CHAPTER 7

CABLING AND FABRICATION METHODS

7.1 CABLE SEGREGATION

Because of the possible electronic interference which may be encountered in an electrical installation, cable and wire segregation shall be considered during the initial installation layout. Electronic interference is defined as any conducted or radiated electromagnetic disturbance that interferes with the operation of electronic equipment. Power and ground interference problems and methods of correction are discussed in Chapter 18. Refer to NAVELEXINST 011120.1, "Shore Electronics Engineering Installation Guidance for Equipments and Systems Processing Classified Information," when Red/Black factors are to be a consideration.

7.1.1 Classification of Cables by Interference Probability

a. Active Cables. Active cables are those cables in the high-level interference class such as:

- Radar modulator pulse cables
- Radio transmitting cables and transmission lines, except those which are part of UHF and VHF systems.

b. Passive Cables. Passive cables are those cables in the medium level interference class such as:

- Control Cables
- Inter-communications cables
- Power and lighting cables
- All other electronic cables not classed as active or susceptible

c. Susceptible Cables. Susceptible cables are those cables in the low-level interference class such as:

- Radio receiving antenna cables including those used with long range navigation (LORAN), electronic countermeasures (ECM), identification friend or foe (IFF), and aircraft early warning (AEW) systems.

- o Instrumentation transducer and thermocouple leads

- o Transceiver cables.

7.1.2 Cable Segregation Techniques

The use of metallic ducts is recommended for mobile installations because of space-saving features. Cable segregation in fixed station installations is accomplished by routing the high-, low-, or medium-level cables in separate wireways or cable trays. When trenches are provided, power and control cables are installed in trenches and RF and audio cables in overhead cable trays, if practical.

The following rules shall be followed as closely as possible when routing cables and wires of different interference classes and levels:

a. Radar modulator pulse cables are the largest contributors to cable radiation interference. For this reason modulator pulse cables shall be installed a minimum of 18 inches away from all other cables.

b. Active cables, if at all possible, shall be installed at least 18 inches from passive and susceptible cables. Active cables should also be separated from each other as a high-power cable can cause conducted interference in a low-power cable. When installing active cables for antenna installations, strict adherence to the separation requirements is not always possible.

c. Passive and susceptible cables should be spaced a minimum of 2 inches apart.

d. In instances when it is impossible to comply with the above rules because of space limitations, physical requirements, or other uncontrollable factors, it is necessary to use shielding. Shielding methods are covered in detail in chapter 18. Shielding or segregation is not required when cables cross at a 90 degree angle.

e. Individually shielded pair cables in accordance with specification MIL-C-28781 (EC) shall be used on timing circuits, high-speed data circuits, and high-level control circuits. Individually shielded pairs are not required on audio circuits provided 0 dBm levels are not exceeded.

7.2 CABLE RACEWAYS

A good cable installation should fulfill several requirements; cable runs must be as short as possible, cables must be suitably protected from mechanical injury, and cables must be easily accessible for troubleshooting. If possible, room must be left for future expansion. Table 7-1 lists raceway applications and the conditions of use for each.

7.2.1 Cable Trays and Racks

Cable trays and racks are steel ladder-like structures which, when properly installed, are capable of supporting a large number of cables. An installation of this type permits an orderly arrangement of cabling for systems containing many interconnecting cables. Trays and racks are used to separate active, passive, and susceptible cables by running separate trays parallel to and above one another. Cable trays permit a flexible equipment arrangement. The cables are easily removed or rerouted without tray modifications; trays may be removed, added, or rerouted without major structural modifications to the building. Figure 7-1 shows typical cable trays and fittings; figure 7-2 shows an actual installation. Figure 7-3 shows typical sections and fittings for one type of tray.

Trays should provide adequate space for all cables and have a capacity adequate for 100 percent expansion. Racks should be routed to prevent interference with the installing or servicing of existing or future equipment. Locations close to hot water pipes, radiators, doors, windows, or any equipment which could adversely affect the cables should be avoided.

