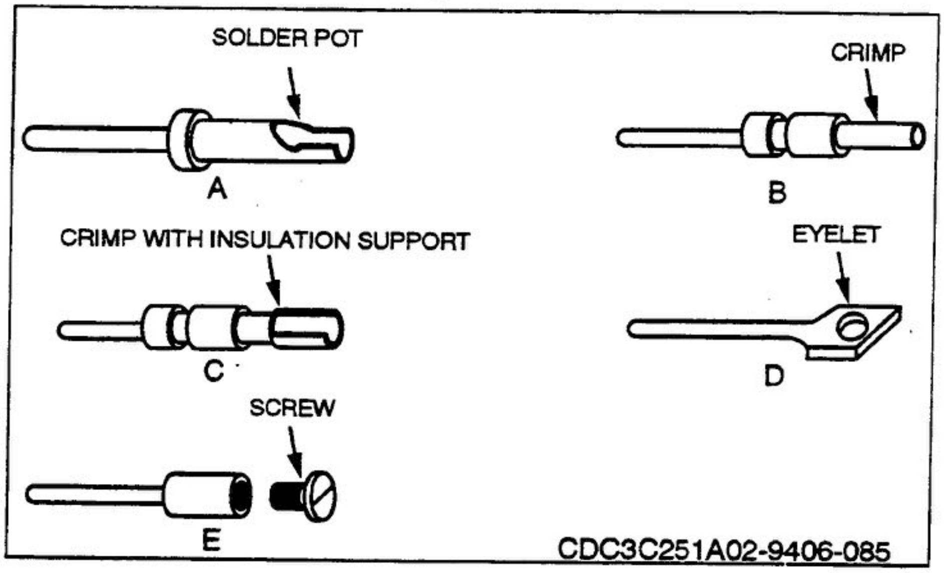


Figure 3–23. Commonly used methods for attaching wire to connector contacts. (©1966, Reproduced with permission of Howard W. Sams & Co.)

The crimp contact method (fig. 3–23,B) has some advantages over the solder pot contact and has become quite popular. No solder is used in this type of contact. Instead, the wire is inserted into a crimp pot or cup on the rear of the contact and the contact is crimped against the wire with a special crimping tool. The same is seen in figure 3–23,C. However, the wire insulation is provided a support that is not available in the contact shown in figure 3–23,B. The contact in figure 3–23,D has an eyelet that is used for wire attachment. In this contact, wires are placed through the eyelet, looped back, and soldered in place. The last contact (fig. 3–23,E) uses a threaded head and screw to fasten wires. If you wrap a wire around the inside of the screwhead and tighten it into the threaded head of the contact, you make positive connection between the wire and contact.

In this section, we've covered electrical connector designs and their components. We now know many factors must be considered when selecting electrical connectors to ensure they meet our specific needs. Among these are electrical, mechanical, and environmental requirements. In our discussions of connector components, we learned about insulators, shells, and contacts and how their different designs give us a variety of options for creating the best electrical connection possible. We use this new found knowledge to learn how to actually create connections in our next section.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

209. The considerations of connectors

1. What factors determine the size of a connector?

2. Why do high-power signals require large connectors?

3. List the environmental factors that affect connector operation.

4. What is the relationship between the electrical resistance of conductors and temperature?

5. How does altitude affect the insulating quality of air?

6. When vibration is a problem, what type of material is used as an insulator?

210. Electrical connector insulating materials and shells

1. What is the most important characteristic of an insulating material?

2. What does the resistance factor indicate in an insulator?

3. What determines the temperature range of a connector?

4. What type of insulator is used in moistureproofing applications?

5. What is the purpose of polarization in a connector?

6. What are two purposes of connector moistureproofing?

7. How are the connectors held together in a cable-to-cable application?

8. What type of locking mechanisms are used in instrument panel applications?

211. The characteristics of electrical connector contacts

1. What kind of protection is achieved with a one-piece resilient insulator?

2. What is the advantage of C-ring retention with a one-piece insulator?

3. Under what conditions would you require the use of nonremovable contacts?

4. How do you fasten a contact to a printed circuit board?

5. What type of contacts are used for radiofrequency circuits?

6. What two methods do you use to attach wires to contacts?

3–2. Assembly, Installation, and Maintenance of Electrical Connectors

The assembly, installation, and maintenance of electrical connectors is relatively simple in comparison to the requirement for other electronic components. Modern connectors are very simple to assemble and install. Also, they require a minimum of maintenance. However, when you are responsible for selecting connectors you must be aware of the basic assembly procedures and techniques. This knowledge enables you to select connectors that are compatible with your requirements.

