SECTION VI. MANUFACTURING AND INSTALLATION TECHNIQUES

6.1 General

This section described the flat-cable harness fabrication and installation using the NASA developed conductor-contact connector system. The NASA system used the MIL-C-55543 cable and MIL-C-55544 connector. To fully correlate the manufacturing and inspection sections, the process flow charts (Section VII) reference specific paragraphs in this section.

6.2 Mock-Up Installation

Most electrical cable and harness installations including those for FCC must be developed in three dimensions to clear structural components, plumbing, electrical equipment, and other cables. Mock-up manufacturing and installation are closely coordinated with design personnel.

This three-dimensional development is generally performed on an inexpensive wood-and-metal mockup or development fixture of the actual vehicle. An example is shown in Figure 6-1.

6.2.1 Materials. An inexpensive mock-up material, such as 10-mil-thick Mylar tape of proper width is used to simulate the flat cable. The Mylar is sufficiently flexible, yet stiff and rugged enough to withstand the rough handling during mockup development.

6.2.2 Installation Aids. Simple shop aids are used to develop the mockup (Fig. 6-2). A brief description in the use of the aids follows:

a. Masking tape is used as a temporary means to hold the Mylar harness together, and for identification of the simulated cable.

b. Plastic cable ties are used extensively throughout the mock-up development to fasten the Mylar to the supports and bundles.

c. A stapler is used:

1. To staple the folds of the Mylar.
2. To splice pieces of Mylar in branched harnesses where rerouting is necessary during mockup.
3. As a tie-wrap to hold bundles of harnesses.
4. To secure the Mylar to wooden panels and supports.

d. A wedge/lock clamp is used for temporarily clamping bundles of Mylar together to prevent them from sliding.

e. Clips with plastic fasteners are used to clamp the Mylar during final mockup installation.

6.2.3 General Procedures. The following step-by-step procedure is intended as a guide to made the user aware of the intended use of the mockup in the overall cable development and fabrication. The procedure may be changed to meet the specific requirements of a given installation. The mock-up cable installation is to be done on either the actual piece of equipment to be wired or on a mockup of the equipment when it is not feasible to use the actual equipment.

a. The 10-mil Mylar is routed between components and assemblies to be interconnected. An example is shown in Figure 6-3. To ensure that proper registration of the cable is maintained, identify each cable segment together with its index edge in accordance with the engineering drawing by rubber stamping with black ink.

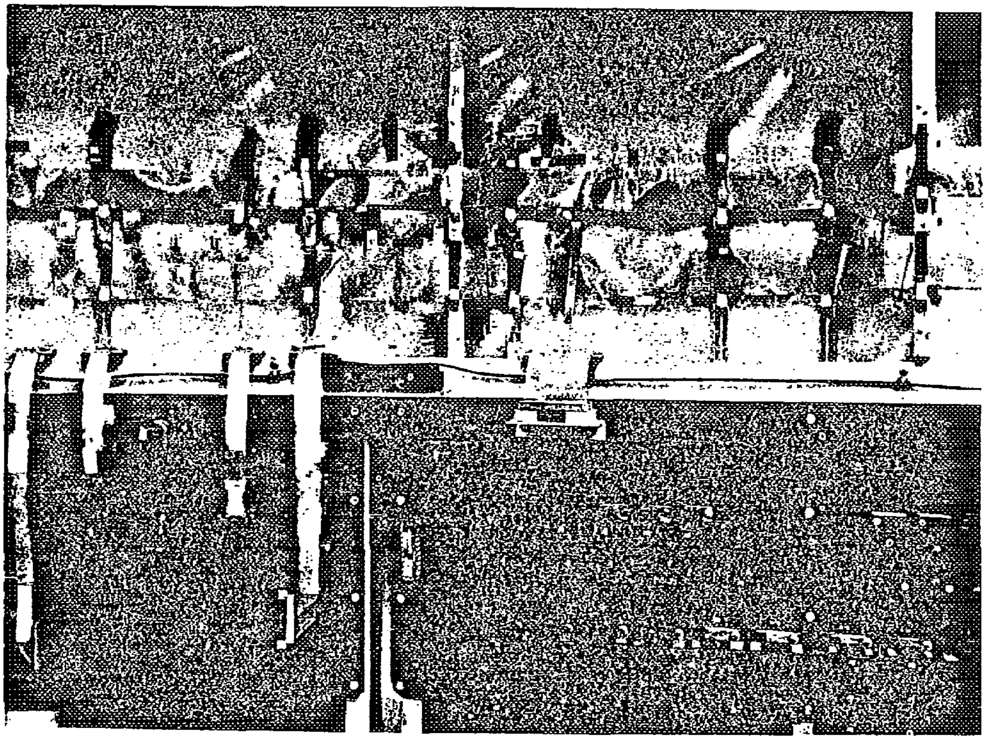


FIGURE 6-1. Mylar FCC harness mockup.

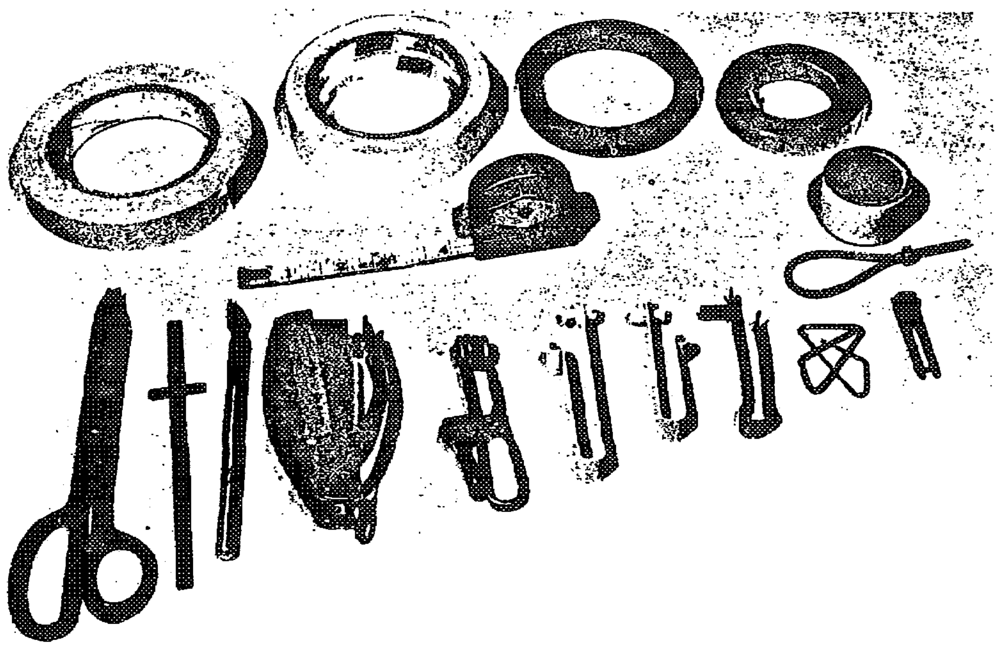


FIGURE 6-2. Tools and aids for mockup and installation.

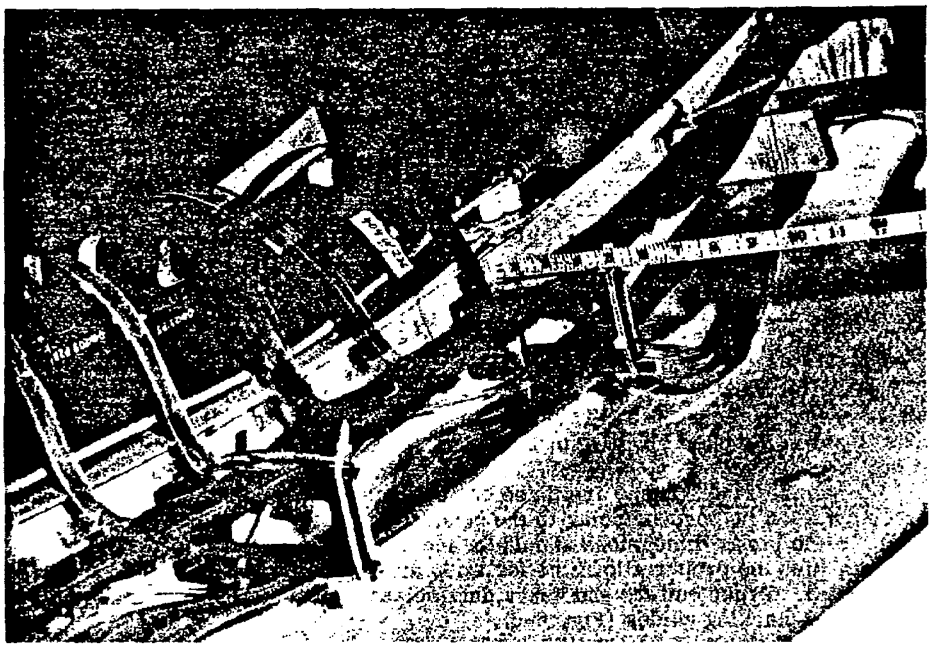


FIGURE 6-3. Mylar FCC mockup.

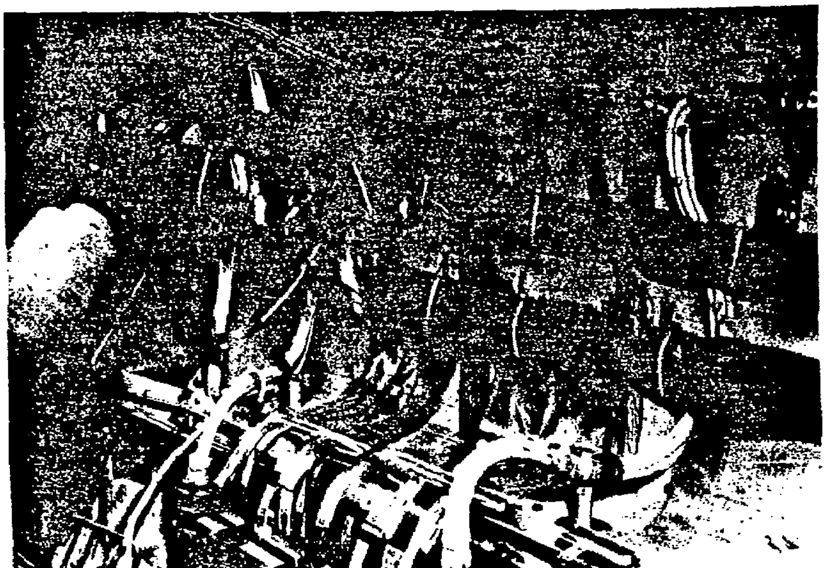


FIGURE 6-4. Basic support bracket.

b. Right-angle brackets of the appropriate length are attached as required to support the cables (Fig. 6-4).

c. The cable harness is arranged in the bundles with the branches routed in a manner to minimize interference and to simplify insertion or removal of harness assemblies.

d. When installing the Mylar mockup, bends or folds are made as required to simplify routing.

e. Upon completion, the mock-up is checked for conformity to design requirements. The mock-up cables are used as patterns in manufacturing the FCC harnesses.

6.3 Detail Manufacturing

6.3.1 Material Handling. It is advisable to package FCC lengths longer than 5 feet in the handling device shown in Figure 6-5. This system can be used during all subsequent manufacturing operations to aid in the plant handling of long runs of cable.

6.3.2 Cable Shearing. There are three basic requirements to be met in the shearing operation: (1) the cut must be perpendicular to the conductors, (2) the conductor ends must not be deformed, and (3) the linear dimensions should be accurate. The cut length shall include the mock-up cable length plus the proper allowance for strip dimensions. The precision D-Arco hand shear is commonly used. Paper cutters and heavy duty scissors provide less satisfactory results and require dimensional marking guides (Fig. 6-6).

6.3.3 Cable Stripping. The stripping lengths may be obtained from MIL-C-55544 for FCC connectors. The exposed conductors should be protected during handling by a device similar to the modified heavy duty paper clip (Fig. 6-7).

6.3.3.1 Cable Stripping Processes.

6.3.3.1.1 Chemical Stripping. All of the FCC insulating and shielding materials used, except the FEP Teflon, can be chemically stripped.

Teflon FEP Fluorocarbon film is virtually impervious to all common chenicals; therefore, any cable system containing FEP cannot be chemically stripped unless it is done in combination with some method which will remove the FEP.

The NASA termination system uses the conductor as the plug contact. Inasmuch as the flat conductor serves as the contact surface, the insulation and shield must be removed prior to terminating the cable into the plug. The actual length of stripped conductor depends on the plug being used. This is referenced in the corresponding Methode Drawing listed in MIL-C-55544.

6.3.3.1.1.1 Polyester (Mylar) Cable. A cable system employing Mylar insulation bonded with polyester adhesive can be chemically stripped. Table 6-1 presents the stripping solutions.

TABLE 6-1. SOLUTIONS FOR REMOVING MYLAR

Solution	Source	Stripping Time (min)	Stripping Temperature (°C)
DS 101 H	Methode Electronics, Inc.	3 to 8	93 to 99
Sulphuric Acid	FED 0-A-115, Class A	2 to 4	93 to 99

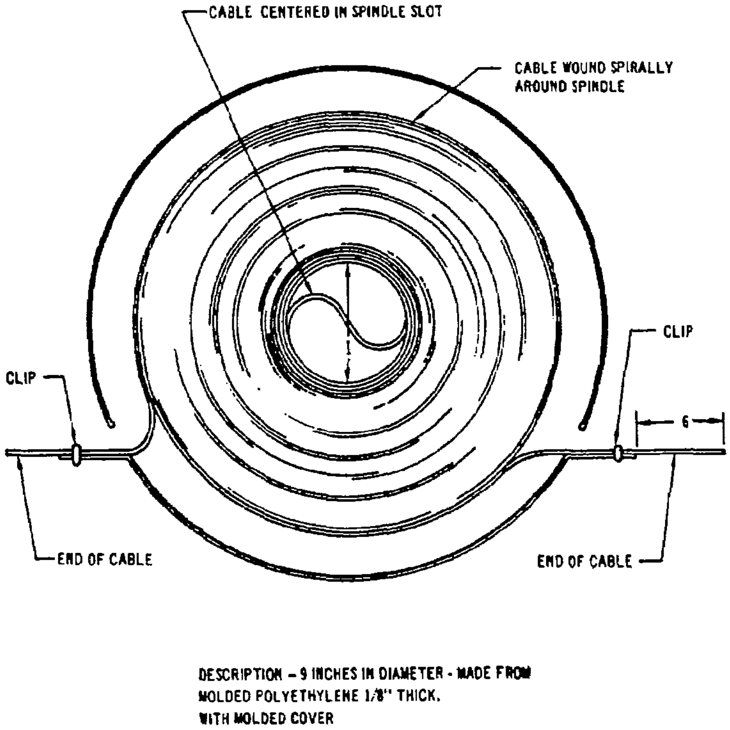


FIGURE 6-5. FCC handling device.

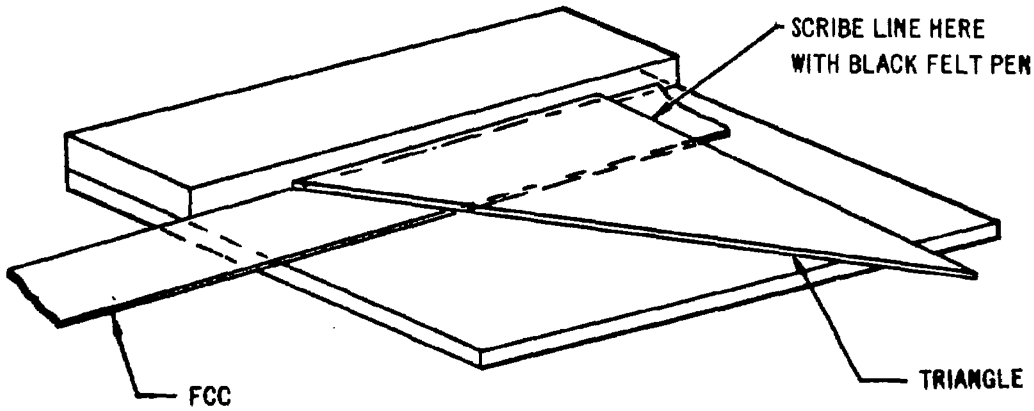


FIGURE 6-6. Right-angle marking tool (conceptual).