7.2.2 Trenches

Concrete trenches are often used to route conductors where equipment locations are fixed. Easy access, removal, and rerouting of cables is possible, but a disadvantage is that concrete trenches must be designed prior to construction and cannot economically be added to an existing structure.

Figure 7-4 illustrates a typical trench arrangement within a room and a typical trench cross-section showing a method of running the cables. Unistrut (paragraph 7.3.2) is fastened to the bottom of the trench to secure cables. Unistrut keeps the cables off the trench bottom, which is especially important in locations where water may enter the trench. Unistrut can also be embedded in the walls of the trench. Special arrangement depend on type and amount of equipment, accessibility requirements, anticipated expansion, physical limitations, etc. A common trench arrangement is one constructed with a side flush with, and parallel to the wall. The trench width extends into the room. This width is sufficient to allow access to equipment serviced from the back and adequate clearance for wall-mounted obstructions such as junction boxes and power panels. The advantages of this type of arrangement are that branch trenches running out from the wall are not required and that a wider trench exists which permits easier cabling. Although power and lighting cables are considered passive, it is still a good policy to isolate power and lighting circuits from control and signal cables. In a trench installation, this separation is easily accomplished by routing power and lighting circuits in ducts or conduits. These enclosures provide efficient shielding. The trench is covered with removable plates for easy access. The plates are notched for cable penetration. (The notch should be lined with rubber channel or sheet lead to prevent cable chafing.) Where cables enter the trench in area of considerable traffic, a kickplate shall be provided for protection.

7.2.3 Metallic Ducts

Metallic ducts fall into two general categories: surface installed and underfloor. Surface installed ducts such as wireways, metal surface raceways, wiremold, and twin duct are discussed in chapter 14.

Underfloor ducts are widely used to route conductors to equipment located away from the walls of a room. Most installations of this sort are in office buildings and are used to route power, telephone, and intercommunication cables. In electronic installations where a large number of cables having various levels of activity are encountered, use of underfloor ducts present numerous problems. Limited space available in ducts, separation of various level cables, and maximum bend radius are typical examples. Therefore, only limited use of underfloor duct is made in an electronics installation.

An excellent application of underfloor duct in an electronics installation is its use in combination with a trench. The trench is located against one wall of the room, and the ducts are run perpendicular to it. The use of a cellular type floor is recommended for maximum separation of cables and servicing of all floor areas. In a typical installation of cellular floor duct which connects trenches located on opposite sides of the room, groups of channels are spaced 6 to 8 feet apart. Active, passive, susceptible, and power circuit cables are contained in separate channels to reduce cable radiation interference. The channel selected shall provide at least a 100 percent expansion capability. Fiber conduit is also extensively used as floor duct. It is light, strong, simple to cut and work, and has a low coefficient of friction (important when pulling cables). The inner diameters available are from 2 to 6 inches. Straights, bends, offsets, elbows, and miscellaneous types of fittings may be obtained. Spacers are used to separate the various classes of cables to reduce radiation interference.

Duct is also used to house cable runs from cabinets to overhead cable trays. Some bases used to support cabinets provide a space under the cabinet that can be used as a cable duct. Ducts can also be installed directly on top of cabinets. The two latter methods of duct installation are discussed in chapter 15.

7.2.4 Conduit

Conduit is a tubular raceway through which insulated conductors or cables are pulled. This tubing not only protects the conductors from mechanical injury, but it also permits easy removal and replacement of the conductors. It is used to conceal conductors whose exposure would constitute a hazard or be otherwise objectionable. The conduit system can be employed for both exterior and interior work and can be constructed to meet a variety of weather and climatic conditions.

Conduit is available in many different materials. The type used is dependent upon installation and location requirements. Certain installation factors often make it necessary to use a particular conduit having definite characteristics. This is generally determined and specified in advance during the engineering or planning phase.