The most important phase of assembling connectors with a direct bearing on their maintenance is the method used to attach the wires to contacts. That's why we are going to cover these methods in detail.

212. Soldering and crimping electrical connectors

Soldering electrical connectors is very similar to the processes we used to solder electric terminals in Unit 2. Let's quickly review the basics of soldering.

Soldering. Soldering is a thermal technique. It uses heat to join or bond metals and is widely used for attaching wires to electrical contacts. Welding is a thermal technique but differs from soldering in that no external metal or alloy and deoxidizing agent (flux) is used for the bonding. Brazing is a thermal technique and is basically the same as soldering. The significant difference between soldering and brazing is that soldering employs a filler material that has a melting temperature range below an arbitrary value (about 400°C) while brazing has a temperature range above this value. For this reason, brazing is not used in attaching wires to electrical contacts. In any event, both methods differ from welding in that the metals to be joined are not heated to the melting point. Therefore, one of the requisites for solder is that the melting point must be lower than the melting point of the metal to be joined.

The two basic methods of soldering wires to electrical contacts are using a soldering iron and resistance soldering.

Soldering irons are the oldest method and still widely used. Essentially, the wires to be attached are stripped and tinned, inserted into the contact solder pot, and heated by a hand-held soldering iron. Once the solder pot is heated to the proper level, the solder is applied to the wire and contact, then the solder melts and fuses the two metals together.

Resistance soldering is one of the more modern methods and involves the use of a resistance soldering unit or tool. The soldering tool (probe) consists essentially of two hand-held electrodes placed on either side of the contact to be soldered. Current is applied through the contacts from the electrodes. The current is controlled by a regulator box that is part of the resistance soldering unit and serves to heat the contact. The remainder of the soldering process is essentially the same as with a soldering iron.

The primary advantage of resistance soldering is that heat can be regulated automatically by the regulator or control box. Just the right amount of heat can be applied, and this heat is removed by an electronic timer when the correct point is reached. In general, resistance soldering requires less heating time than a soldering iron; however, the cooling time is usually longer. This means that the wire must be held in the contact for a longer period of time to allow the solder to return to a solid state.

Problems of soldering. Regardless of the soldering method used to attach wires and contacts, certain characteristics and problems are encountered. Let's look briefly at some examples of soldering problems that relate to electrical connectors.

One problem is heat control. Insufficient heat will result in a poor solder joint; excessive heat can damage a contact or the insulator. Although most connector insulators are designed to withstand high environmental temperatures, they can be damaged by the concentrated heat conducted by a contact that is being soldered. It is also possible to accidentally touch the soldering iron tip directly to the insulator. The heat control problem is minimized by using the resistance soldering method.

Wires may be stripped and tinned before being inserted in the contact solder pot. The contact pot is tinned, unless pretinned contacts are used. Just the right amount of solder is applied. Not enough solder results in a joint that is not strong mechanically, not good electrically or both. Too much solder causes shorts between contacts. Solder and flux dropped between contacts are cleaned away immediately after the contact is soldered to avoid shorts between wires.

The proper selection of solder is another factor of great importance. Obviously, the solder must have a melting point below the melting point of both metals being joined. A lower melting point is required for miniature contacts and fine wires. However, solder with a very low melting point melts or loses its strength when subjected to high environmental temperatures. Therefore, a balance between tensile strength and melting point must be maintained.

Usually, an eutectic alloy solder is best for general-purpose use. An eutectic solder is one in which there is no appreciable "plastic" or semimolten state. A few degrees of temperature change results in a change in the solid-to-molten state of the solder. This type of solder minimizes the possibility of a cold solder joint. Such joints occur when the wire (or contact) is moved while the solder is still in the semimolten state. If the solder requires a large temperature drop before it becomes solid, the wire and contact must be motionless for a correspondingly long time. This decreases the possibility of cold solder joints.

Most solder used in electrical wiring is a combination of lead and tin. A noncorrosive rosin flux is "built in" to the solder which is usually supplied in the form of a 1/32-inch wire. Acid-type fluxes are not used since they tend to corrode electrical wiring and contacts. The percentage of lead and tin determines the strength of the solder over a given temperature range. In general, a 50 percentage or a percentage of 60 percent tin and 40 percent lead, is considered best for soldering electrical contacts.

Choosing the right soldering method. The selection of a soldering iron is important. A larger iron is required for large, heavy contacts. However, crimp-type contacts are now being used almost exclusively in larger sizes. Therefore, the major concern in soldering is with smaller contacts and those on hermetic seal connectors.