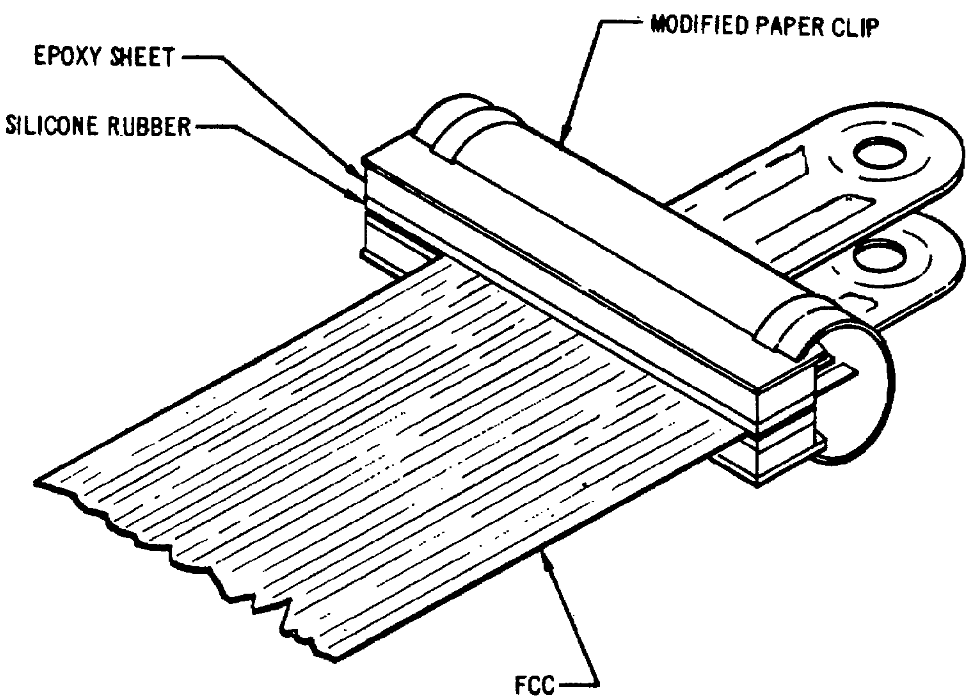


FIGURE 6-7. Conductor protecting clip.

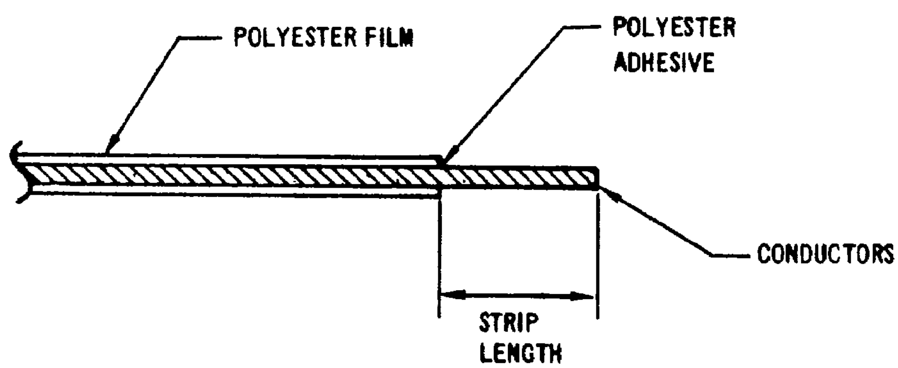


FIGURE 6-8. Unshielded polyester configuration.

The cable is masked to define the stripping area and to prevent degradation of the adjacent cable. See Table 6-2 for suitable Maskants.

TABLE 6-2. MASKANTS

Maskant	Source
Mascoat No. 2	Western Coating Company, Los Angeles, California
Maskant No. 1-2021-66	Organoceram Inc., *Placentia, California*
TFE Teflon Tape	3M Company, St. Paul, Minnesota
Lead Foil Tape No. 420	3M Company, St. Paul, Minnesota

6.3.3.1.1.1.1 Unshielded. The cable configuration is shown in Figure 6-8. The procedure for the stripping of the insulation to expose the conductors is as follows:

a. Apply Maskant around cabling at desired length from cut end of cable.

b. Immerse the cable in stripping solution (Table 6-1) to remove insulation.

c. Spray-rinse the stripped conductors with water to remove any residual insulation.

d. Remove Maskant. Any Maskant remaining on the cable may be removed with Toluene (TT-T-548) and a cotton swab.

e. Air-dry cable.

6.3.3.1.1.1.2 Shielded. The shielded-cable configuration consists of a polyester (Mylar) and metal-shield lamination (Fig. 6-9). The procedure for the stripping of the insulation and shielding to expose the conductors is as follows:

Removing Outer Insulation

a. See Paragraph 6.3.3.1.1.1.1.

Removing Shield

b. Apply lead tape around cabling at desired length from cut end of cable. Be sure tape is pressed firmly against cable and shield to eliminate wicking of the stripping solution.

c. *Strip metal shield with ferric chloride etchant (45-degree Baume, commer*cially available). Etchant may be used at room temperature.

Removing Inner Insulation

d. Remove tape and apply new tape around the cabling at desired length from conductor ends.

e. Immerse the cable in stripping solution (Table 6-1) until the insulation is removed.

f. Spray-rinse the stripped conductors with water to remove any residual insulation.

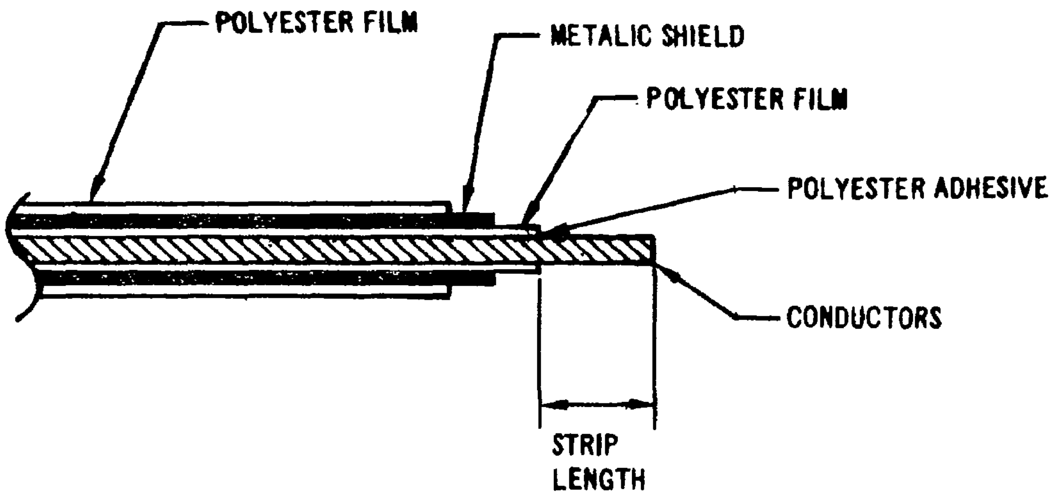


FIGURE 6-9. Shielded polyester configuration.

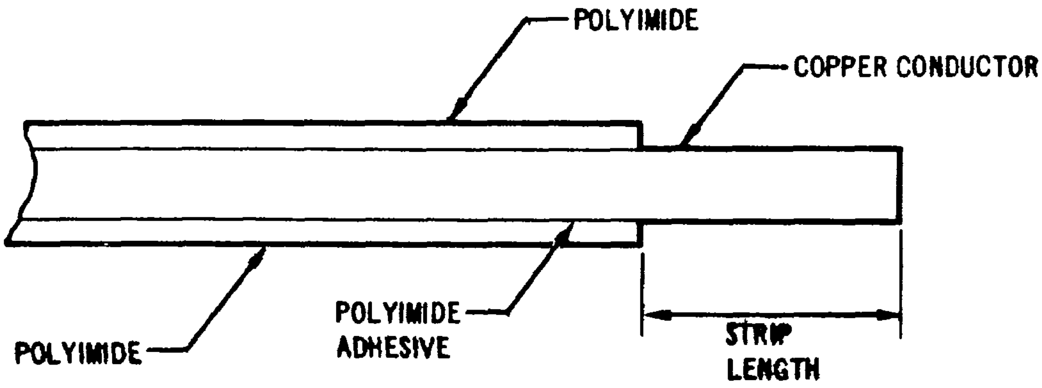


FIGURE 6-10. Unshielded polyimide cable.

g. Remove tape, and remove residual adhesive with Toluene TT-T-548 on a cotton swab and dry.

h. Protect stripped conductors (Fig. 6-7).

6.3.3.1.1.2 Polyimide Cable. An all-polyimide cable can be chemically stripped by using the step-by-step approach outlined below for both an unshielded and a shielded cable.

The cable is masked prior to stripping to prevent degradation of the insulation beyond the designated area.

The stripping solution listed in Table 6-3 can be used in insulation removal. The Maskants listed in Table 6-2 have also been applied to the cable and found to be acceptable in preventing deterioration of the insulation beyond the specified stripping area.

6.3.3.1.1.2.1 Unshielded. The unshielded cable configuration consists of polyimide and copper conductors as shown in Figure 6-10. The procedure for stripping of insulation to expose the conductors is as follows:

a. Apply Maskant (Table 6-2) around cabling at desired length from cut end of cable with the aid of the masking fixture shown in Figure 6-11, or with other suitable fixture.

b. Immerse the cable in stripping solution (Table 6-3) to remove insulation.

TABLE 6-3. STRIPPING SOLUTIONS FOR POLYIMIDE INSULATION MATERIALS

Solution	Stripping Time, 2-Mil Polyimide (min)	Stripping Temperature (°C)
(1) MER-1	3 to 6	93 to 99
(2) Lea Insolstrip	3 to 6	93 to 99
(3) PT-5-ML	5 to 8	96 to 99
(4) Endox L-76	5 to 8	99 to 110
(5) Clarcosub	5 to 10	93 to 99
(6) Sodium Hydroxide (50 parts Na OH to 50 parts H_2O	5 to 10	99 to 110

Notes:

(1) and (3) — London Chemical Company, Incorporated, Melrose Park, Illinois.

(2) — The Lea Manufacturing Company, Waterbury, Connecticut.

(4) — Ethone Incorporated, West Haven, Connecticut.

(5) — Clarkson Laboratories, Camden, New Jersey.

(6) — O-S-598 Types 1 or 2.

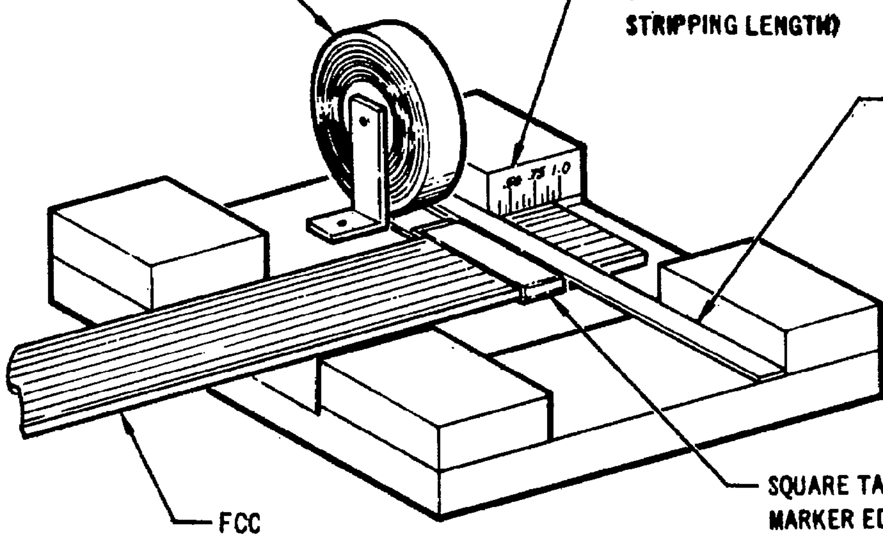


FIGURE 6-11. Masking fixture.

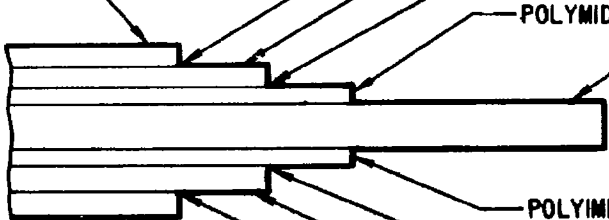


FIGURE 6-12. Shielded polyimide cable.

c. Spray-rinse the stripped conductors with water to remove any residual polyimide.

d. Remove tape. Any tape adhesive remaining on the cable may be removed with Toluene (TT-T-548).

e. Air-dry cable.

f. Protect stripped conductors (Fig. 6-7).

6.3.3.1.1.2.2 Shielded. The shielded-cable configuration consists of polyimide and a metal-shield lamination as shown in Figure 6-12.

The procedure for the stripping of the insulation and shielding to expose the conductors is as follows:

a. Remove outer insulation per paragraph 6.3.3.1.1.2.1 (a through e).

b. Apply Maskant around cabling at desired length from cut end of cable. Be sure tape is pressed firmly against cable and shield to eliminate wicking of the stripping solution.

c. Strip metal shield. Ferric chloride (45-degree Baume) etchant may be used at room temperature.

d. Remove tape, dry cable, and apply new tape around the cabling at desired length from conductor ends.

e. Immerse the cable in stripping solution (Table 6-3) until the polyimide is removed.

f. Spray-rinse the stripped conductors with water to remove any residual polyimide.

g. Remove tape. Any tape adhesive remaining on the cable may be removed with Toluene (TT-T-548).

h. Protect stripped conductors (Fig. 6-7).

i. Air-dry cable.

6.3.3.1.2 Mechanical Stripping.

6.3.3.1.2.1 Unshielded TFE Teflon Cable. The best present method for stripping this type of cable is the use of rotary abrasive-type stripping tools as described in Paragraphs 6.3.3.2.4 through 6.3.3.2.6.

6.3.3.1.2.2 Polyimide/FEP Cable.

6.3.3.1.2.2.1 Unshielded. To strip the insulation from the end of polyimide/FEP unshielded cable use the NASA-developed mechanical stripper (Fig. 6-13); also refer to Paragraph 6.3.3.2.1.

6.3.3.2 Cable-Stripping Tools.

6.3.3.2.1 NASA Cold Blade Stripper. Properly manufactured cables with FEP-bonded polyimide (Kapton) films can be stripped easily and quickly with a sharp blade stripper without applying heat (Fig. 6-13). The cutter blade must be adjusted to the thickness of the cable insulation. Additional cleaning is not needed except for routine pickling before electroplating.

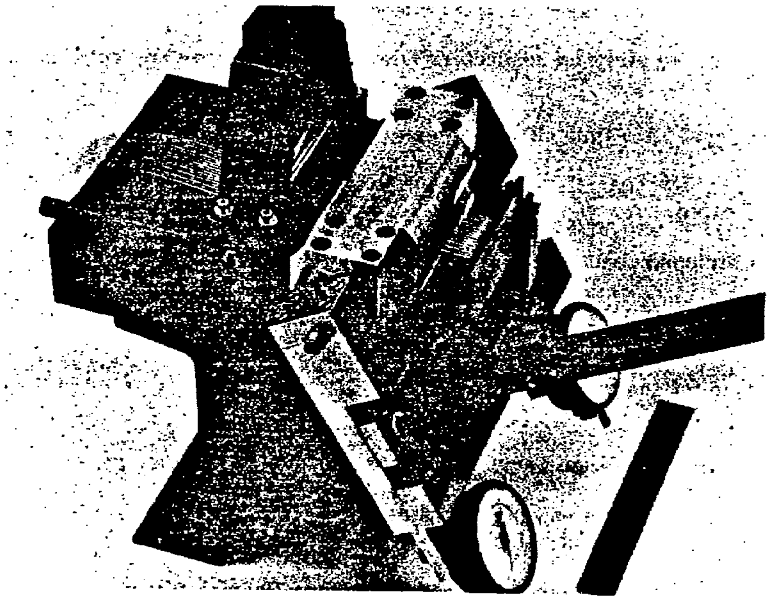


FIGURE 6-13. NASA/MSFC cold blade FCC stripper.

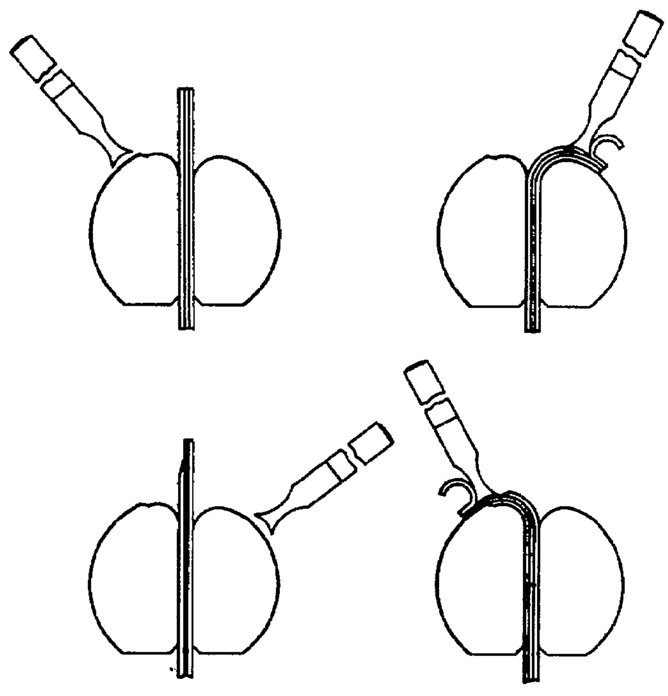


FIGURE 6-14. Stripping operations - NASA mechanical stripper.

The success of this cold blade stripper depends on the fair or poor bond of FEP to the conductors. If the bond strength is very high, then the cold blade stripper fails. A hot blade stripper may do the job superficially, leaving a thin smear of FEP that must be removed mechanically.

Briefly, the method of operating the cold stripper (Figs. 6-13 and 6-14) is as follows: The blade clearance gages are first checked to ensure that the blade is adjusted to cut through the Kapton or outer insulation but does not touch the conductors. The end of the cable is positioned in the stripper against the cable stop. The position of the cable is maintained by clamping. Rotating the blade in one direction strips one side of the cable. Moving the handle in the opposite direction strips the other side. The clamp is released and the cable is removed from the stripper.