There are four common types of conduit: flexible conduit; threaded, rigid conduit; threadless, thin wall conduit (Electrical Metallic Tubing, EMT); and plastic conduit (Polyvinyl Chloride).

a. Flexible Metal Conduit. Flexible conduit (see figure 7-5) is made from a strip of steel that is spirally wound and interlocked on itself. This construction affords great flexibility. Flexibility is important where cramped conditions make the use of rigid conduit difficult or impossible and when a conduit is required to be concealed in an existing building. Flexible conduit is often used in combination with rigid conduit to run cables to motors or other equipment that cause vibration.

This conduit shall not be used in wet locations (unless the conductors are lead-covered); in locations where rubber-covered conductors may be exposed to oil, gasoline, or other deteriorative materials; in hazardous locations; or where corrosive fumes are present unless the conduit is protected by noncorrosive coatings.

A liquid-tight flexible conduit that consists of standard flexible conduit with a vinyl plastic jacket is available. Special fittings are required for use with this type of conduit in order to preserve its liquid-tight integrity.

b. Rigid Metallic Conduit. Rigid conduit (see figure 7-6) is made from steel, aluminum, or copper alloy and is suitable for use under all atmospheric conditions. It is moisture and fireproof and will withstand severe mechanical abuse. Steel is usually selected where strength is of prime importance. Where weight is to be considered, aluminum is usually selected; aluminum also is more corrosive resistant than steel. Copper alloy, although more costly than either steel or aluminum, is required where corrosion resistance and heat dissipation are critical factors.

Rigid conduit uses threaded fittings and is available in standard pipe sizes from 1/2 to 6 inches and in black, galvanized, or plastic coated finishes. The smaller sizes (up to 1 inch) may be bent on the job with a hickey. Larger sizes usually require the use of hydraulic power benders, or preformed elbows are used. Rigid conduit is sold in 10-foot lengths, threaded on the both ends, and obtained with one coupling attached. Threading of rigid conduit is accomplished by standard pipe threading equipment, either manual or power driven.

c. Thinwall Conduit. Thinwall conduit (see figure 7-7) also known as electrical metallic tubing (EMT) is similar to rigid conduit but has a thinner wall. It is made of steel, aluminum, or copper alloy tubing and is available in sizes from 1/2 to 2 inches. EMT cannot be threaded and uses compression type, identation type, set-screw type, or push-on type connectors. Thinwall conduit up to 1-1/4 inches is bent manually with a thinwall bender; larger sizes are bent with a hydraulically powered thinwall bender. Preformed elbows are often used in the larger sizes.

d. Plastic Conduit. Polyvinyl chloride conduit (PVC) is impervious to corrosive substances and, therefore, may be installed in areas with a high degree of salt in the atmosphere or buried in acid or alkaline soil. PVC fittings are similar to those used with conventional conduit. Joints are made by using sealant which causes a chemical reaction at the two mating surfaces and fuses them together. Although threading is not normally required when connections to conventional conduit fittings are to be made, PVC may be threaded or threaded end-adapters may be used. Bends are made after the conduit is softened by the application of heat. Because PVC is non-conductive, a separate ground wire must be run in the conduit.

7.2.5 Conduit Installations

There are conduit installation practices which must be followed. Theoretically the shortest and straightest conduit run is preferable, however this may be neither practical nor within the imposed restruction brought on by the inherent peculiar requirements of a given piece of equipment.

a. Underground. Conduit shall be buried in a trench that will permit the conduit to be installed below the frost line. In all instances the trench will be at least 18 inches deep. The trench bottom should be relatively smooth, and the first six inches of backfill shall be free of large rocks. Conduit shall not be used in or under cinder-fill unless manufactured from a corrosion resistant material. Where conduit is run under roadways or in heavy traffic areas, it shall be encased in concrete or run in oversize steel casing.

b. Buildings or Other Structures. Conduits are to be routed in accordance with the detail plans or engineering specifications. Normally, all exposed runs of conduit shall be run parallel with or at right angles to the walls and floors of the structure as far as practicable. Conduits shall be located so as not to interfere with cable racks or auxiliary supports and, wherever possible, shall be run together.

c. Assembling of Conduit. Fabrication procedures (cutting, bending, threading) are essentially the same for rigid, thin wall, and flexible conduit. (Plastic conduit requires specialized fabrication techniques and is discussed in the latter portion of this paragraph).