Generally speaking, there are two types of soldering irons suitable for soldering miniature contacts. The first is the 100-watt iron. The second is the pencil-type iron. The 100-watt irons are on the borderline of safety and require a great deal of skill to solder 5-ampere contacts having a diameter of 0.041 inch which is the usual size for miniature connectors. You must perform the soldering operation quickly to avoid damage to insulators and still obtain a flow of solder.

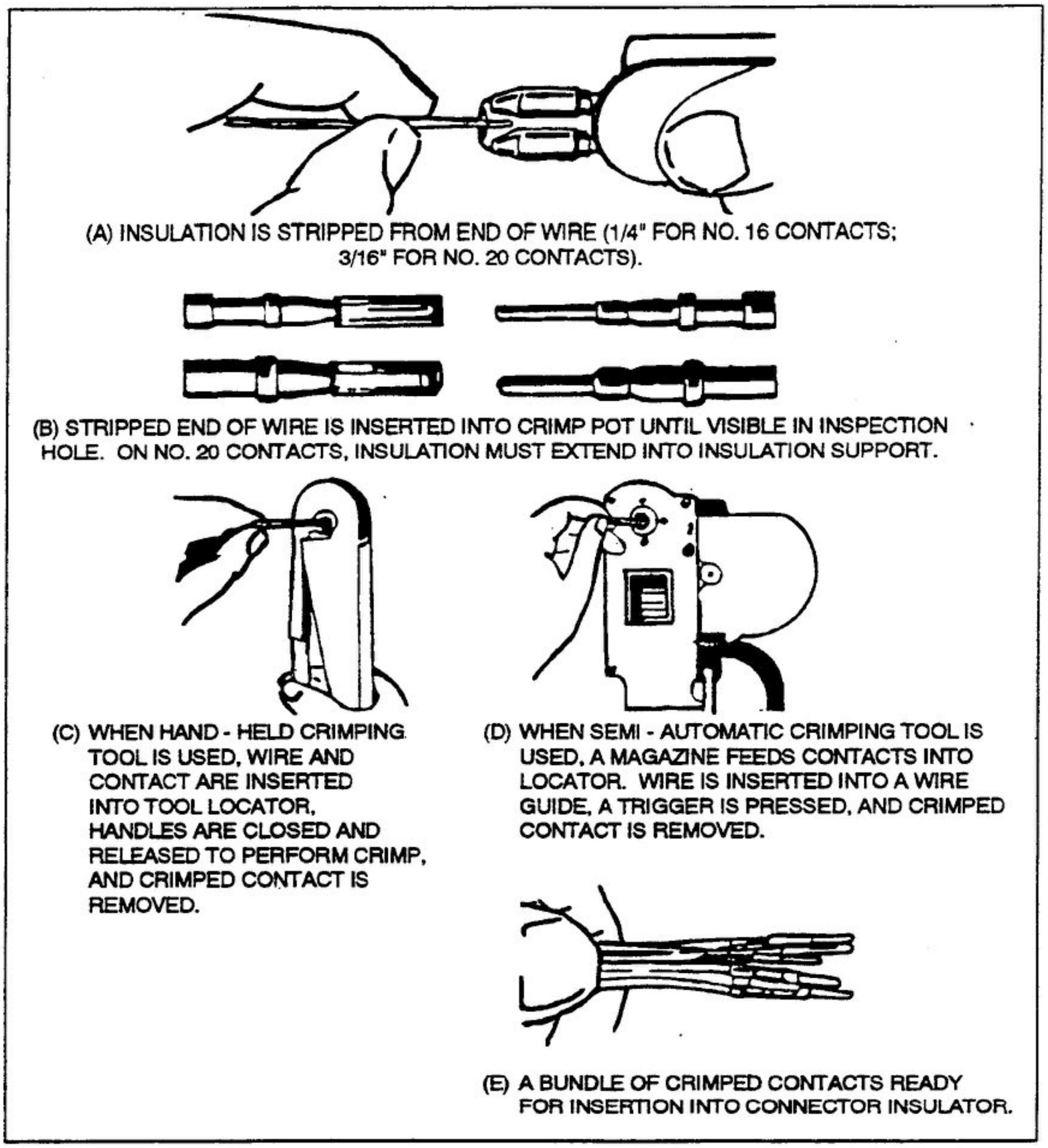
Sixty-watt irons are a safer compromise and are more widely used. Pencil-type irons such as the 20- to 30-watt irons are more adaptable to small contact soldering. Care should be taken when the operating temperature of the iron does not exceed 450°F. To avoid higher temperatures (some pencil irons reach 800°F), a form of temperature regulation is advisable. This may be accomplished by placing a suitable resistance in series with the iron to limit the heating current or by using a thermostat attached directly to the iron. There are various types of irons with built-in heat regulators. Heat regulators making use of a thermostatic switch in the holder or stand on which the iron is placed when not in use are usually not recommended for small contact soldering since the iron temperature is uncontrolled when it is taken from the stand.