An enlargement of a stripper blade profile for stripping Kapton FEP in the cold stripper is shown in Figure 6-15. The established dimensions will produce optimum results in the stripping operation.

6.3.3.2.2 NASA/MSFC Plane Stripper (Drawing No. PM2235).

Description.

The plane stripper (Fig. 6-16) functions on a principle similar to that of a carpenter's plane. An adjustable blade is rigidly supported by a frame that is pushed across the material to accomplish the required stripping.

With the ±0.0001-inch-depth precision required for stripping flat cables, however, it is necessary to supplement the basic "plane" with a jig for holding the cable and a guide to keep the plane square with the cable and to control the width advancement of each successive cut. The blade (Fig. 6-17) clamped between the two frames produces a shearing action at the point of the blade and a shearing action between the blade and frame, thereby producing a very clean strip.

Application.

The plane stripper can be used to strip either shielded or unshielded cables, provided the shields do not contain waves or dents and all conductors are in line with each other. The blade can be adjusted as necessary for removing insulation from the shield or conductor, as the case may be. Almost any insulating material can be removed with the plane stripper, but the stripper works best with the FEP-bonded insulations that are not fused to the conductors. The stripper is readily portable and accommodates the stripping of all cable widths without special adjustment.

Operating Procedure, Unshielded Cables.

The blade is adjusted by loosening the blade clamping screw (Fig. 6-17) and by manipulating the blade adjustment screws.

The cable is placed into the longitudinal slot of the cable jig; the plane guide is placed upon the cable with the registration pin in the hole to the extreme left. Each time the plane is pushed across the cable, the plane guide is moved one registration mark to the right. When all marks have been cleared, a shim is placed in the stripped area, the cable is turned over, and the stripping procedure is repeated. Figure 6-18 shows an unshielded cable that has been stripped and is ready to be terminated.

The insulation at the end of the cable is left to support the conductors during the stripping process, and to keep them from being bent before the cable is terminated with a plug.

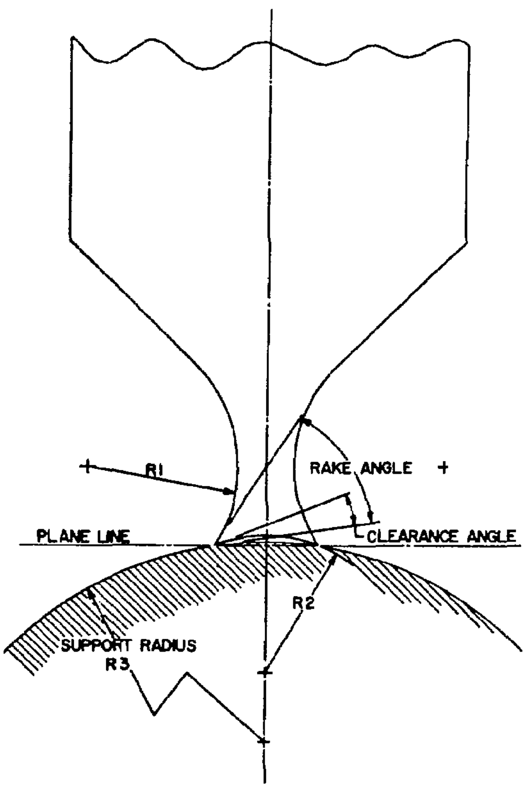


FIGURE 6-15. Stripper blade profile - NASA mechanical stripper.

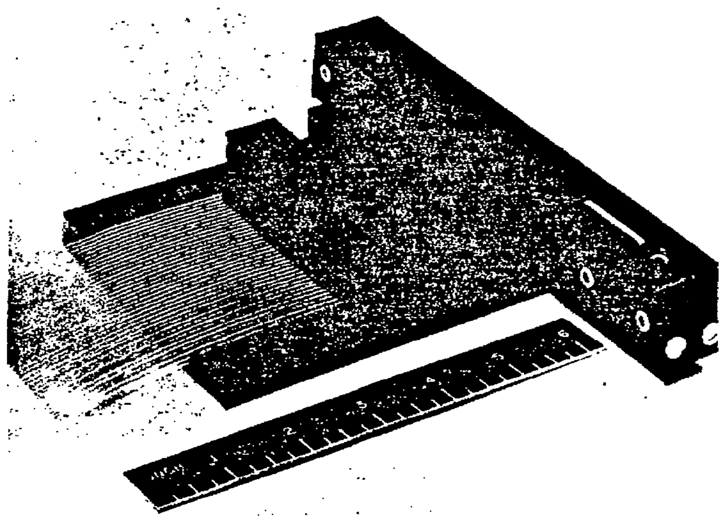


FIGURE 6-16. NASA/MSFC plane stripper (Drawing No. 2235).

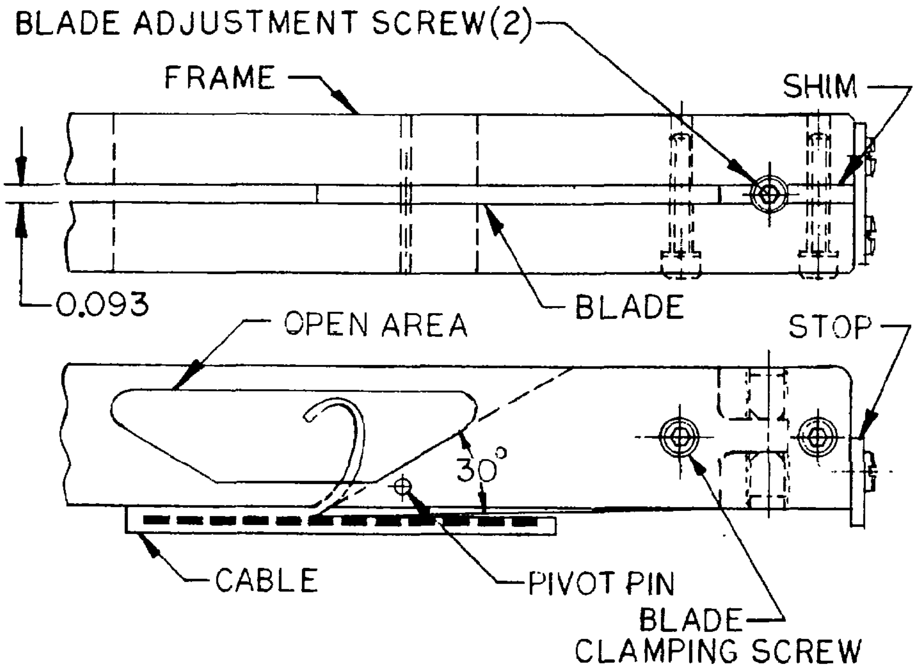


FIGURE 6-17. Blade action of the plane stripper.

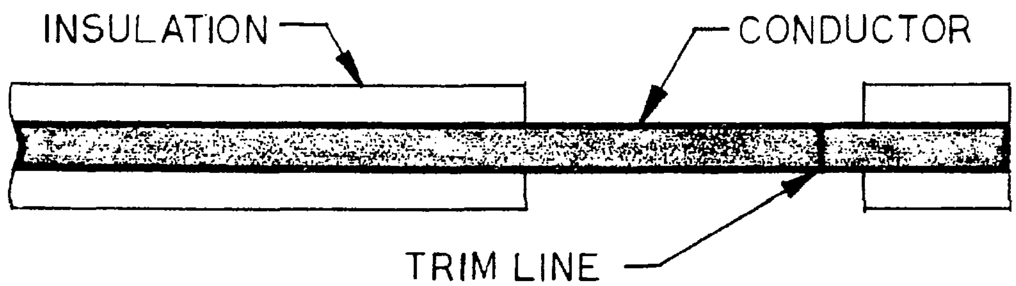


FIGURE 6-18. Unshielded cable stripped with plane stripper.

Operating Procedure, Shielded Cables.

The basic procedure for stripping shielded cables is the same as that given for stripping unshielded cables. However, more steps are involved and more than one plane should be used. The blade of a single plane may be adjusted for each of the three required depths (Fig. 6-19), but for production, the use of three planes, each having a different blade adjustment, is mandatory.

6.3.3.2.3 Gore Stripper. The Gore stripper is designed and manufactured by W. L. Gore and Associates, Newark, Delaware, for stripping Teflon-insulated FCC and round conductor ribbon cables. A pair of parallel, sharp, knife edges mounted in a sliding frame are adjusted to a distance of a little more than the conductor thickness. After the cable is clamped, the pair of knives is pushed across the cable at a distance from the cable end to be stripped. This cuts the top and bottom sides of the insulation, which is then removed by lever-arm force applied to the blade frame in the direction parallel to the conductors. Figure 6-20 shows a Gore stripper, modified by MSFC for experimental purposes. This stripper can only be applied when the insulation is not bonded to the conductors.

6.3.3.2.4 Viking FCC Stripping Machine. The Viking Industries, Inc., Canoga Park, California, manufactured (Contract NAS8-11742) a flat cable stripping machine that uses one wheel only (Fig. 6-21). Its axis of rotation is parallel to the conductor length. This means the friction force is crosswise to the conductors and has a tendency to bend the conductors. To minimize the bending, the stripping should not extend to the cable end, but should leave about a half-inch unstripped to be cut off after stripping and plating.

The wheel diameter of the Viking stripper is 2.2 inches, the width is 0.25 inch, the motor has 0.5 horsepower, and the wheel surface speed is adjustable up to 9,000 feet per minute. The table feed system is motor driven and can be regulated for various speeds.

6.3.3.2.5 Rush FCC Stripping Machine. This machine is designed by Rush Wire Stripper Division of the Eraser Company, Inc., Syracuse, New York, and has been the first friction wheel cable stripper commercially available (Fig. 6-22). The machine has two wheels, 20 inches wide and 1.25 inches in diameter, rotating in opposite directions. An 0.25-horsepower motor drives both wheels with about 300 feet per minute surface speed. To prevent grabbing of the cable, a clamp must be used to control the area of the cable to be stripped. For convenience and safety of operation, a guiding mechanism was added for the cable clamp. The older model Rush stripper has insufficient pressure and thickness control, besides having cantilevered wheel shafts that cause a tapered gap between the grinding wheels.

6.3.3.2.6 Carpenter FCC Stripping Machine. The Model 44 (Fig. 6-23) is a product of the Carpenter Manufacturing Company in Manlius, New York. It uses two wheels, 1.5 inches in diameter and 0.25-inch wide, rotating in the same direction. The axis of rotation is parallel to the FCC conductors. The 0.25-horsepower motor drives the wheels with about 800 feet per minute constant surface speed. Provision is made to adjust the gap between the wheels as well as the position of the gap with regard to the cable. The grinding force can also be selected.

Since the working surfaces of two wheels are moving in opposite directions as they touch the cable, the force acting at the conductors is nearly compensated which results in a minimum bending danger for the conductors.

6.3.4 Conductor and Shield Plating. The following procedure applies to the plating of the copper conductors and shields to be used in the FCC conductor-contact plug system. The plating serves two purposes: (1) good surface conductance, and (2) prevention of copper corrosion. The nickel plating serves as a corrosion barrier and as a receiving surface for the gold plating that provides excellent surface conductivity and resistance to contact wear.

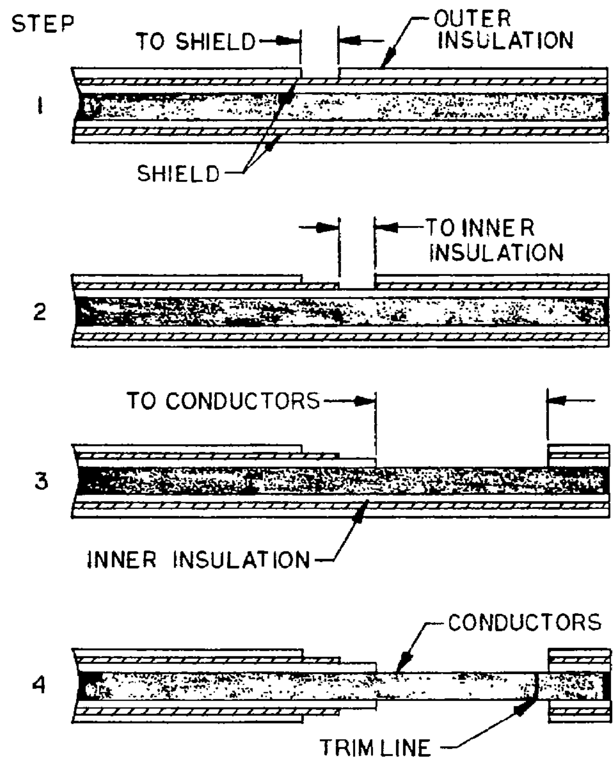


FIGURE 6-19. Shielded cable stripping with plane stripper.

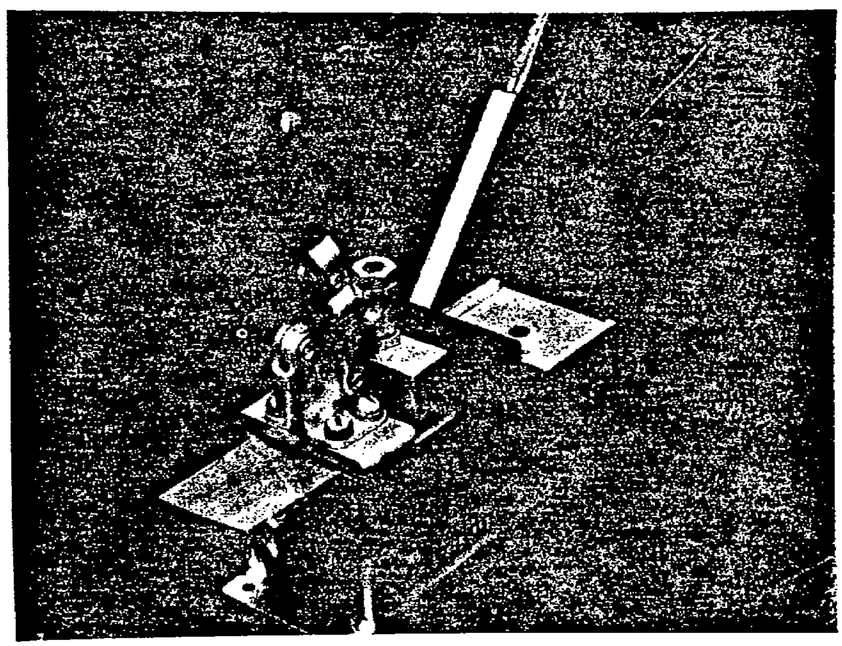


FIGURE 6-20. FCC cold blade stripper (W. L. Gore).

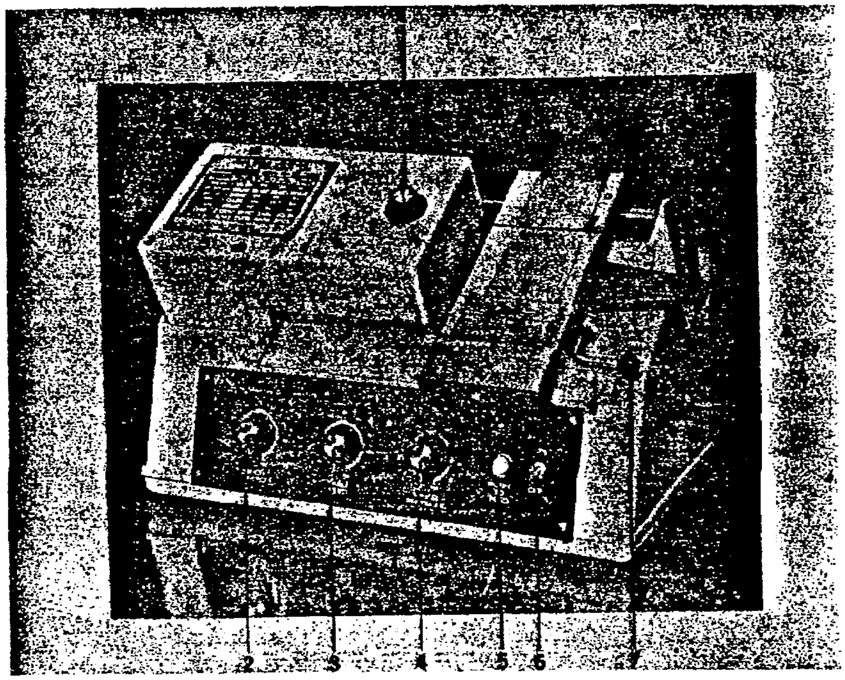


FIGURE 6-21. Abrasive wheel stripper (Viking Industries).