(1) Conduit Cutting. Rigid or thinwall conduit may be cut with a tube or pipe cutter, hand hacksaw, or power hacksaw. Flexible conduit can only be cut with a hand hacksaw. In any cutting method employed care must be exercised to assure that the conduit is firmly secured during the cutting process and that the cut is at a right angle to the conduit.

(2) Conduit Reaming. Irrespective of the cutting method used, a sharp edge always remains inside the conduit after cutting. To avoid damage to the conductor, the conduit must be reamed to remove this sharp edge.

(3) Conduit Threading. The outside and inside diameters of rigid conduit are the same as those of gas, water, or steam pipes, the standard thread forms, and consequently similar threading tools and dies, are used. Normally the smaller sizes of pipe are threaded with dies that cut a thread for every turn of the die. For larger sizes (1-1/2 inch and over) a ratchet type cutter is generally used. Motor-driven pipe-threading machines are also available when large installations are made and when considerable conduit must be threaded.

(4) Conduit Measuring. When making measurements in preparation for cutting a desired length of conduit, take into consideration fittings (bends, els, etc.) that are to be used. Temporarily support these fittings in position before the measurement for the conduit is made. Since the fittings are apt to vary in dimension, use the same fittings that the measurements were made with. Measure length of conduit to connect two fittings as follows:

o Measure the distance M between centers of the conduit fittings.

o Measure the distance from the centers to the end of each fitting, F1 and F2, and add these dimensions.

o Subtract the sum of F1 and F2 from M, and add twice the distance S by which the conduit penetrates into the fitting to obtain N, the length of conduit to be cut.

(5) Conduit Bending. Bends of rigid conduit must be made without collapsing the conduit wall or reducing the internal diameter of the conduit at the bend.

Most bends are made on the job as an integral part of the installation procedure. The radius of the curve of the inner edge of any bend must be at least six times the internal diameter of the conduit for rubber-, braid- or thermoplastic-covered conductors, and not less than 10 times the internal diameter of the conduit for lead-covered conductors. Table 7-3 shows the minimum radii for field bends. The maximum number of quarter bends for a conduit run between two openings is four. Moreover, a 10-foot length of conduit should have no more than three quarter bends. Factory-made bends may be used instead of bending conduit on the job. However, they are not generally used since they increase the wiring cost. This is because more conduit cutting and threading is required and additional couplings must be used.

Conduit up to and including 1 inch is usually bent with a hand conduit bender called a hickey as shown in (1), figure 7-8. This can be slipped over the conduit. Conduit bending forms are also available as built-in units of pipe-vise stands.

The procedure listed below, illustrated in (2), figure 7-8 is recommended as one method of making a right-angle bend in a length of conduit. If a 90-degree bend is to be made in a length of conduit at a distance of 20 inches from one end, the electrician must:

o Mark off 20 inches from the end of the conduit.

o Place the conduit hickey 2 inches in front of the 20-inch mark and bend the conduit about 25 degrees.

o Move the bender to the 20-inch mark and bring the bend up to 45 degrees.

o Move the bender about 1 inch behind the 20-inch mark and bring the conduit up to 70 degrees.

o Move the hickey back about 2 inches behind the 20-inch mark and bring the bend up to 90 degrees.

Miscellaneous conduit bends (offset bends, (3), figure 7-8) can be made more accurately if the contour of the bend is drawn with chalk on the floor and the bend in the pipe is matched with the chalk diagram as the bend is formed. Conduit in excess of 1 inch is usually bent by a hydraulic bender.

(6) Plastic Conduit. The cutting, coupling, and bending procedures for plastic conduit are illustrated in figures 7-9 and 7-10.

(7) Pulling Cable Through Conduit. Prior to pulling cable or conductors through a long conduit run, it is good practice to pull a test mandrel (see figure 7-11) through to remove any obstructions that may exist. This should be followed by any of several types of conduit cleaners available (see figure 7-12).