Heat regulation is controlled automatically in resistance soldering units. For this reason alone, resistance soldering units are widely used with miniature or small contact electrical connectors.

The soldering of hermetic seal connectors requires special techniques. These techniques differ from those applied to standard aluminum shell, plastic insulator connectors. Since the principle of most hermetic seal connectors is based on the nearly equal expansion and contraction coefficients of all the essential parts (shell, glass insulation, and contacts), the three must remain in relative balance. Heating of these elements during soldering should remain in the same range. The contact should not heat to a difference in expansion and contraction between the two. A timed heat-resistance soldering unit is well adapted to soldering hermetic seal connector terminals.

You can create reliable electrical connectors with soldered contacts if you choose your materials carefully, use the proper tools and soldering method, and watch out for characteristic problems. There is another method you may use to fabricate some connectors that does not require the use of soldering techniques called *crimping*.

Crimping as applied to electrical connectors, refers to a method of attaching wires to contacts. It is accomplished by inserting a wire into a crimp pot on the end of a contact and compressing the crimp pot by means of a special tool until the wire is held securely (fig. 3–24). Crimping has many advantages and some disadvantages when compared to other methods of attaching wires to electrical contacts. Before going into the advantages and disadvantages, let's discuss the development of crimping so that you'll have a better understanding of what is available in crimping tools and techniques and what led to their development.



(A) INSULATION IS STRIPPED FROM END OF WIRE (1/4" FOR NO. 16 CONTACTS; 3/16" FOR NO. 20 CONTACTS).

(B) STRIPPED END OF WIRE IS INSERTED INTO CRIMP POT UNTIL VISIBLE IN INSPECTION HOLE. ON NO. 20 CONTACTS, INSULATION MUST EXTEND INTO INSULATION SUPPORT.

(C) WHEN HAND - HELD CRIMPING TOOL IS USED, WIRE AND CONTACT ARE INSERTED INTO TOOL LOCATOR, HANDLES ARE CLOSED AND RELEASED TO PERFORM CRIMP, AND CRIMPED CONTACT IS REMOVED.

(D) WHEN SEMI - AUTOMATIC CRIMPING TOOL IS USED, A MAGAZINE FEEDS CONTACTS INTO LOCATOR. WIRE IS INSERTED INTO A WIRE GUIDE, A TRIGGER IS PRESSED, AND CRIMPED CONTACT IS REMOVED.

(E) A BUNDLE OF CRIMPED CONTACTS READY FOR INSERTION INTO CONNECTOR INSULATOR.

Figure 3–24. The crimping method of attaching wires to contacts.
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The crimping operation is simple but must be performed before a contact is inserted into the connector insulator. Otherwise, there is not enough room around the contact to accommodate the crimping tool. A number of removable (or insertable) contact and insulator designs have been developed to overcome this problem. They permit contacts to be inserted in the insulator after the wire has been attached. The first point to remember about crimping is it must be used with insertion-type contacts. It cannot be applied to contacts that are permanently mounted within an insulator such as the contacts in hermetic seal connectors.

The development of proper crimping tools has been instrumental in making the crimping technique practical for use with electrical connectors. Early crimping tools were designed for use with terminals such as spade lugs, and when used on connector contacts, would mash and distort their shape excessively. Such crimped contacts could not be used in high-density layouts where the center-to-center spacing of the contacts must be kept within critical limits because of electrical considerations. The first crimping tools designed specifically for contacts used a close die configuration to perform the crimp. These tools produced a satisfactory joint with a minimum of contact distortion. However, they were limited to only one or two wire sizes for each die. The die configuration maintains a constant area cross section through the crimp whereas the cross sections of different wire sizes vary. This means that if two different sizes of wire are crimped in the same size crimp pot, the result will be different degrees of compression on the material in the crimp. Small wires will be undercrimped and large wires will be overcrimped.

Today's crimping tools are more flexible because many wire sizes can be crimped in a single size crimp pot. This is done by tools with three or four indenters that impress themselves into the crimp pot and allow the excess material to flow freely out between the indenters. Figure 3–25 illustrates several typical crimping methods and configurations. For reference, experimentation has proven that three indenters give the best crimp force for a size 20 contact, three or four indenters for a size 16 contact, and four indenters for a size 12 contact. This multiple indenter design provides a great deal of flexibility and a wider range of acceptable gage settings than is possible with other indenter designs. The gage setting determines the diameter of the crimp.