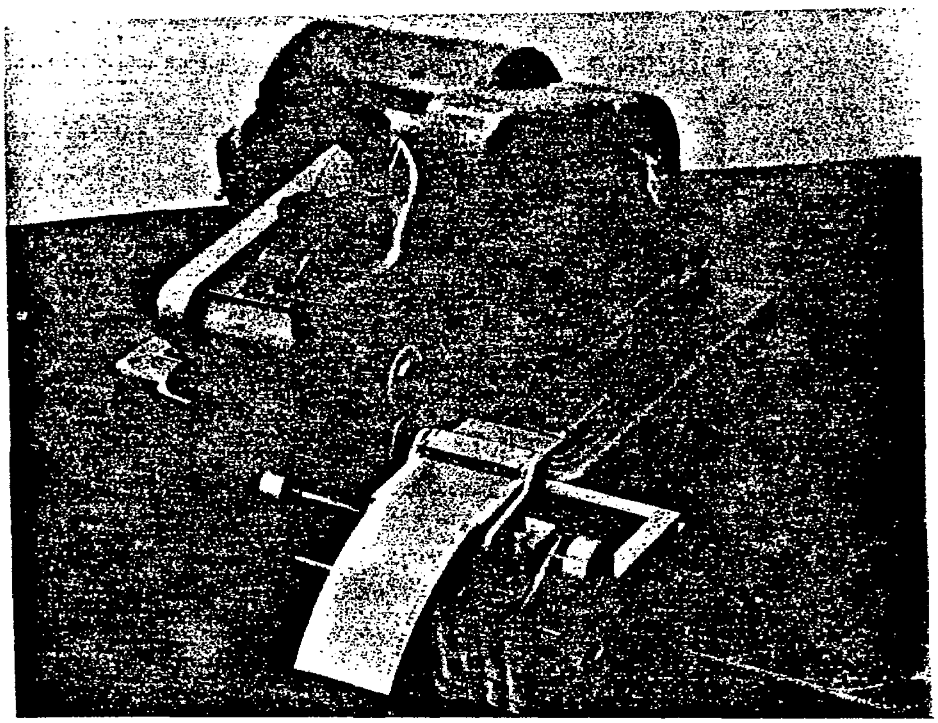


FIGURE 6-22. Abrasive wheel stripper (Rush Division of Eraser Co., Inc.).

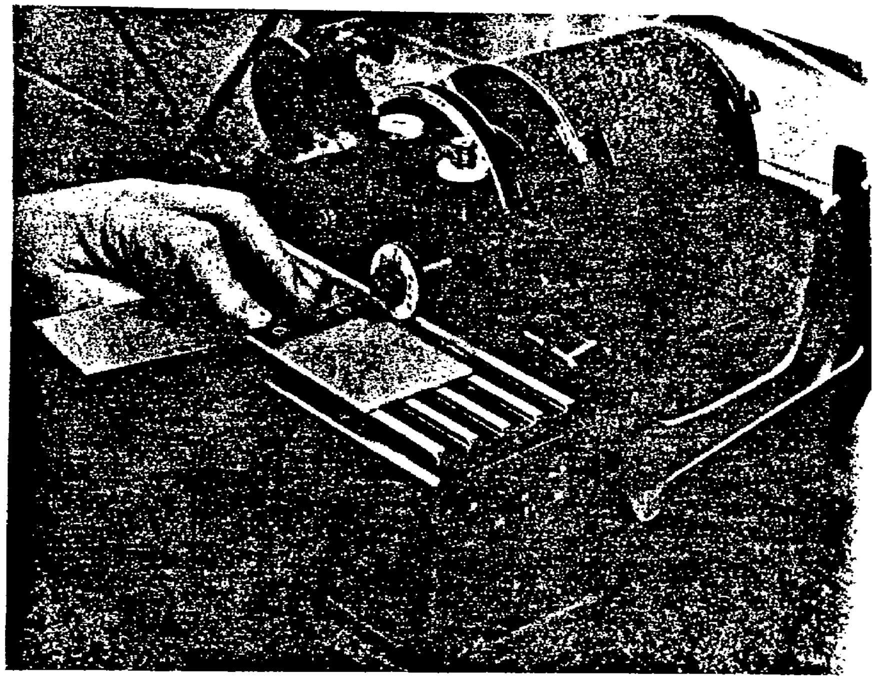


FIGURE 6-23. Abrasive wheel stripper (Carpenter Manufacturing Co.).

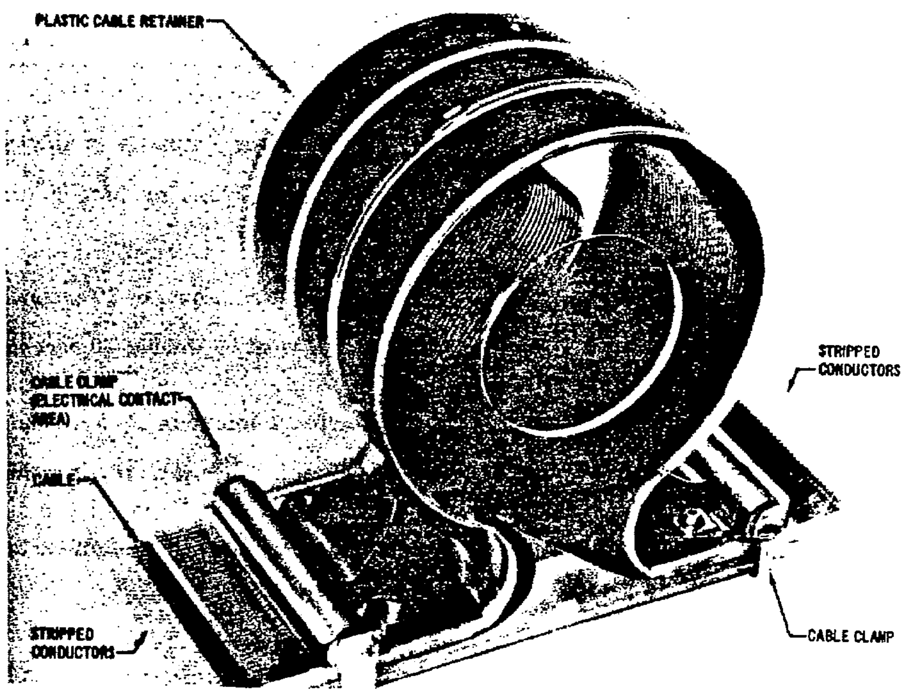


FIGURE 6-24. NASA/MSFC plating rack with cable.

CAUTION

To reduce the ionic action of dissimilar metals, the conductors are plated with nickel and gold. After the conductors have been stripped and the cleaning and plating operation has been started, do not allow more than 30 minutes to elapse between each operation until the conductors are plated. This will prevent subsequent oxidation.

Procedures for plating shall conform to the appropriate federal and military specifications as follows:

a. QQ-N-290 (Federal) - Nickel plating (Electro-deposited), Class 2

b. MIL-G-45204 (Military) - Gold plating (Electro-deposited), Type II, Class 1

The preparatory steps toward implementation of both nickel and gold plating are listed below. For detailed procedures, refer to the respective paragraph for plating (Paragraph 6.3.4.1 for nickel plating or Paragraph 6.3.4.2 for gold plating).

a. Mount cable into plating rack (Fig. 6-24). Clean conductors and attach jumper wire from cathode rod to rack.

b. Chemically clean conductors. To minimize wicking of the plating solution, do not submerge cable into the solutions beyond the stripped portion of the conductors.

c. In an emergency, if a plating rack is not available, electrical contact between the cathode rod and cable may be made by carefully applying Scotch Electrical Tape No. X-1226, 3M Company, St. Paul, Minnesota (or equal) to the exposed conductors and connect the jumper wire from the cathode rod to the tape. Plate opposite end of cable. Use extreme care in removing tape to avoid bending conductors.

6.3.4.1 Nickel Plating. If the cable has bare copper conductors, the conductor contact (stripped) areas shall be nickel plated per QQ-M-290 and the following subparagraphs (see Figure 6-25 for sequence).

6.3.4.1.1 Preparation for Plating. The preparation for plating is as follows:

a. Dip conductors in plater's cleaner (P-C-535A) for 60 to 90 seconds.

b. Rinse in overflow rinse for a minimum of 15 seconds.

c. Spray-rinse with deionized water for a minimum of 30 seconds.

d. Dip in ammonium persulfate, 10 percent by weight (90 percent H_2O), for 15 to 30 seconds.

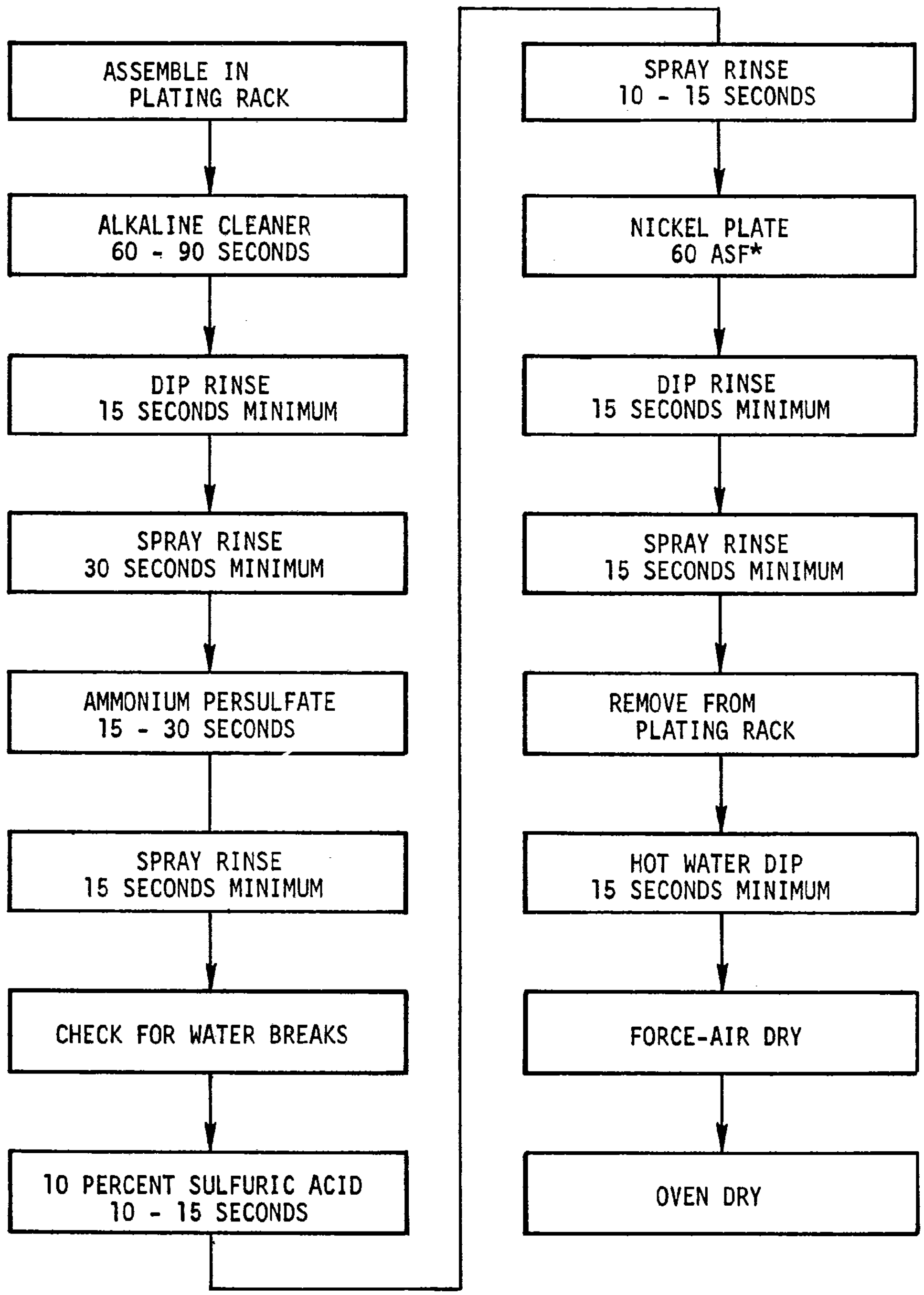
e. Spray-rinse with deionized water for a minimum of 15 seconds.

f. Check both sides of conductors for water breaks. If water breaks are present, reclean conductors per Paragraph 6.3.4.1.1, steps a through e.

g. Dip in sulfuric acid (Fed O-A-115 Class A, Grade 1) for 10 to 15 seconds.

h. Spray-rinse with deionized water for 10 to 15 seconds.

i. Nickel plate immediately.



*ASF - amperes per square foot

FIGURE 6-25. Process flow sequence for nickel plating.

6.3.4.1.2 Nickel-Plating Procedure. The nickel plating procedure is as follows:

a. Connect jumper wire from cathode rod to plating rack, before placing the conductors in the plating solution.

b. Lower conductors into the solution, making sure cable is positioned vertically.

c. Plate for a time sufficient to obtain a plate thickness of 0.000,050-inch (0.000,127-cm) minimum.

d. Dip-rinse the cable for a minimum of 15 seconds immediately upon removal from the nickel tank.

e. Spray-rinse with deionized water for a minimum of 15 seconds.

6.3.4.1.3 Post-Nickel-Plating Procedure. The post-nickel-plating procedure is as follows:

a. Soak in clean, heated, deionized or distilled water for a minimum of 15 seconds, maintaining water temperature at 150° ±30° F (66° ±17° C).

b. Force-dry with compressed, filtered air.

c. Place cable in a clean, filtered, circulating air oven for 30 minutes at 126° ±10° F (52° ±6° C).

6.3.4.2 Gold Plating. For the gold-plating sequence see Figure 6-26.

6.3.4.2.1 Cleaning Procedure. The cleaning procedure is as follows:

a. Immerse cable ends of racked cables in plater's cleaner (P-C-535A) for 60 to 90 seconds.

1. Wipe thoroughly with soft cellulose sponge.

2. Wipe only towards ends of the conductors so they will not be deformed during this process.

b. Rinse in overflow rinse for a minimum of 1 minute.

c. Spray-rinse with deionized water for a minimum of 15 seconds.

d. Check both sides of the conductor for water breaks. If water breaks are present, reclean conductor per Paragraph 6.3.4.2.1, steps a through c.

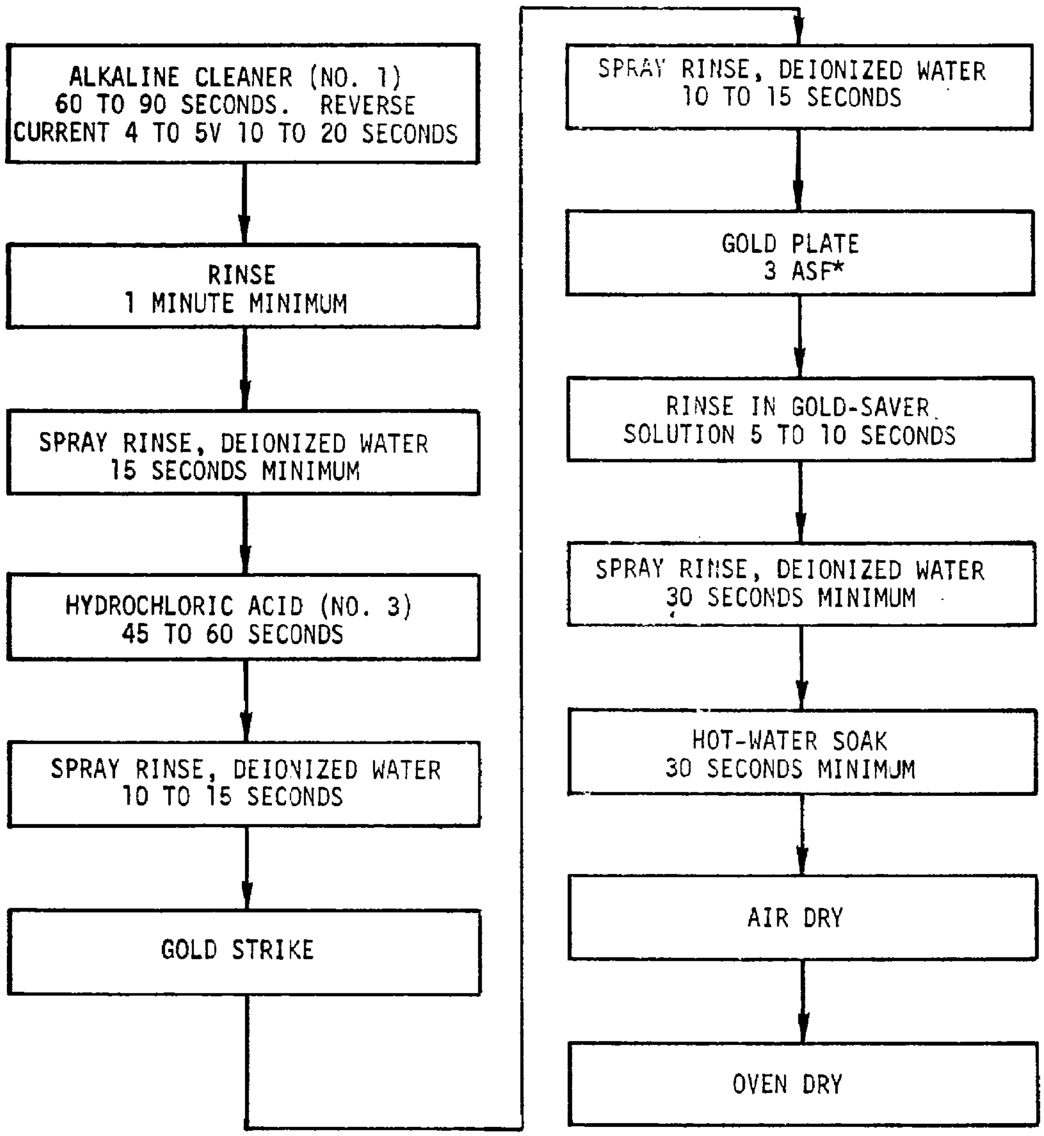
6.3.4.2.2 Gold-Strike-Plating Procedure. It is necessary to gold-strike the surface of the nickel-plated conductor before it is gold plated to enable the surface to better receive the final gold plating. The procedure for gold-strike plating is as follows:

a. Connect jumper wire from cathode rod to plating rack before placing any part of the conductors in solution, and turn current on.

b. Lower rack into solution and strike for 25 to 35 seconds at proper voltage.

c. Leave current on and jumper wire connected between cathode rod and plating rack while withdrawing conductors from solution.

d. Spray-rinse conductors with deionized water for 10 to 15 seconds.