For short runs with few wires, conductors can be paried and pushed through the conduit run from box to box. When the conduit run has several bends and more than two conductors, a fish wire (or tape) must be used in pulling wire. For normal runs the fish wire is pushed through the conduit run from one end to the other. After the conductor ends are bared of insulation, they are wrapped around the fish wire and taped for pulling through the conduit. Taping of the fish wire and conductor junction is required to preclude damaging the conduit interior and existing conductors in the conduit. In taping, the joint is also compacted and strengthened, thus insuring easier pulling. For efficient and safe operation, wire pulling is generally a two-man operation. One man is required to pull the conductors through the conduit while the other feeds the conductors into the conduit. In this operation, care must be used in feeding and pulling the wires so they maintain their same relative position in the conduit throughout the run length, thus avoiding insulation injury. For ease of operation a wire lubricant such as powdered soap-stone may be rubbed on the conductors or blown into the conduit. In intricate runs, wire pulling may be performed in sections between boxes. This procedure requires a large amount of additional splicing to be made in the boxes and requires that more time be taken in wiring. The preferred practice in wire pulling is to pull the conductors from the source through to the last box in the conductor run. Loops which extend about 8 inches from the box openings are made for each conductor which is to be tapped or connected to a device in the box. Conductors which are not to be tapped are pulled directly through the box to their connection.

7.3 CABLE FASTENINGS

Every manufacturer in the cable fastening business produces a line of cable fastening devices. All will perform adequately in a given application, while the same device will not provide satisfactory performance in another application. To describe all these devices is beyond the scope of this handbook. Therefore, only some commonly used types are discussed.

7.3.1 Cable Clamps

a. Plastic Clamps. Plastic clamps (see figure 7-13) are manufactured in a variety of shapes. Such materials as polypropylene, nylon, teflon and ethylcellulose are commonly used in their production.

b. Reinforcing Washers. When required, D-shaped metal washers (see figure 7-14) may be used with plastic clamps to give added strength. One application is where lock washers are used under the screwhead. They are made from 22 to 24 gauge steel and are available with various corrosion resistant finishes. These washers are not supplied as a part of the plastic clamp.

c. Clamping Pads and Bars. Clamping pads and bars are employed in conjunction with binding straps to both bundle and affix the cable bundle to walls, floors and the like. Figure 7-15 illustrates some typical applications.

d. Cradle Clamps. Cradle clamps are available in a variety of sizes; each size is further adaptable by the use of different clips (see figure 7-16). Cradle clamps are fastened to a bulkhead to support harness conductors and bundles of cables.

7.3.2 Unistrut-Type

Unistrut-type cable fastening devices are used extensively (see figure 7-4). Typical clamps, fittings, etc. are shown in figure 7-17. Channels shall be installed a maximum of 16 inches apart center-to-center. A greater distance permits sagging of small cables. After the channels are installed, clamps such as those shown in figure 7-17 are then inserted and clamped around the cable. These clamps are available in outer diameter sizes from 1/4 to 5/8 inch in increments of 1/8 inch and are made of steel, copper, or aluminum. This same clamp configuration is available for rigid steel conduit and thinwall conduit.

7.3.3 Use of Explosive Set Studs

If a large installation requires numerous anchoring in concrete, the explosive set stud greatly speeds up the installation effort. It should be noted that these power actuated tools must be operated, repaired, serviced and handled only by personnel who have been trained and certified by the manufacturer, its authorized representative, or certified Navy instructors. Refer to NAVSO P-2455 "Department of Navy Safety Precautions for Shore Activities", for complete safety data. Refer to chapter 15 for additional fastener and anchoring data.

7.4 CABINET WIRING

Equipment cabinet wiring accessories are numerous. Typical accessories are described in following paragraphs. Conductor harnessing and fastening of harnesses to the cabinet are discussed separately since they are two independent operations.