In sensitive crimp tools, the gage setting must be maintained within very critical limits. Multiple indention tools are "nonsensitive" in this respect. For example, a multiple indention tool can crimp wire sizes 20, 22, 24, and 26 to a standard 20 contact, all with a single gage setting of the tool. Furthermore, tensile tests have shown that with such wire sizes and a single gage setting, wires will break before they pull out of the crimp pot. Some applications call for two or more feed wires to be connected to a single contact.

Modern crimping tools incorporate a design feature known as the double indenter configuration. Each of the three or four indenters in the crimping tool has two teeth that entrap a ball of wire between them in the crimp. This design gives higher wire retention forces with less distortion and disfiguration of the contact than a single indenter configuration. For example, a size 16 crimp made with a double indenter tool set at 0.057-inch crimp diameter has an average retention force of 66 pounds. The same crimp made with a single indenter tool would have to be made at a gage setting of 0.040 inch and would have an average retention force of 60 pounds.

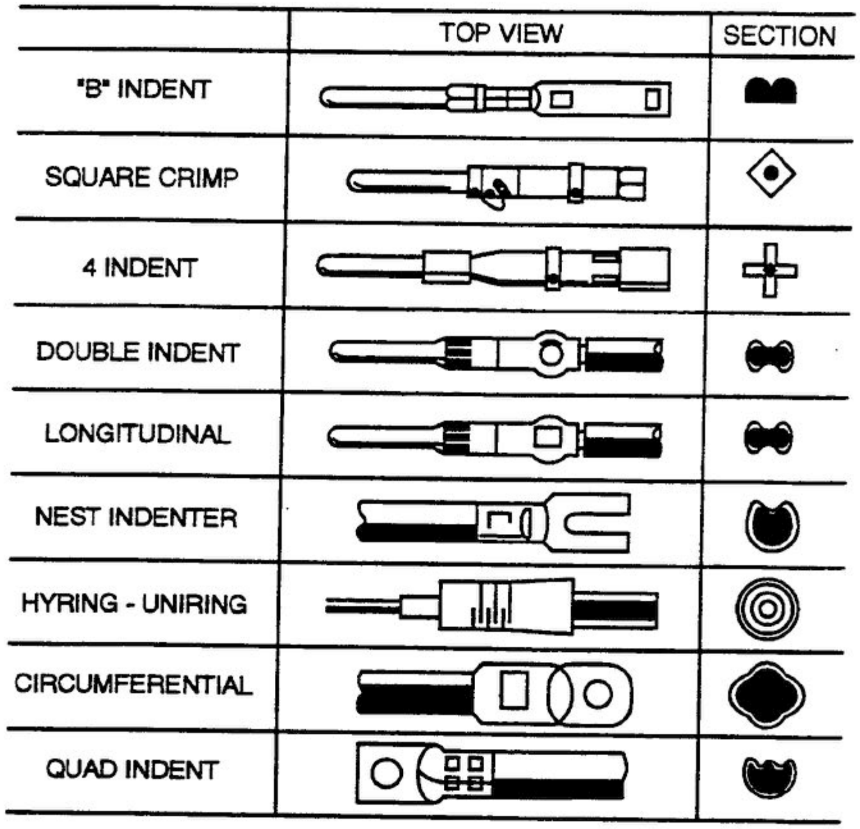

Figure 3–25. Some typical crimping methods and configurations. (©1966, Reproduced with permission of Howard W. Sams & Co.)

Advantages of crimping. A properly designed and executed crimped connection has excellent electrical properties. Contact resistance is low and resistance stability is excellent within the operating temperature limits determined by the physical properties of the metals or alloys involved. However, since the connection is established by pressures of the contact crimp pot on the wire (actually it is the residual force in the crimp that determines the electrical properties), high temperatures can partially or completely eliminate the residual stresses in the material. Consequently, the service temperatures will set a limit to the use of each individual crimp.

The mechanical properties of crimped joints are excellent and are usually established by proper die designs. Crimping can be used with such conductors as solid wire, stranded wire, insulated wire, aluminum wire, and tinsel wire. A crimped contact has good resistance to environments such as vibration, salty and humid air, and nuclear radiation.

The operation of crimping tools is simple and can be learned in minutes. Many crimping tools are automatic or semiautomatic, reducing human error to a minimum. The crimping tool controls the depth of indention to within a few thousandths of an inch. Once the crimping operation is started, the tool will not open until full tool closure has been reached. The only remaining variable that can affect the consistency of a crimp joint is the depth the wire is inserted in the crimp pot. This is inspected visually through an inspection hole.