*ASF - amperes per square foot

FIGURE 6-26. Process flow sequence for gold plating.

6.3.4.2.3 Gold-Plating Procedure. After the gold-strike plating is complete, the steps listed below are to be followed for the gold plating:

a. Connect jumper wire from cathode rod to plating rack before placing any part of the conductor in the solution.

b. Lower conductors into the plating solution, making sure conductors are positioned vertically.

c. Plate for a time sufficient to obtain a plating thickness of 0.000,050-inch (0.000,127-cm) minimum.

d. At the conclusion of the plating cycle, permit gold solution to drain from conductors back into tank.

6.3.4.2.4 Post-Gold-Plating Procedure. After the nickel-plated conductors have been gold plated, the post-plating procedure listed below shall be followed:

a. Spray-rinse with deionized water for a minimum of 15 seconds.

b. Soak in clean, heated, deionized or distilled water for a minimum of 30 seconds. Maintain water temperature at 150° ±30°F (66° ±16°C).

c. Force-dry with clean, filtered, compressed air.

d. Place cable in clean, filtered, circulating air oven for 30 minutes at 126° ±10°F (52° ±6°C).

e. Protect exposed conductors during subsequent handling.

6.3.5 FCC Plug Assembly.

6.3.5.1 Molded-On.

6.3.5.1.1 Rectangular (MIL-C-55544). The assembly procedure for molded-on plugs consists of three basic phases: (1) parts assembly, (2) molding, and (3) finishing (consisting of sprue removal, potting, and installation of the outer seal). This plug is shown in Figure 6-27.

6.3.5.1.1.1 Parts Assembly. The following is a detailed procedure for assembly of molded-on plugs:

a. Cables shall have been stripped per Paragraph 6.3.3 and plated per Paragraph 6.3.4 prior to assembly. The conductors shall have been exposed (stripped) a distance of 0.47 ±0.01 inch.

b. Make sure the registration of the cable corresponds to the requirements of the engineering drawing.

c. Thread conductors through windows of window piece.

d. Lift cam handle of seating tool (Fig. 6-28) into horizontal position, and retract the cam to provide space between the pressure plate and base.

e. Pass the conductors and window piece through the opening from the lower side of the tool.

f. Spread conductors with a suitable tool, insert cabling separator (thin one) between cabling strips, and lower the window piece almost to the base.

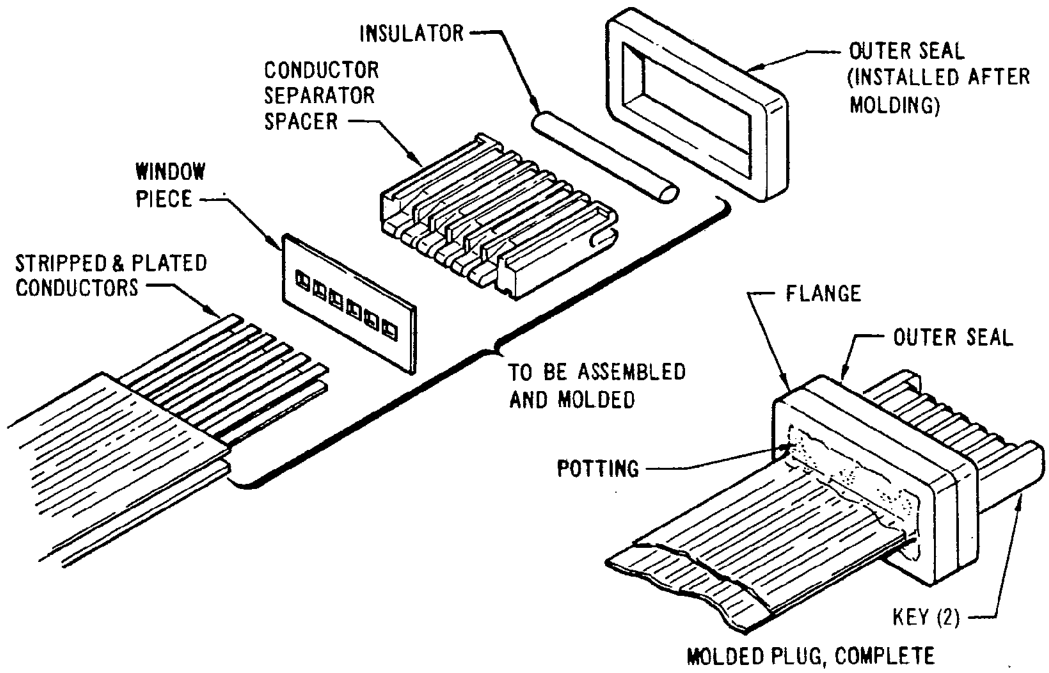


FIGURE 6-27. Molded-on plug.

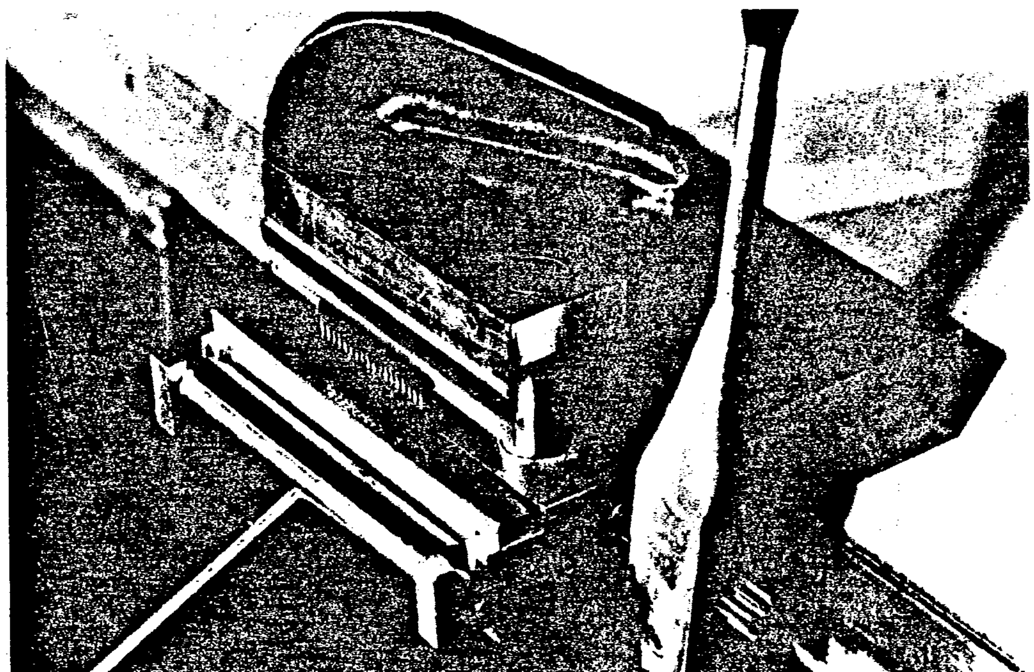


FIGURE 6-28. Seating tool - cable, window, and shuttle (spacer).

g. Move pressure plate against cabling, apply slight pressure with the cam handle, and press window piece to the base with the seater.

h. Apply full pressure to the pressure-plate lift seater and install conductor separator. (Turn small holes in conductor spacer toward cabling strip which is to be on the unkeyed side.)

i. Seat the conductor spacer, comb conductors into conductor spacer grooves, and remove cabling from the seating tool.

j. Open all jaws of the folding tool (Fig. 6-29) and insert cabling through the front opening to the adjustable stop.

k. Clamp conductor spacer with vise jaws by means of the vise jaws actuator.

l. Rotate left-horizontal jaw actuator counterclockwise to actuator stop, and return actuator stop, and return actuator to the jaw-open position.

m. Lower the vertical-fold plate actuator until the plate has folded the conductors into the conductor spacer groove.

n. Rotate the right horizontal-fold jaw actuator clockwise to actuator stop, and return actuator to the jaw-open position.

o. Repeat step m.

p. Remove cabling from folding tool, cut and install insulator (1/16-inch (0.15 cm) diameter) round, silicone-rubber rod into conductor spacer, and cut off flush at both ends using an Xacto knife.

6.3.5.1.1.2 Molding. Either molding material described below may be used if it meets the temperature requirements of the systems:

a. L-P-393 is a thermoplastic polycarbonate resin with exceptional impact strength, dimensional stability, low mold shrinkage, and a useful temperature range up to 270° F (132° C). The polycarbonate should be predried and kept dry during the melt processing. Fast injection rates are usually optimum; molding conditions and mold surface should be highly polished.

b. Polyphenylene oxide (PPO) is a high-performance thermoplastic that can be used over a wide temperature range with a brittle point of approximately 340° F (171° C) and heat distortion temperature of 374° F (190° C) at 264 psi (18.48 kg/cm^2). When molding PPO, it is desirable to have a cool mold, but it is essential to have maximum cooling in gate areas. Experience has shown that few problems are encountered with molds that can be run during production at surface temperatures between 64° F (18° C) and 100° F (38° C) in the gate area.

1. Figure 6-30 shows an example of how the inserts would look in the mold-halves for preparing plugs. To attain the assumed display, one must imagine that the mold-halves are hinged away from each other.

2. Mold halves must be partially disassembled to gain access to screws that secure the upper mold-half inserts.

3. To reduce downtime during molding operations, several runs of flat cable should be assembled.

4. With the appropriate mold die set up in the machine, all connector plugs of that size should be molded.

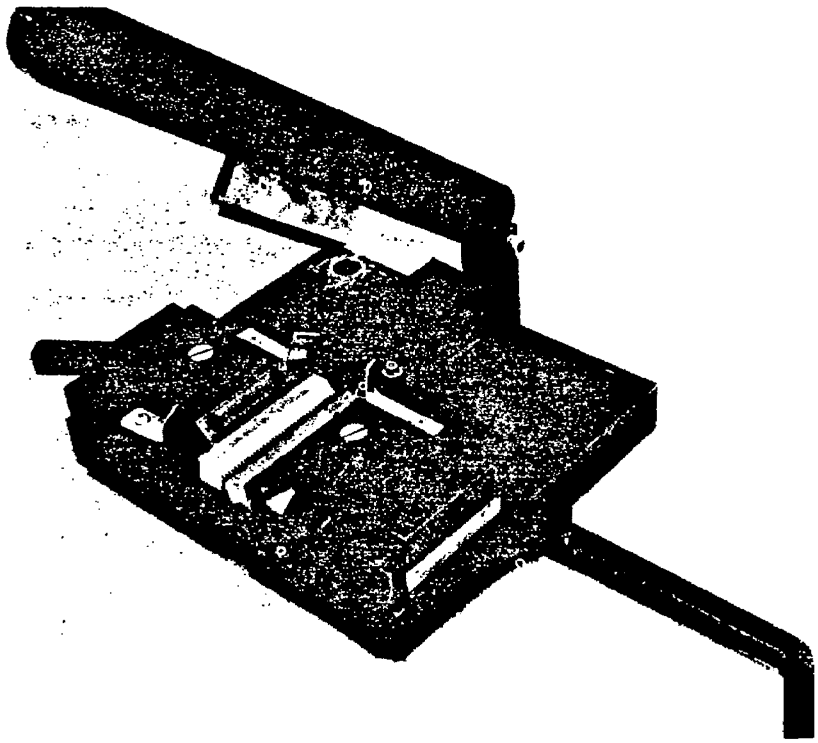


FIGURE 6-29. Conductor folding tool.

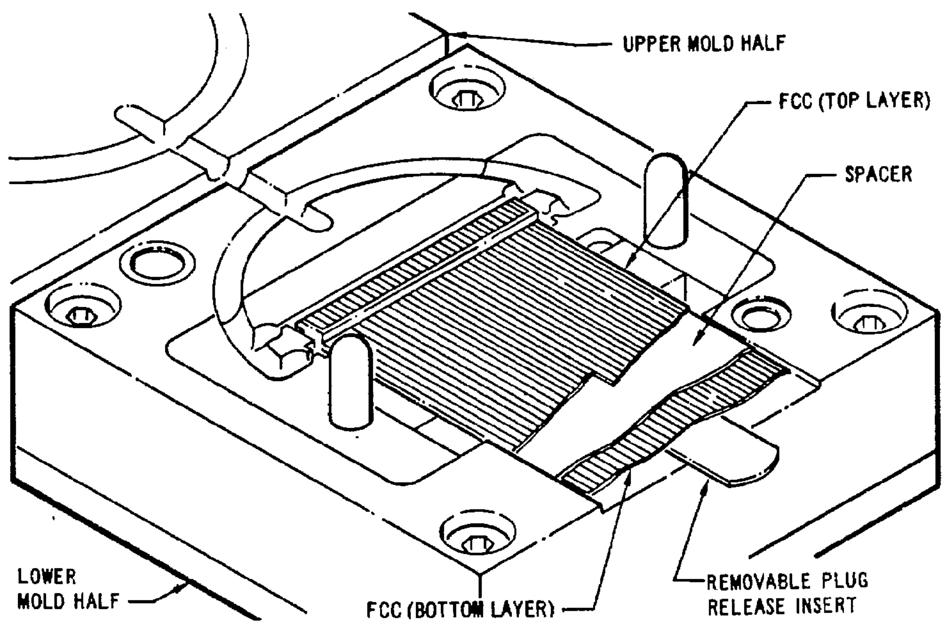


FIGURE 6-30. Plug molding - die.

c. Insert spacer between cable layers. If harness cable segments do not fill both layers, install short lengths of filler cables.

d. Place assembled plug into lower mold-half so that the guide pins of the mold-half fit into the small holes in the conductor separator.

e. Close mold halves and inject molding material.

f. At completion of molding cycle, open mold and remove plug and spacer.

6.3.5.1.1.3 Finishing. The third phase of the procedure for molded-on plugs follows:

a. Remove mold sprue from plug (Fig. 6-31).

b. Using an Xacto knife, trim the flash and excess material.

c. Remove any material that has flowed over the contact area.

d. Visually examine the plug to be potted.

1. Carefully remove pieces of foreign matter from the area to be potted.

2. Use isopropyl alcohol and clean the area to be potted, as well as the flat cable, for at least 2 inches (5.00 cm) above the area to be potted.

e. Place the plug assembly in the potting tool as shown in Figure 6-32.

f. Pot the rear end of the plug with a potting compound, meeting the requirements of MSFC-Spec-202A, Type III, per MSFC-Proc-186C.

6.3.5.1.2 Cylindrical (MIL-C-55544). Cylindrical plugs are composed of PPO (refer to Paragraph 6.3.5.1.1.2).

The assembly procedure listed below for cylindrical plugs (Fig. 6-33) is similar to the procedure used for molded-on plugs.

a. Select cables that have been stripped per Paragraph 6.3.3, plated per Paragraph 6.3.4, and are to be terminated in the same plug. The conductors shall have been exposed a distance of 0.425 ±0.05 inch (1.08 ±0.1 cm).

b. Insert the conductors through their respective openings (beveled side) of the window piece.

c. Separate conductors of one cable from those of the other cable, and insert the conductor spacer into the window piece.

d. Clamp the conductor spacer with the vise jaws, using the conductor folding tool.

e. Rotate the horizontal jaws one complete cycle to bend the conductors over the end of the conductor spacer.

f. Lower the vertical-fold plate actuator until the conductors are seated in the spacer grooves.

g. Press insulator into the conductor spacer groove and trim the insulator flush with the sides of the conductor spacer.

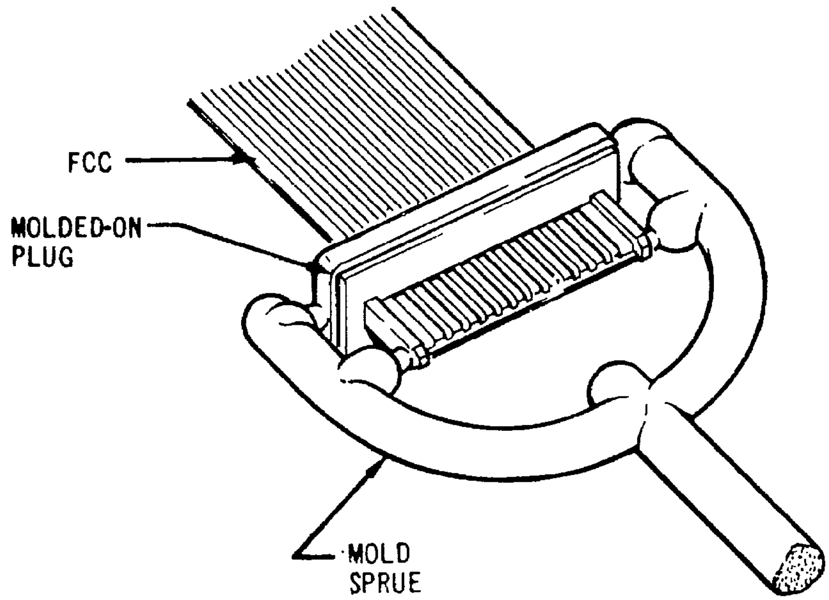


FIGURE 6-31. Molded plug with sprue intact.