7.4.1 Harnessing

Harnessing is the process of securing individual wires in laced bundles so they may be handled as a single cable.

a. Lacing. The use of lacing twine is the oldest method of fastening individual wires together. Many new securing devices which have become available in recent years have limited the use of lacing twine, especially in mobile or semi-permanent installations where equipment is frequently removed and reinstalled. Lacing twine is still an acceptable harnessing method for use in most permanent installations. Although lacing twine is low in material cost, it is more expensive in labor costs than some other methods. Lacing twine, when properly installed, provides a relatively rigid and neat appearing harness.

A lock stitch is used to hold the conductors together under pressure and is applied at about 1/2-inch intervals. The running stitch between lock stitches shall be run in a straight line parallel to the harness and shall not wind around the harness. A length of twine about 2-1/2 times the length of the harness is required if a single twine is used.

b. Spiral Wrap Tubing. Spiral wrap tubing is a spirally cut plastic tubing that is used to combine individual conductors into a bundle. It is especially suitable for prototype installations where conductors are constantly being changed. Black, white, red, and blue are readily available colors, but almost any color can be obtained. Spiral wrap tubing may be procured to accommodate cable bundles ranging from 1/16 inch to 4 inches in diameter. Figure 7-18 illustrates installation procedures.

c. Banding Straps. Banding straps (see figure 7-19) are nylon strips with raised perpendicular ridges on one end and a clamping head on the other. The straps are placed around the bundle and tension is either applied by hand or special tool.

d. Zippered Tubing. Another method of making up a wiring harness is to enclose the wires in zippered plastic tubing. Zippered tubing is especially useful when a replaceable cable jacket is desirable. The principal advantages of using zippered tubing are that it permits quick installation, repeated access to work points, and rapid addition or removal of circuits. It also presents definite advantages in external wiring applications where laced and tied cables between equipment would be too rigid and where protection against abrasion is required. A typical zippered plastic tubing is shown in figure 7-20. Zippered tubing is available in the following materials: vinyl, vinyl-coated fiberglass laminated to aluminum foil, vinyl-backed butyl rubber, lead-saturated vinyl, mylar, polyethylene, and aluminized asbestos fiber.

Zippered tubing is useful when wires are to be soldered to a connector. The tubing can be unzipped, folded back from the connector to expose the work area, then zipped shut either manually or by use of a special tool to cover the soldered area. The tubing can be easily and effectively terminated by using one of the following:

- AN or other type connectors in conjunction with two matching ferrules.
- Pressure-sensitive tapes (plastic electrical tape).
- Potting.

Termination of the tubing using the matching ferrules is illustrated in figure 7-20. A special type of zippered tubing provides electrostatic and electromagnetic shielding. Installation of this tubing on conductors is a one-step operation which eliminates the laborious hand wrapping or expensive braiding normally required to shield conventional types of cables and wiring harnesses. This tubing can be terminated and grounded by grounding adapters which fit in back of a connector or plug, grounding wires, or grounding tabs. Perforated zippered tubing is available for use where branch-outs are necessary or where moisture condensation must be avoided. Special configurations of zippered tubing are available to satisfy special requirements. Two frequently used shapes are the "Y" and the "T".

Special compounds are available to use for permanent sealing of zippered tubing. This compound is brush applied to the tracks a few inches ahead of the slider. The surface of the sealer dries very rapidly; therefore, the sealer must not be allowed to dry before the zipper is closed. The sealer dries completely in 30 to 60 minutes.

When sealed in this manner, zippered tubing has the same properties as an extruded jacket. It is both moisture-proof and water-proof. The zippered jacket must be stripped off the wires if repair of these wires is required. A new zippered tubing jacket is then used to replace the stripped portion.

7.4.2 Plastic Wiring Duct

Plastic wiring duct (see figure 7-21) is used extensively in routing wires in cabinets. The duct is usually made of polyvinyl chloride and is supplied with a clip-on cover of the same material. The duct may be mounted to the equipment cabinet by means of machine screws or snapped into spring steel clips.

7.4.3 Terminating Shielded Conductors with Individual Grounding Sheaths

The shields of shielded conductors must be grounded before final assembly of a connector. Figure 7-22 illustrates a method of terminating conductor shields with grounding sheaths.