Because of the simplicity, crimping compares favorably with soldering. Most soldering methods call for equipment not readily portable and the quality of solder joints is dependent on a number of variables. The depth of wire insertion is difficult to inspect. Temperature and cleanliness of the wire, solder, and solder pot at the time the joint is made are not controlled. These variables are impossible to inspect on a mass production basis (where the advantages of crimping are best demonstrated).

Since the crimping operation is relatively foolproof, and joints are uniform, the reliability of crimping is good. In a test of crimp joints conducted by the Naval Air Development Center, a total of 7,000 crimps were made and tested, using a number of crimping tools and contacts from several different manufacturers. Some of these tools were still in the experimental stages, yet only one contact out of the 7,000 failed to meet standards.

Exhaustive tests show that crimped joints are electrically reliable. The resistance measured across a crimped joint is less than the resistance measured over an equal length of the wire conductor. This is because the average cross section of the joint is larger than that of the wire and there is no measurable resistance across the actual juncture of the two surfaces after crimping.

Disadvantages of crimping. Considerable space is required around contacts to perform crimping operations. It is difficult to produce reliable connections with extremely fine wires. The very nature of crimping, which is establishing contact by deforming the materials, sets a limit on wire size. Extremely fine wires are reduced to the breaking point by indentions.

A lack of standardization hampers the use of crimp contacts. The various electrical connector manufacturers have produced a large number of crimp contact designs with varying crimp pot shapes and dimensions. A corresponding variety of crimping tools has been developed to accommodate them. This is further compounded by the fact that the contacts are made in all sizes and shapes without any common means of locating them in the crimping tool. Despite efforts to standardize, it is necessary to use the corresponding connector manufacturer's tools to crimp their particular contacts.

To sum up, crimping is superior to soldering except with very fine wires or in connectors where the contacts are permanently secured to the insulator.

213. Maintenance and potting of electrical connectors

Electrical connectors generally require little maintenance unless they suffer physical damage. Some connectors may require potting to prevent moisture from getting to the contacts and causing problems. Let's look at a few maintenance tips then see how potting is accomplished.

Maintenance. Electrical connectors require no operating maintenance other than keeping them clean and out of environments that may damage or deteriorate their electrical and mechanical characteristics. As a matter of routine give all connector parts a careful visual check for dents, scratches, corrosion, cracks, and other physical damage or deterioration. Check threaded parts for damaged threads.

Most connectors can be "quick-cleaned" externally by using a cleaning solvent such as trichlorethylene or Stoddard solvent. Exercise care in using the proper amount of solvent to do the job and to prevent entrapping moisture.

A *thorough* cleaning of connectors is not usually necessary when adequate quick cleaning has been carried out. A complete cleaning consists of the complete disassembly and reassembly of a connector. The inconvenience and total time spent make it more economical to replace the connector.

If a connector must be cleaned, use trichlorethylene and Stoddard solvent for all metal parts. The same cleaning material is used for melamine, nylon, and diallylphthalate material insulators. Rubber insulators and seals are cleaned with alcohol or detergent and water. By brushing a connector with cleaning solvent, using a small brush, you can minimize moisture traps by blowing the connector thoroughly with an air hose. Use a mild abrasive such as an ordinary pencil eraser to take tarnish off silver contacts. Silver cleaning compounds may be used, but thoroughly remove them afterwards. The tarnished appearance caused by the presence of silver sulfides is not reason for rejection. Silver sulfide is a very good conductor.

Limited repairs, such as replacing a bent contact or a cracked insulator or resoldering a loose connection is done when necessary. Generally this is not desirable because these repairs require assembly and disassembly of intricate parts. Also, it is not economically feasible in relation to the cost of replacing the connector. In general, replace connectors whenever there are any signs of physical or electrical damage or deterioration.

There are special tools available from various sources to aid in the repair or the initial assembly of electrical connectors. In addition to the contact crimping, insertion, and extraction tools, there are wrenches (spanner, strap, and cylindrical) to install and remove endbells and to tighten coupling nuts as well as special pliers for use on endbells and coupling nuts.

Potting of electrical connectors is accomplished where extreme moisture resistance is required. Basically, potting involves filling the solder pot area around the rear of a connector with a free-flowing compound, such as synthetic rubber, having a high solids content. When cured at room temperature, the potting material forms a resilient seal around the wires at the rear of the connector.

In some cases, the conventional endbell is completely removed and replaced by an aluminum endbell to reduce weight. In other cases, no endbell is used at all. A temporary nylon potting cup or form is placed around the connector solder-pot area so the area can be filled with potting compound. Then the cup is removed. An aluminum endbell is used on the cable half of connectors, and a removable potting cup is used at the permanently mounted half. Where no nylon potting cup is available, a potting form is built up with masking tape.