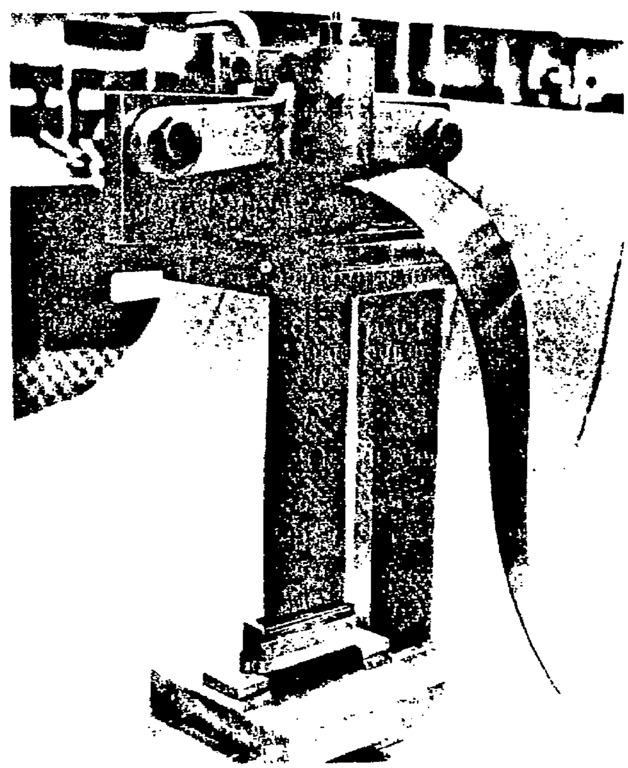


FIGURE 6-32. Plug assembly in potting tool.

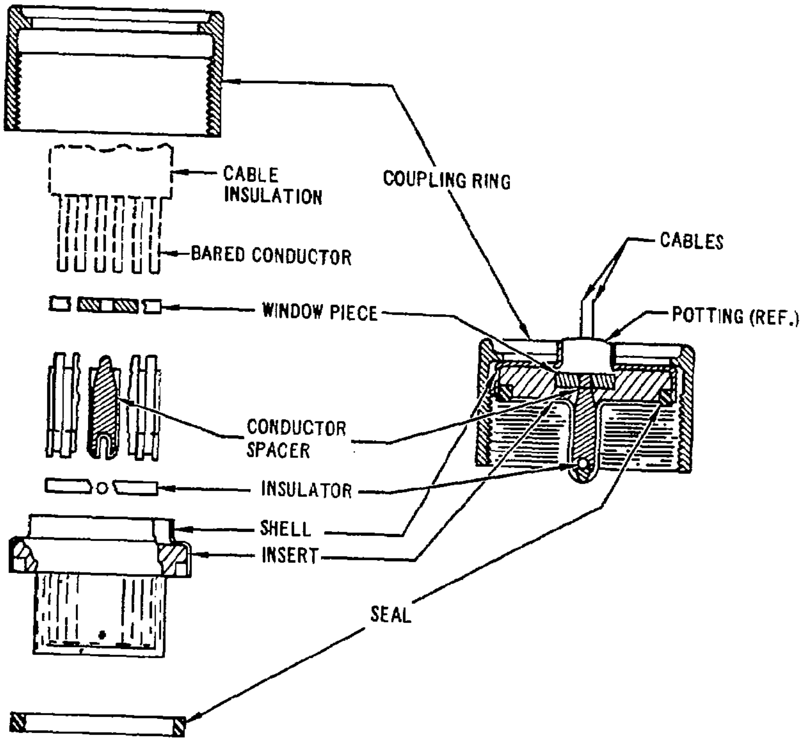


FIGURE 6-33. Cylindrical plug parts.

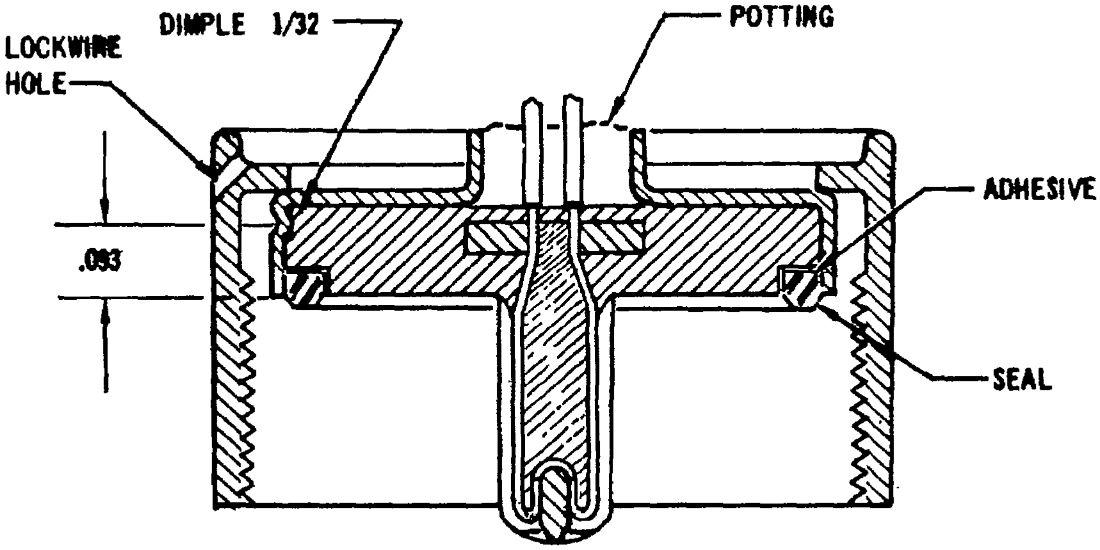


FIGURE 6-34. Cylindrical plug (dimpled).

h. Mold the insert around the assembled parts. The suggested molding procedure is given below:

1. Install proper mold halves into the molding machines, and heat the mold to 285°F (141°C).

2. Load hopper with dry molding material, and heat the material between 590° and 610°F (310° and 320°C).

3. Purge machine, and charge cylinder with approximately 20 percent more material than is required for the part.

4. Insert cable spacer, and place the assembled parts properly in the lower mold half.

5. Close the mold-halves and apply 10,000 to 14,000 psi (700 to 900 kg/cm^2). Hold the pressure for 15 to 20 seconds.

6. Release pressure and recharge cylinder.

7. Allow 40 seconds cooling time between pressure release and opening of the mold halves. (Cycle requires approximately 1 minute.)

8. Open mold halves about 0.5 inch (1.27 cm) and pull bottom insert out. Open mold halves more to eject the molded part.

i. Remove molded part from machine.

j. Remove cable spacer from between cables.

k. Trim sprues from molded plug body with an Xacto knife.

NOTE

The above is a suggested procedure for injection molding. This material may also be compression molded for additional physical advantages at a higher price.

l. Allow 4 hours to cool.

m. Move shell onto body.

n. Dimple shell with a spring-loaded punch to keep shell on molded body.

o. Dimples must be 120 degrees apart and 0.09 inch (0.24 cm) from front rim of shell (Fig. 6-34).

p. Per Paragraph 6.3.5.1.1.3, apply potting compound around and between the cables at the rear of the plug (Fig. 6-34).

q. Apply adhesive to groove around plug body and carefully seat the seal into the groove (Fig. 6-34).

6.3.5.2 Premolded. Premolded plugs are composed of parts that require no additional molding. The premolded parts are assembled and potted to further secure and seal the assembly. A seal is cemented into a groove on the plug housing to seal the junction between plug and receptacle.

The potting compound for bonding the assembly is Lefkoweld Type 185 epoxy structural adhesive manufactured by Leffingwell Chemical Company, Whittier, California (or equal). This is a high-purity epoxy polymer that, when thoroughly blended with Lefko activators LP and LSA, cures at 199 °F (93 °C) to a pale-yellow casting, with a minimum of shrinkage.

6.3.5.2.1 Unshielded (MIL-C-55544). Unshielded, premolded plugs (Fig. 6-35) are composed of Fiberlite E-2748 manufactured by Fiberite Corporation, Winona, Minnesota. This is a glass-reinforced, medium-impact, epoxy molding compound that offers good impact strength combined with very low flow. It also offers good electrical properties and excellent heat and chemical resistance.

The following is a procedure for fabricating these plug assemblies:

a. Strip conductors to a 0.525 ±0.05-inch (1.33 ±0.1 cm) length using the appropriate procedure given in Paragraph 6.3.3.

b. Plate conductors as instructed in Paragraph 6.3.4.

c. Select plug parts that will accommodate the cabling-strip widths.

d. Thread-stripped conductors (both cables) through central opening of base plate. Move base plate back on cabling far enough to give liberty in working with each strip.

e. Position conductors of the cables into the slots of the conductor spacer, moving the stripped margin of insulation against the base of the conductor spacer ribs. Bend conductors into the wedge groove and install the wedge.

f. Thread conductor spacer through housing, making sure that it is seated well into the housing.

g. Move base plate into position in the housing.

h. Insert locking keys and twist ears of each key (Fig. 6-36).

i. Pot base of plug with potting compound Lefkoweld Type 185 (or equal) per Paragraph 6.3.5.1.1.3.

j. Apply a thin film of Dow Corning, No. 140 cement (or equal) into seal groove of plug housing.

k. Install silicone rubber seal into groove. Make sure that the seal is seated well.

l. Stamp conductor numbers on plugs.

6.3.6 Folding Flat Cable. Angular fold or folds shall be made in the following manner:

a. Unshielded cable - Fold the cable over on itself as depicted in Figures 6-37 and 6-38. Each cable may be folded individually and secured with H-Film tape.

b. Shielded cable - Fold the cable over a 0.25-inch minimum diameter rod. The rod shall be 0.25-inch longer than the fold line of the cable. After folding, secure with H-Film tape as shown in Figure 6-39.

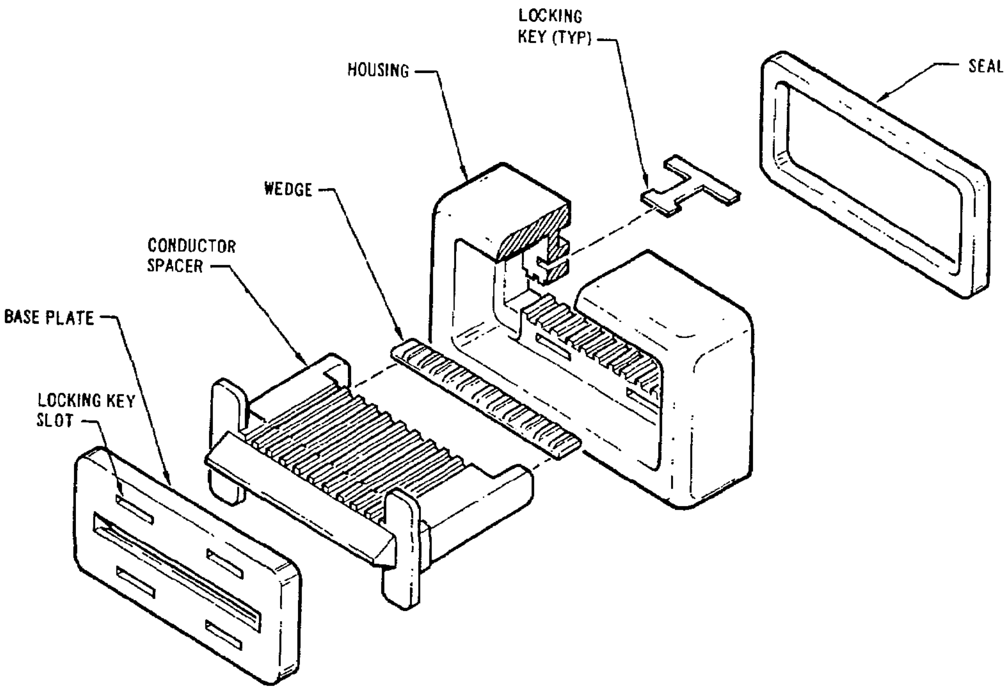


FIGURE 6-35. Typical premolded plug parts.

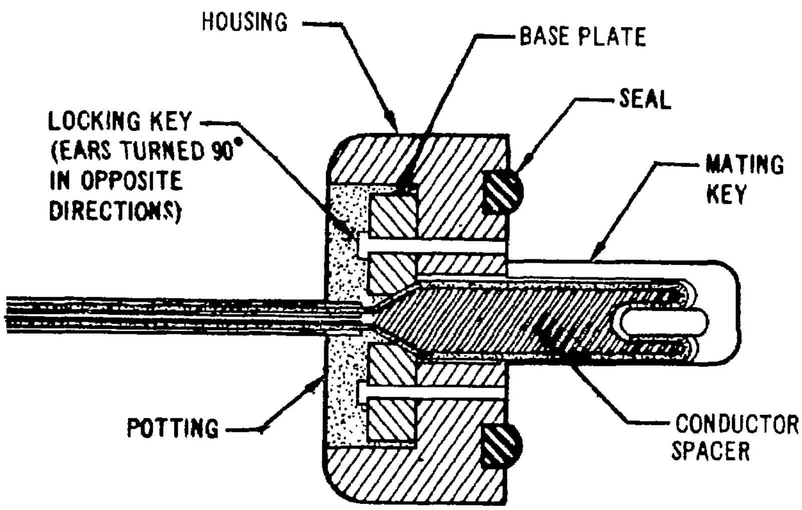


FIGURE 6-36. Premolded plug (section).

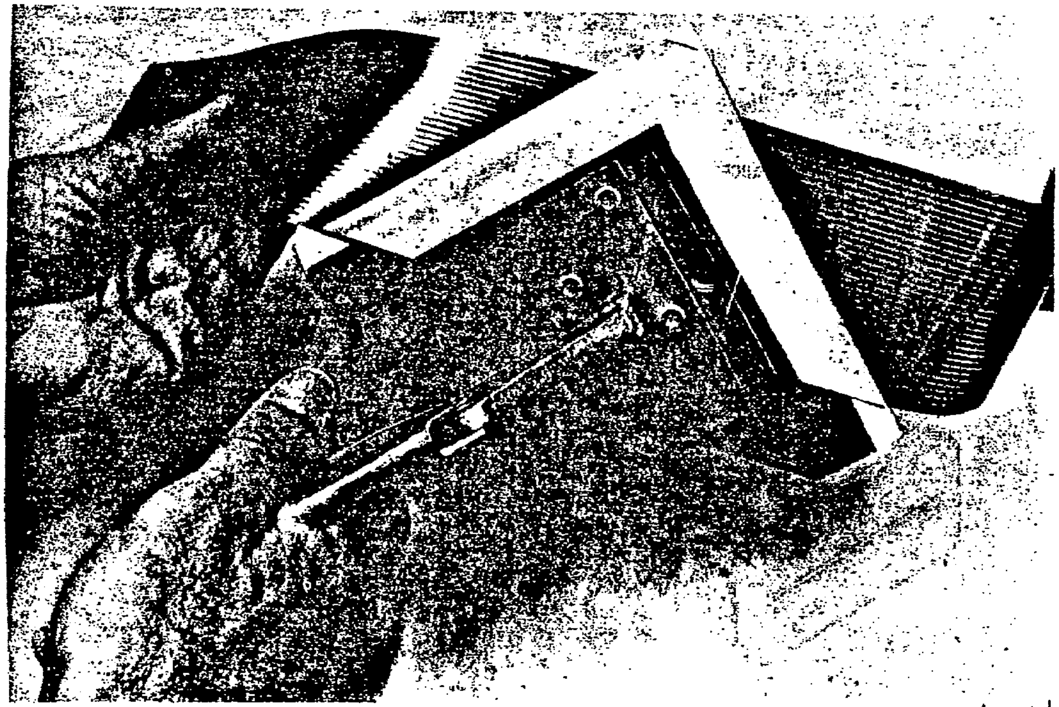


FIGURE 6-37. FCC folding tool.

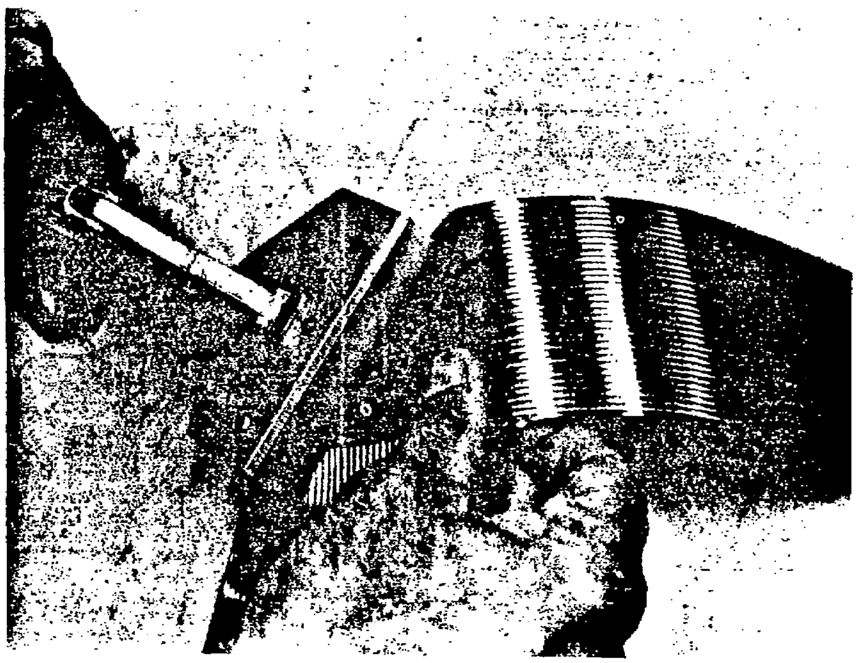


FIGURE 6-38. FCC folding tool.