7.4.4 Terminating Multi-Conductor Shielded Cable with a Single Grounding Sheath

This terminating technique is illustrated in figures 7-23 through 7-29.

7.4.5 Terminating Shielded Conductors with Grounding Ring

Another method of terminating shielded conductors is illustrated in figure 7-30.

7.5 FABRICATION OF SPECIAL AND PROTOTYPE EQUIPMENT

Screw or stud terminals must be in perfect mechanical condition and clean. The terminal must be installed with both a flat and lock washer with the thread length of the screw or stud adequate in length to accommodate the two washers.

All wire or cable that is to be connected to terminals must be terminated with the proper type of terminal log. Spade type terminal lugs are permissible on signal wiring. "Closed end" terminal should be used for power wiring to avoid accidental disconnection while loosening the hold-down screw or nut. When two or more wires are connected to a single terminal the heaviest wire shall be installed at the terminal base with succeeding wires attached in order to relative size with the smallest wire being on top.

The terminal lugs when installed on the terminal should be positioned in a manner that anticipated tugs on the wire will increase the torque.

Table 7-1. Raceway Applications

N.E. CODE ARTICLE	TYPE STEEL RACEWAY / LIMITATIONS ON USE OF VARIOUS TYPES OF STEEL RACEWAYS	CONDITIONS OF USE																
		Inside Buildings	Outside Buildings	Underground	Cinder Fill	Embedded Concrete	Wet Locations	Dry Locations	Corrosive Locations	Severe Corrosive Locations	Hazardous Locations	Mechanical Injury	Severe Mech. Injury	Exposed Work	Concealed Work	Services Outside	Voltage to Ground	Volts—between Cond's.
346	Rigid Conduit, Enamelled	X	O	O	O	E	O	X	X	O	X	X	X	X	X	O	No Limit	
346	Rigid Conduit, Zinc Coated	X	X	X	E	X	X	X	X	X	X	X	X	X	X	X	No Limit	
348	Electrical Metallic Tubing	X	X	X	E	X	X	X	E	E	O	X	O	X	X	X	No Limit*	
350	Flexible Steel Conduit	X	E	O	O	E	E	X	O	O	E	X	O	X	X	O	No Limit	
351	Liquid-Tight Flex. Conduit	Limited Use					X	X	X	X	E	O	O	X	O	O	No Limit	
352	Surface Steel Raceways	X	O	O	O	O	O	X	O	O	O	X	--	X	E	O	**	**
354	Underfloor Steel Raceways	X	--	--	--	X	--	X	O	O	O	--	--	--	X	--	**	**
356	Cellular Steel Raceways	X	--	--	--	X	--	X	O	O	O	--	--	--	X	--	**	**
362	Steel Wireways	X	X	O	O	O	X	X	O	O	O	X	O	X	O	O	**	**
364	Steel Busways	X	E	O	O	O	E	X	O	O	O	X	O	X	O	X	**	**
374	Auxiliary Steel Gutters	Limited Use Inside Buildings															**	**

E—denotes exception. See Rule. (NE code article)

O—denotes not recognized.

X—denotes recognition.

-- —Conditions do not apply.

L—Limited.

*—Service use 600 Volts.

**—Voltage limitation: The wiring methods covered by Chapter 3 of the Code are limited to 600 Volts unless specifically permitted elsewhere. Code Section 7103 recognizes raceways for voltages exceeding 600 volts.

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Table 7-2. Radius of Conduit Bends

SIZE OF CONDUIT	CONDUCTORS WITHOUT LEAD SHEATH	CONDUCTORS WITH LEAD SHEATH
1/2 in.	4 in.	6 in.
3/4 in.	5 in.	8 in.
1 in.	6 in.	11 in.
1 1/4 in.	8 in.	14 in.
1 1/2 in.	10 in.	16 in.
2 in.	12 in.	21 in.
2 1/2 in.	15 in.	25 in.
3 in.	18 in.	31 in.
3 1/2 in.	21 in.	36 in.
4 in.	24 in.	40 in.
5 in.	30 in.	50 in.
6 in.	36 in.	61 in.