Some of the advantages of potting are positive sealing against dirt and moisture, prevention of wire fatigue under extreme vibration, improved electrical characteristics, weight reduction from eliminating the endbell and clamp, space saved due to shorter overall length, reduction of lateral fatigue at the solder pot, and one shell style for both straight and 90° angle requirements.

While various potting compounds and potting tools are available, there are certain basic materials and tools required for any potting system. These include a solvent for cleaning the connectors prior to potting (a nontoxic, odorless type of solvent is recommended); a small stiff brush for cleaning the potting area, masking tape for fabricating a potting cup (if none is supplied with the connector), the potting compound (packaged in gallons, half-gallons, quarts, pints, and half-pints with necessary amounts of accelerator attached—the basic compound is light colored, while the accelerator is dark); paper or cardboard for testing the sealer mixture, and a flow gun for applying the sealer to the connector.

Although the potting procedure varies, the basic steps are (1) clean the potting area thoroughly with cleaning solvent and a brush, (2) install the potting form or aluminum endbell (or make a form from masking tape), (3) mix and test the potting material, (4) pour into the potting area (where many connectors are to be potted on a production line basis a flow gun is used to advantage applying the potting compound), and (5) allow the compound to dry or cure.

It is extremely important to maintain electrical connectors in order for them to sustain high reliability. Fortunately, keeping them clean and potting those requiring special protection from moisture prevents most problems.

Congratulations! You've made it through the first half of the course and hopefully, discovered it's not all that bad. This volume covered soldering basics and tools and procedures necessary to create reliable electrical connections. Further, information was given on developing wire wrapped and crimped connections and how to maintain reliability of all connections through proper care. The second half of the course offers more challenges for you. Make good use of the following self-test questions and enjoy the half-time unit review exercises. Then, it's back to the gridiron for the third quarter, "Modulation and Multiplexing."

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

212. Soldering and crimping electrical connectors

1. How does welding differ from soldering?

2. What is the difference between soldering and brazing?

3. What is the advantage of resistance soldering?

4. What problem does excessive heat cause in soldering?

5. How is the heat control problem in soldering reduced?

6. What irons are suitable for soldering miniature contacts?

7. Describe crimping.

8. What are the benefits of a multiple indenter crimping tool?

9. What factors give crimping an advantage over soldering?

10. What is the problem with crimping very fine wires?

213. Maintenance and potting of electrical connectors

1. What solvent is used to externally clean a connector?

2. What is used to clean rubber insulators?

3. When is potting used in an electrical connector?

4. How is potting an advantage in extreme vibration?

Answers to Self-Test Questions

209

1. Number of contacts, current per contact, and voltage.
2. To handle large contacts needed for high currents and large air gaps needed for high voltage.
3. Temperature, altitude, moisture, and vibration.
4. Conductor resistance increases with a temperature increase.
5. The higher the altitude, the less insulation efficiency.
6. Resilient materials such as polychloroprene or silicone rubber.

210

1. Dielectric strength.
2. Amount of resistance offered to voltages on adjacent contacts.
3. Temperature range of the insulator.
4. Hermetic seal.
5. Prevents mismatching or cross-plugging.
6. Provides a moisture seal between connector and equipment, and between the insulator and shell.
7. By locking screws or engaging screws.
8. Engaging screws or engaging drive mechanism.

211

1. Protection against moisture.
2. Ensures contact alignment.
3. Requirements for full hermetic seal or large pressure differentials to prevent leakage.
4. Push the contact through a slot in the insulator and give it a quarter turn.
5. Coaxial.
6. Solder and crimping.

212

1. Welding uses no external metal or flux to do the bonding.
2. Soldering uses a filler material that has a melting temperature range below an arbitrary value, while brazing has a temperature range above this value.
3. Heat can be regulated.
4. Damaged contacts or insulator material.
5. By using the resistance soldering method.
6. 100-watt and pencil-type.
7. Place the wire in a crimp pot on the end of a contact and compress the pot with a special tool.
8. Greater flexibility and a wider range of gage settings.
9. Wire insertion easy to inspect, no temperature or cleanliness problems, and more portable.
10. Wires can be reduced to their breaking point.

213

1. Trichloroethylene or Stoddard solvent.
2. Alcohol or detergent and water.
3. When extreme moisture resistance is required.
4. Prevents wire fatigue.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to ECI Form 34, Field Scoring Answer Sheet.

Do not return your answer sheet to ECI.

47. (209) Two characteristics of rectangular connectors are that they are
    a. used in cable applications and use bayonet lock coupling.
    b. used in rack panel applications and use latchlock coupling.
    c. easier to produce and less expensive than circular connectors.
    d. used in rack panel applications and have no coupling mechanism.