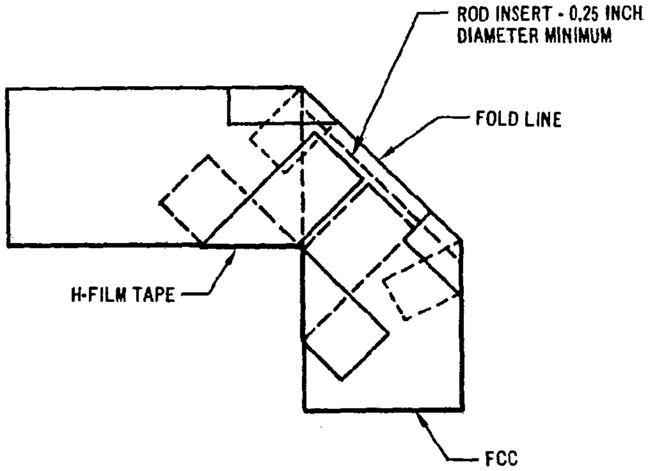


FIGURE 6-39. Shielded cable fold.

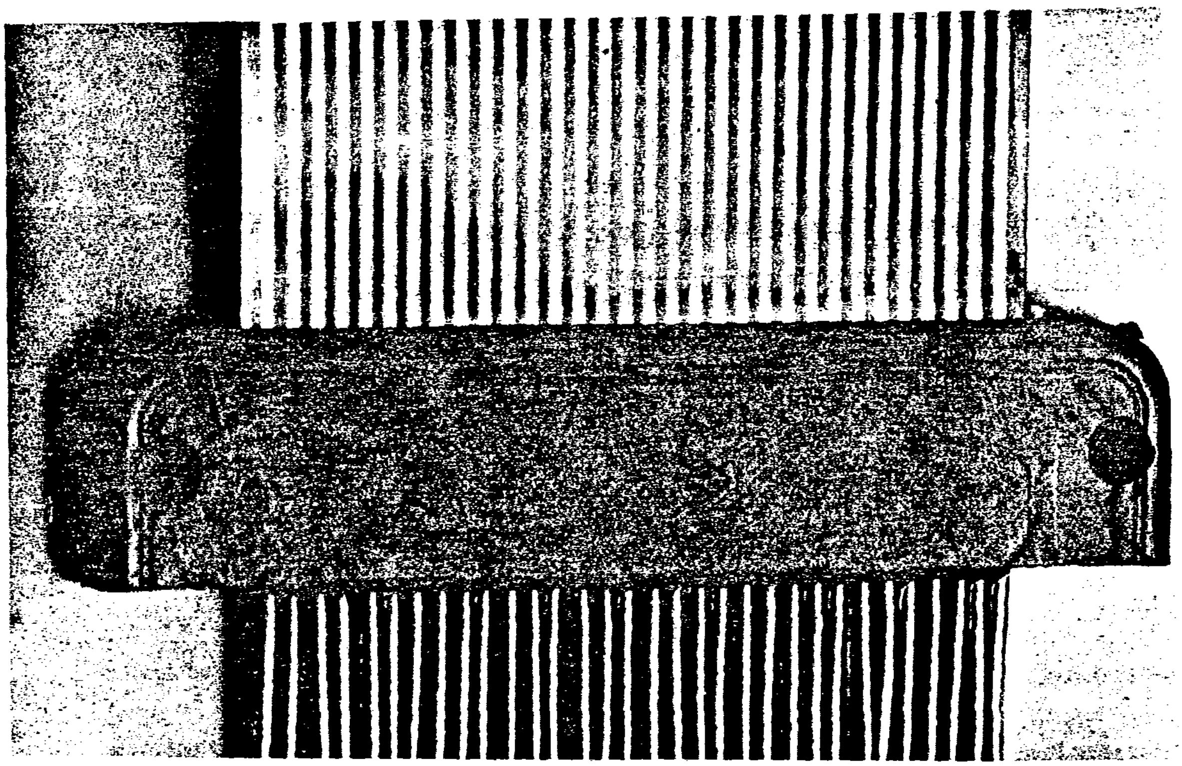


FIGURE 6-40. Transition from FCC to RWC.

c. Angles other than 45 or 90 degrees may be accomplished in a similar manner.

Up to 10 cables may be folded in a bundle. If there are more than 10 cables in one run, a new run should be started along side the first. Refer to Section III, Paragraph 3.2.6.3.2, for other considerations.

6.3.7 FCC to RWC Transition. The transition from flat wires to round wires (Fig. 6-40) is accomplished by preparing the conductors (Fig. 6-41), clamping the conductors in a handling fixture (Fig. 6-42), and soldering. With the soldered conductors still in the handling fixture, molds are installed, and the junctions are molded with a suitable compound. Transitions can be made for all sizes of FCC.

6.3.7.1 Conductor Preparation. All conductors must be stripped, cleaned, and tinned before being fixed into position for soldering. In addition to the stripping, cleaning, and tinning processes, FCC's must be prepared with a window piece, conductor spacer, and insulator (Fig. 6-41).

6.3.7.1.1 Cable Shearing. Shear the cable square as specified in Paragraph 6.3.2.

6.3.7.1.2 Stripping Procedure (Flat Cable). Strip the cable as outlined in Paragraph 6.3.3 in accordance with the type of cable being used.

6.3.7.1.3 Stripping Round Wire. All round wires must be stripped 0.375 ±0.030 inch (Fig. 6-41). Any conventional method may be used, provided the conductor is not damaged and the stripped insulation margin is smooth.

6.3.7.1.4 Cleaning and Tinning. The following steps are recommended for the cleaning and tinning procedures:

a. Clean both flat and round conductors ultrasonically for 5 minutes in Freon-113.

b. Allow the clean conductors to dry, and tin by dipping them into an ultrasonic-excited bath of SN 60 solder at 250° to 260°C for 1 to 2 seconds.

c. Allow the tinned conductors to cool, and remove all flux residues by brushing with ethyl alcohol. Brush away from insulation, giving particular care to the area between the round-wire conductor and insulation, which is most likely to collect residue.

d. Protect conductors from bending (Fig. 6-7) and becoming contaminated.

6.3.7.1.5 Final Preparation of FCC. Thread the conductors into the conductor spacer, fold the conductors into the insulator groove, and insert the insulator.

CAUTION

Repeated flexing of the cables behind the window piece will break the cable conductors. Care must be exercised to prevent cable bending until the potting material is applied.

6.3.7.2 Soldering and Potting. The procedure for soldering and potting is as follows:

a. Insert separator plug (Fig. 6-43) between cables with the unflanged end against the window piece.

b. Place the cables and separator plug in the left slot of the fixture body with the separator plug flanges against the left, outside edge of the fixture (Fig. 6-42).

c. Position the flat-cable retainer plate over the cables, and secure the plate loosely with two short thumbscrews.

d. Insert gage block over cables between window piece and fixture body. With the gage block fitting snugly and the separator plug against the fixture body, tighten the thumbscrews just enough to hold the cables in position.

e. Remove the gage block.

f. Select the proper retainer, or retainers (depending upon the round wires to be installed), and position it on the fixture body, making sure the tapped holes of the central retainer correspond to the untapped holes of the fixture body.

The basic wire installation possibilities are:

1. All unshielded-round wires to both flat cables.

2. All shielded-round wire to both flat cables. Skip every other cable conductor.

3. All unshielded-round wires to one flat cable and all shielded-round wires to the other flat cable.

4. Combination of unshielded-and shielded-round wires to either or both flat cables.

g. Holding the retainer (or retainers) in position, turn the fixture over (Fig. 6-44) and install two short thumbscrews. Use the untapped holes of the fixture body and the tapped holes of the central retainer. Leave retainers just loose enough to receive the anticipated wires.

h. Insert the prepared conductors of the round wires through the appropriate grooves (Fig. 6-44), aline the conductor ends approximately 0.05 inch from the flat-cable conductor spacer, and tighten the thumbscrews just enough to hold the wires snug, but not so tight that the wires cannot be adjusted into the cable conductors. Be sure to arrange the spacing of conductors for convenient soldering and effective potting.

i. Starting with the most remote wire to be soldered, position the round conductor on the corresponding flat-cable conductor as shown in Figures 6-41 and 6-42. (The tolerances are essential to facilitate cleaning between conductor ends and window piece and to prevent particles of insulation from being embedded in the solder fillets.)

j. Add a slight amount of solder to the contact area.

CAUTION

Never use a soldering iron that is hotter than 290°C, nor leave the iron in one place longer than 5 seconds; otherwise, the conductor spacer or round-wire insulation may be damaged.

k. Repeat steps i and j for joining other wires to this particular flat cable, and tighten the thumbscrews slightly to protect the solder joints from any possible strain that might be incurred during further handling.

l. Turn the handling fixture back over and install the peripheral retainer (with grooves up) and round-wire retainer plate with the two long thumbscrews.

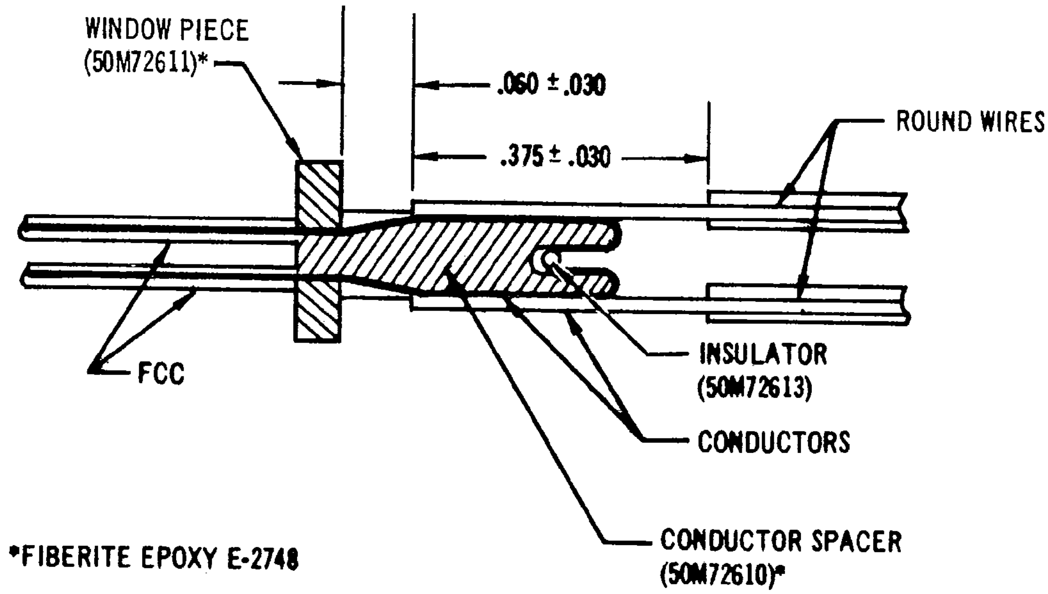


FIGURE 6-41. Conductors prepared for soldering.

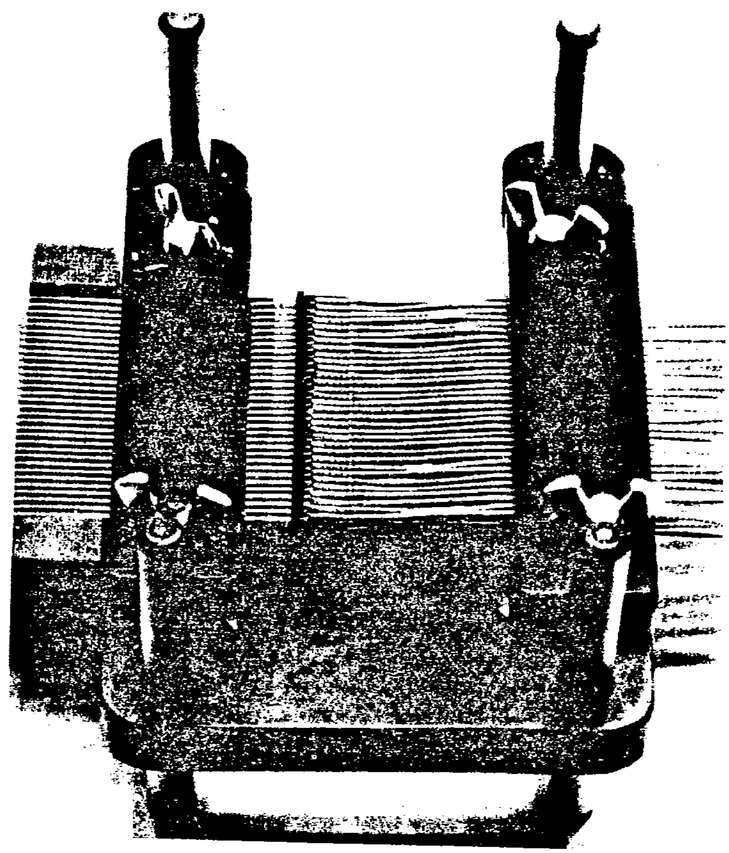


FIGURE 6-42. Handling, soldering, and potting fixture.

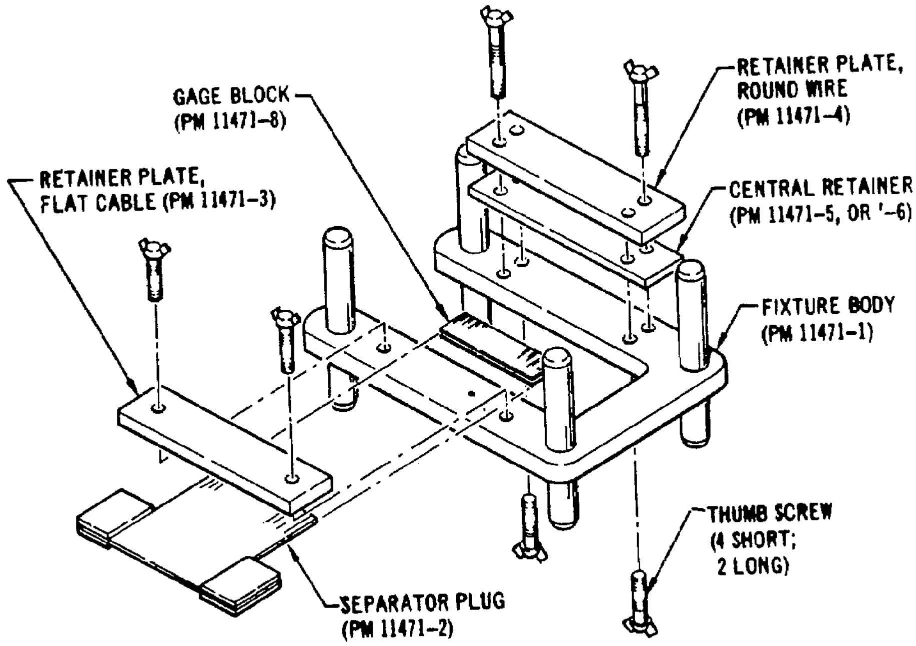


FIGURE 6-43. Handling fixture components.

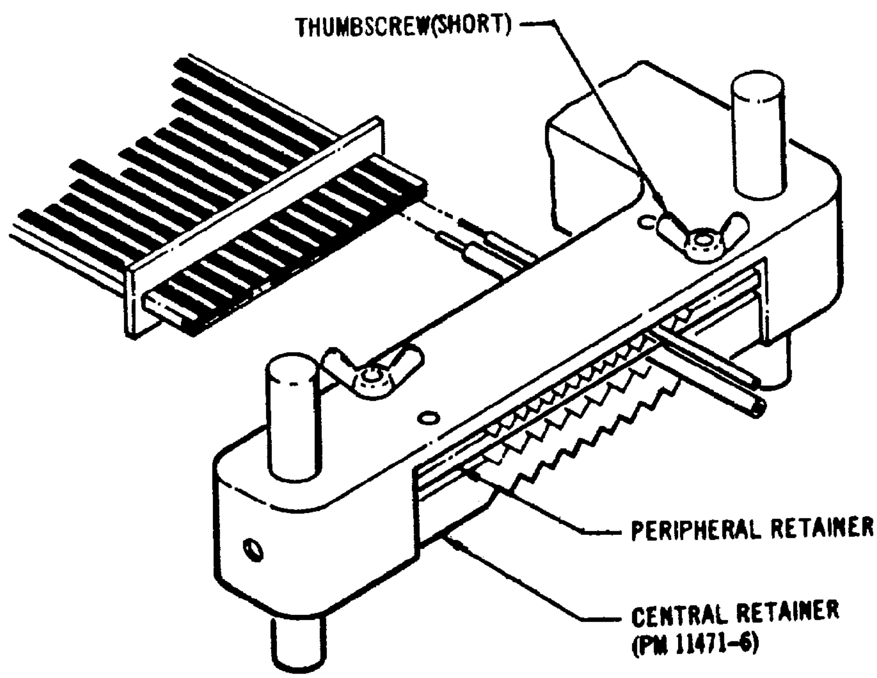


FIGURE 6-44. Shielded-unshielded wire installation (first cable).

m. Repeat steps h through k for joining wires to the second FCC.

n. After all wires are soldered, remove flux residues with a soft brush and ethyl alcohol.

o. Inspect all joints to make sure that joints are secure, that no parts have been damaged, and that excessive solder does not create a possibility of short circuiting.

p. Apply mold-release material to the mold cavity according to the recommendations and processes given in MSFC-Proc-196. If mold leaks, apply a small amount of silicone RTV-501 around the mating surfaces of the mold halves. The silicone RTV-501 must meet requirements on MSFC-Spec-379 and be applied in accordance with MSFC-Proc-380.

q. Install mold halves (Fig. 6-45) and pot with Stycast 2651. The potting material must meet the requirements of MSFC-Spec-222, Type II, and be applied in accordance with MSFC-Proc-196. Care should be given to the flex relief area where cable exits from the potting material.

r. Allow potting material to cure for 8 hours at room temperature (or for 1 hour at a temperature between 71° and 76°C) and remove the mold halves.

s. Remove handling fixture and inspect the molded form.

6.3.8 Procedure for Termination FCC to Ground Lugs. The following describes the joining of FCC conductors to copper ground lugs and the conformal coating of the joint area (Fig. 6-46).

a. Clean the conductors and the area of the ground lug which is to be soldered with an abrasive rubber eraser, being careful at all times not to deform the conductors.

b. Follow the abrasive cleaning by wiping with a clean cloth dampened with Toluene (JT-458).

c. Tin the conductor ends and the ground lug using SN63 resin core solder.

d. Apply flux to the tinned area on the ground lug.

e. Arrange the cable and ground lug so that both parts are firmly held and the conductors are bearing flat against the ground lug.

f. Apply heat to the ground lug with a 100-watt soldering iron, and add solder if necessary.

g. For larger ground lugs, an auxiliary heat source may be necessary.

h. Completely remove the flux residues using a nonmetallic-bristle brush wet with Toluene.

i. Brush-coat epoxy potting compound EPD TC459 over the soldered conductors and over 0.25-inch of the adjacent cable insulation. Cover the corresponding areas on the opposite side of the cable, and fill the space between the cable and the unsoldered area of the ground lug.

j. Cure the epoxy coating for 24 hours at 60°C.

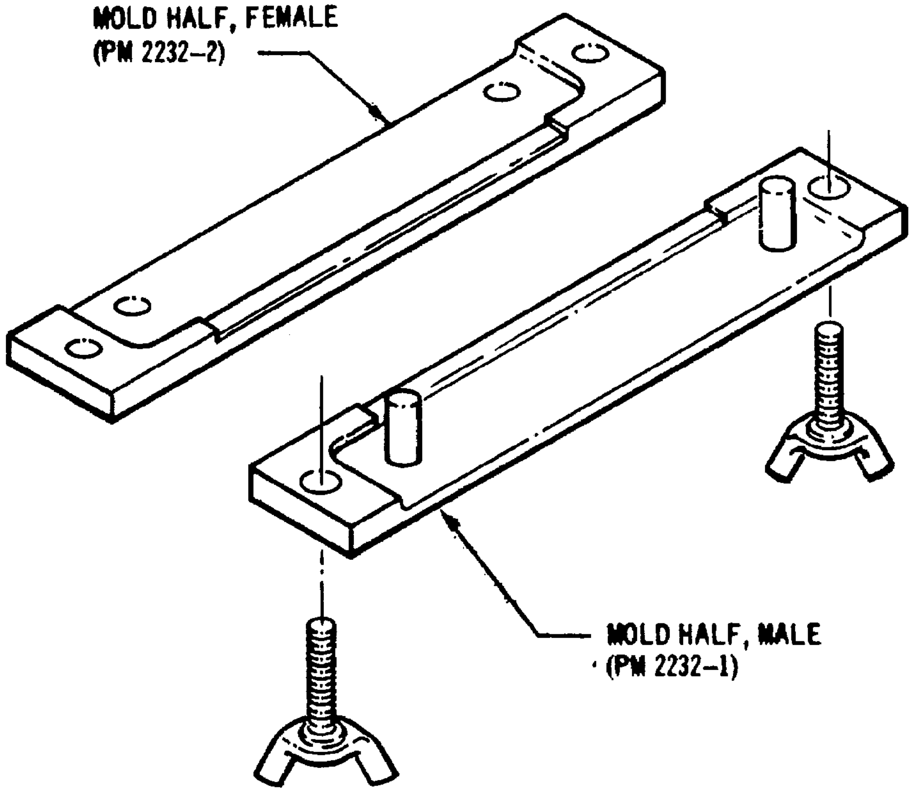


FIGURE 6-45. Mold halves before installation.

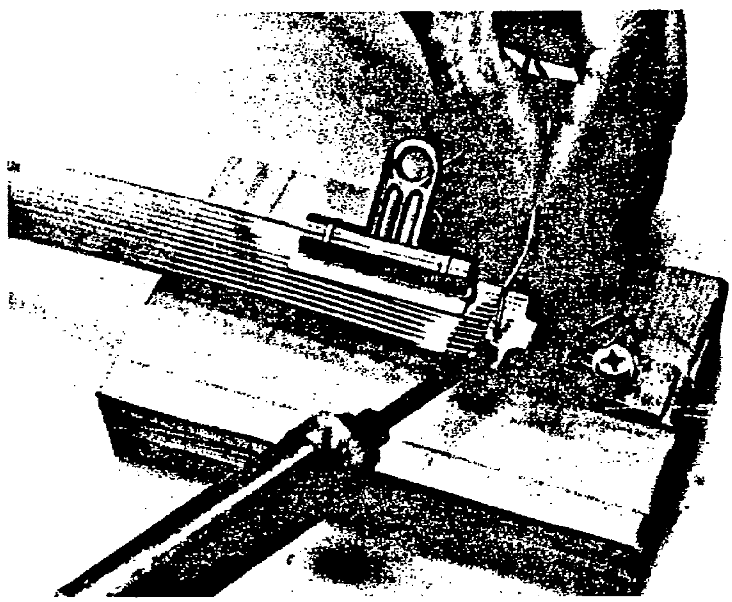


FIGURE 6-46. Soldering FCC to ground lug.

6.4 Assembly and Installation of FCC Harnesses

The mockup is used to develop, route, and support the required FCC harnesses as explained in Paragraph 6.2.

6.4.1 FCC Cable Assembly. The developed Mylar mockup cables are removed from the mockup and used as patterns for the manufacturing of the production FCC harnesses (Fig. 6-47). Particular attention must be paid to cable conductor registration in the plugs and cable segment registration in the harness runs. The cable identification provided by the cable manufacturer, along one edge of the FCC, identifies the index edge for each cable segment.

6.4.2 FCC Harness Installation. The production FCC harnesses are installed on the end items to duplicate the installation on the mockup and to conform to the requirements of the engineering drawings.

6.4.3 Installation of Supports and Clamps. The installation of the supports and clamps for FCC is governed by the number of bundles, the distance between bundles, and the branches of each bundle. Cables are to be supported as required by engineering drawings.

Figure 6-48 shows various types of support sections that have been used for FCC. The modular hole patterns on the FCC mounting surfaces permit the acceptance of the modular-width clamps selected. The various support sections may be bonded, riveted, or bolted to existing structure.

The installation of a typical high-temperature FCC clamp (Fig. 6-49) is accomplished as follows:

a. The FCC harness is aligned and positioned on the support.

b. The clamp is positioned on top of the harness.

c. The fasteners in each end of the clamp are aligned with the holes in the support.

d. Pressure is applied on the clamp until the aluminum spacers of the clamp come in contact with the support.

e. The fasteners are turned to secure the clamp to the support.

The installation of a typical Velcro clamp (Paragraph 2.5.3.1) is accomplished as follows:

a. The Velcro clamp is positioned between the FCC and the support bracket.

b. The fasteners are aligned with the holes in the support bracket and the plungers depressed, securing the cable clamp to the support bracket.

c. The cable clamp is opened by separating the hook-and-pile fabrics.

d. The FCC bundles are positioned over the clamps and the Velcro pile material is attached to the bundles. The bundles are then pressed down in the clamp area and the loose ends of the clamps are secured by applying hand pressure.

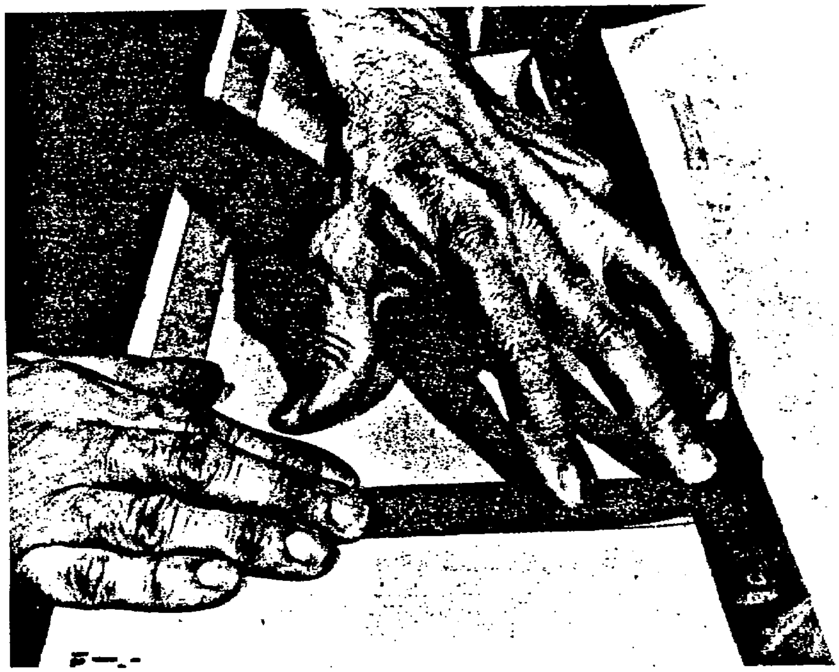


FIGURE 6-47. Duplicating Mylar mockup harness with FCC.

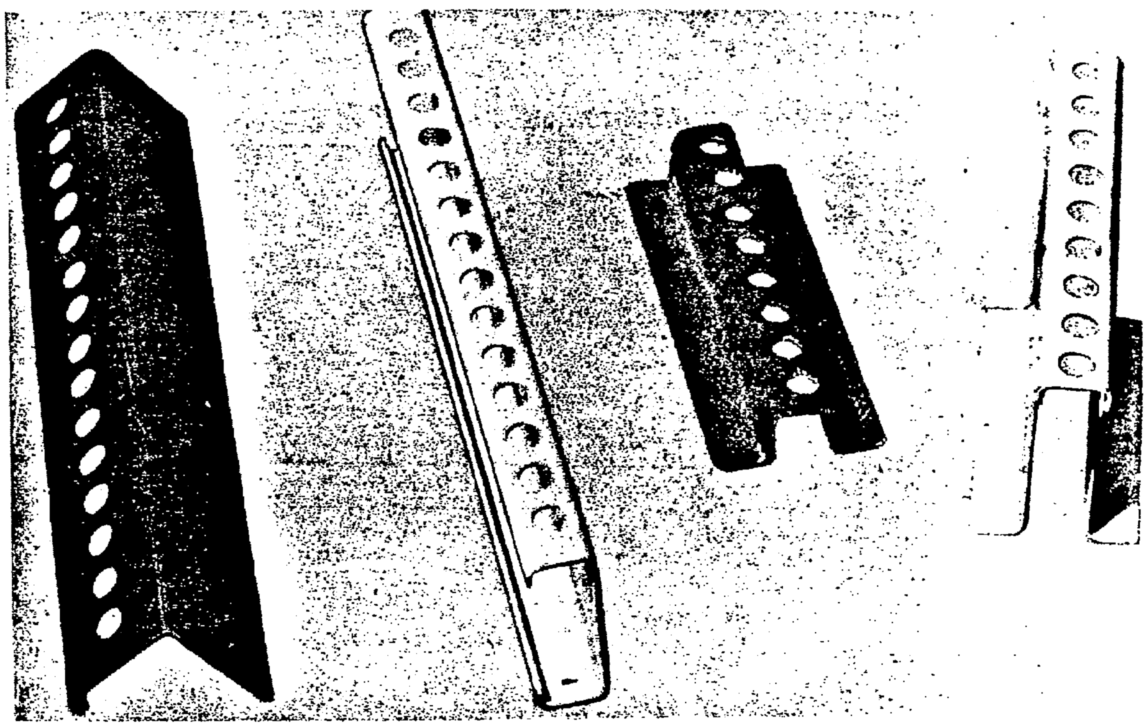


FIGURE 6-48. FCC clamp supports.

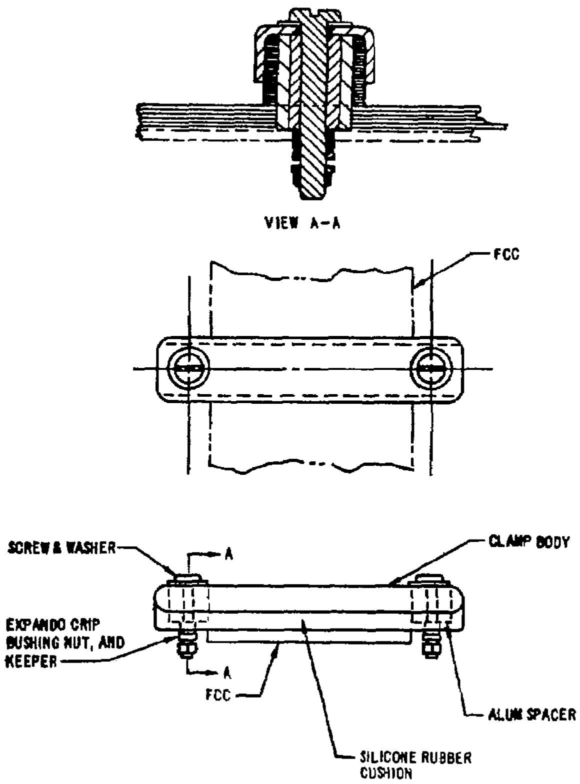


FIGURE 6-49. High temperature, 200° C clamp.

6.5 Summary

This section contains information for the development, fabrication, and installations of interconnecting FCC harnesses, both shielded and nonshielded. Methods for protection of FCC harnesses during manufacturing are also included.

Following is a tooling and materials list which summarizes those discussed in this section for FCC manufacture and installation. This list, plus appropriately selected FCC hardware from Section II, represents the type of physical items required to produce FCC harnesses and systems. Common shop items, such as benches and hand tools, are not included in the tooling and materials list.

MANUFACTURING TOOLING AND MATERIALS LIST

1.0 Mockup Manufacture and Installation.

- 1.1 10-mil Mylar tape (varying widths and appropriate length)
- 1.2 Masking tape
- 1.3 Plastic cables ties
- 1.4 Stapler
- 1.5 Wedge/lock clamp
- 1.6 Clips with plastic fasteners
- 1.7 Other miscellaneous (Fig. 6-2)

2.0 Cable Shearing

- 2.1 Di-Arco precision shear
- 2.2 Heavy duty scissors
- 2.3 Paper cutter
- 2.4 Cutoff line-marking fixture
- 2.5 Handling device (Fig. 6-5); also used in other operations.

3.0 Cable Stripping

- 3.1 Chemical
  - 3.1.1 Heater
  - 3.1.2 Beaker
  - 3.1.3 Thermometer
  - 3.1.4 Maskants
  - 3.1.5 Stripping solutions.

3.2 Mechanical

3.2.1 Abrasion

a. Viking FCC stripping machine

b. Rush FCC stripping machine

c. Carpenter FCC stripping machine

3.2.2 Cold Blade

a. NASA cold stripper

b. Plane stripper

c. Gore stripper

3.3 Conductor protector (Fig. 6-7)

4.0 Conductor and Shield Plating

4.1 Plating rack (Fig. 6-24)

4.2 Nickel-plating equipment

4.3 Gold-plating equipment

5.0 Plug Assembly

5.1 Molded-On

5.1.1 Injection, transfer, or compression molding equipment

5.1.2 Plug mold dies

5.2 Premolded

5.2.1 Seating tool (Fig. 6-28); also used for molded-on plug

5.2.2 Conductor folding tool (Fig. 29); also used for molded-on plug

5.2.3 Potting fixture (Fig. 6-32); also used for molded-on plug

6.0 Cable Folding

6.1 Folding tool (Fig. 6-37)

6.2 Folding tool (Fig. 6-38)

6.3 Permacel H-Film tape (Fig. 6-39)

7.0 FCC Harness Installation

7.1 Temporary supports (Fig. 2-43)

7.2 Silastic impregnated glass cloth tape

8.0 FCC to RWC Transition Manufacture

8.1 Handling fixture (Fig. 6-42)

8.2 Separator plug (Fig. 6-43)

8.3 Mold halves (Fig. 6-45)