48. (209) Which of the following is a true statement concerning the effects temperature has on electrical connectors?
    a. As temperature increases, resistance of conductors increases and resistance of insulators increases.
    b. As temperature increases, resistance of conductors increases and resistance of insulators decreases.
    c. As temperature increases, resistance of conductors decreases and resistance of insulators increases.
    d. As temperature increases, resistance of conductors decreases and resistance of insulators decreases.

49. (209) One way to overcome the adverse effects high altitudes have on the performance of electrical connectors is by
    a. excluding air as a dielectric.
    b. using insulators with higher resistance.
    c. maintaining lower operating temperatures.
    d. maintaining higher operating temperatures.

50. (210) Insulator material for electrical connectors is chosen primarily for its
   a. dielectric strength.
   b. physical strength.
   c. weight.
   d. cost.

51. (210) Insulators used in connectors are rated for their
   a. physical resistance and power dissipating capability.
   b. electrical inductance and current controlling ability.
   c. electrical resistance and ability to withstand breakdown.
   d. electrical conductance and ability to withstand breakdown.

52. (210) A characteristic of two-piece insulators is that
   a. they are molded in block form.
   b. they are held within their shell by retaining flanges.
   c. they are made of special material like compressed glass.
   d. their halves are held together by a shell, or screws and spacers.

53. (210) Guide pin plates are used in connectors to
   a. provide polarization of circular connectors.
   b. provide float-mount action for circular connectors.
   c. combine with polarizing pins to polarize rectangular connectors.
   d. provide polarization and float-mount action for rectangular connectors.

54. (210) A purpose of moistureproofing connectors is to provide a moisture seal between
   a. the shell and connector.
   b. wires and the connector.
   c. equipment and the insulator.
   d. the connector and equipment.

55. (211) The characteristics of electrical connector contacts are contact
   a. termination, engagement, and resistance.
   b. retention, engagement, and termination.
   c. retention, engagement, and resistance.
   d. retention, termination, and resistance.

56. (211) Electrical connector contact engagement characteristics are primarily determined by the
    a. shape of the contact pins and sockets.
    b. method used to terminate the contacts.
    c. application for which the connector is used.
    d. skill with which the connector is assembled.

57. (211) A popular method of connecting a wire to a connector is
    a. insert the wire in a crimp pot and crimp it.
    b. solder the wire in a solder pot and crimp it.
    c. crimp the wire to the connector and solder it.
    d. solder the wire to a screw threaded in the connector.

58. (212) A difference between brazing and soldering is that
    a. soldering is a thermal technique.
    b. brazing uses no external metal for bonding.
    c. brazing uses a filler material that melts above 400°C.
    d. soldering uses a filler material that melts above 400°C.

59. (212) What is the first procedural step taken to attach a wire lead to an electric connector contact using the hand-held soldering iron method?
    a. Strip and tin the wire lead.
    b. Apply heat to the contact solder pot.
    c. Apply solder to the wire lead and contact.
    d. Insert wire lead into the contact solder pot.

60. (212) In soldering, the problem of heat control can be overcome by using a
    a. low-wattage soldering gun.
    b. low-wattage soldering iron.
    c. resistance soldering system.
    d. inductance regulating soldering iron.

61. (212) The correct procedure for creating a crimped contact termination for an electrical connector with a hand-held crimping tool is to
   a. insert a contact into the crimping tool locator, then insert the wire lead into the contact crimp pot and activate the crimping tool.
   b. insert a prestripped, pretinned wire lead into the contact solder pot, then insert both into the crimping tool locator and activate the crimping tool.
   c. insert a prestripped wire lead into the contact crimp pot, then insert the wire and contact into the crimping tool locator and activate the crimping tool.
   d. insert a prestripped, pretinned wire lead into the contact crimp pot, then insert the wire and contact into the crimping tool locator and activate the crimping tool.

62. (212) A disadvantage of a crimped connection is it
   a. has low contact resistance.
   b. has poor resistance stability.
   c. makes a poorer connection than soldering.
   d. requires extra space around the contact area to create.

63. (213) Which statement concerning maintenance of an electrical connector is *most* accurate?
   a. It is checked for moisture periodically.
   b. It is thoroughly cleaned at regular intervals.
   c. It is more economical to replace it than repair it.
   d. It is checked by maintenance personnel quarterly.

64. (213) What is the purpose for potting electrical connectors?
   a. To remove pits and holes from soldered connections.
   b. To protect the connectors from extreme moisture.
   c. To insulate against high temperatures.
   d. To prevent having to tin wire leads.

Bibliography

Applications Handbook for Electrical Connectors. Indianapolis, Indiana: Howard & Sams Company, 1966.