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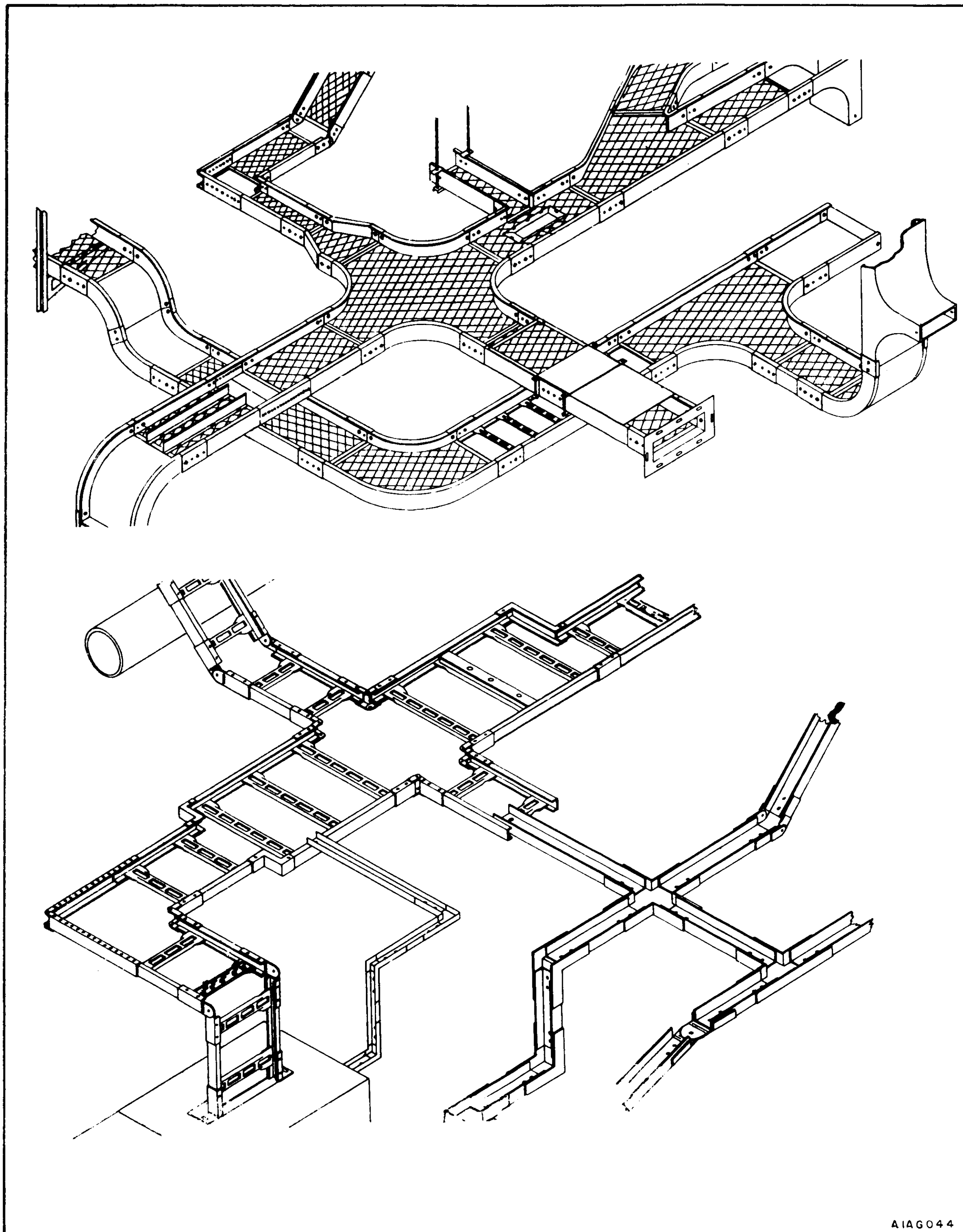


Figure 7-1. Typical Cable Trays and Fittings

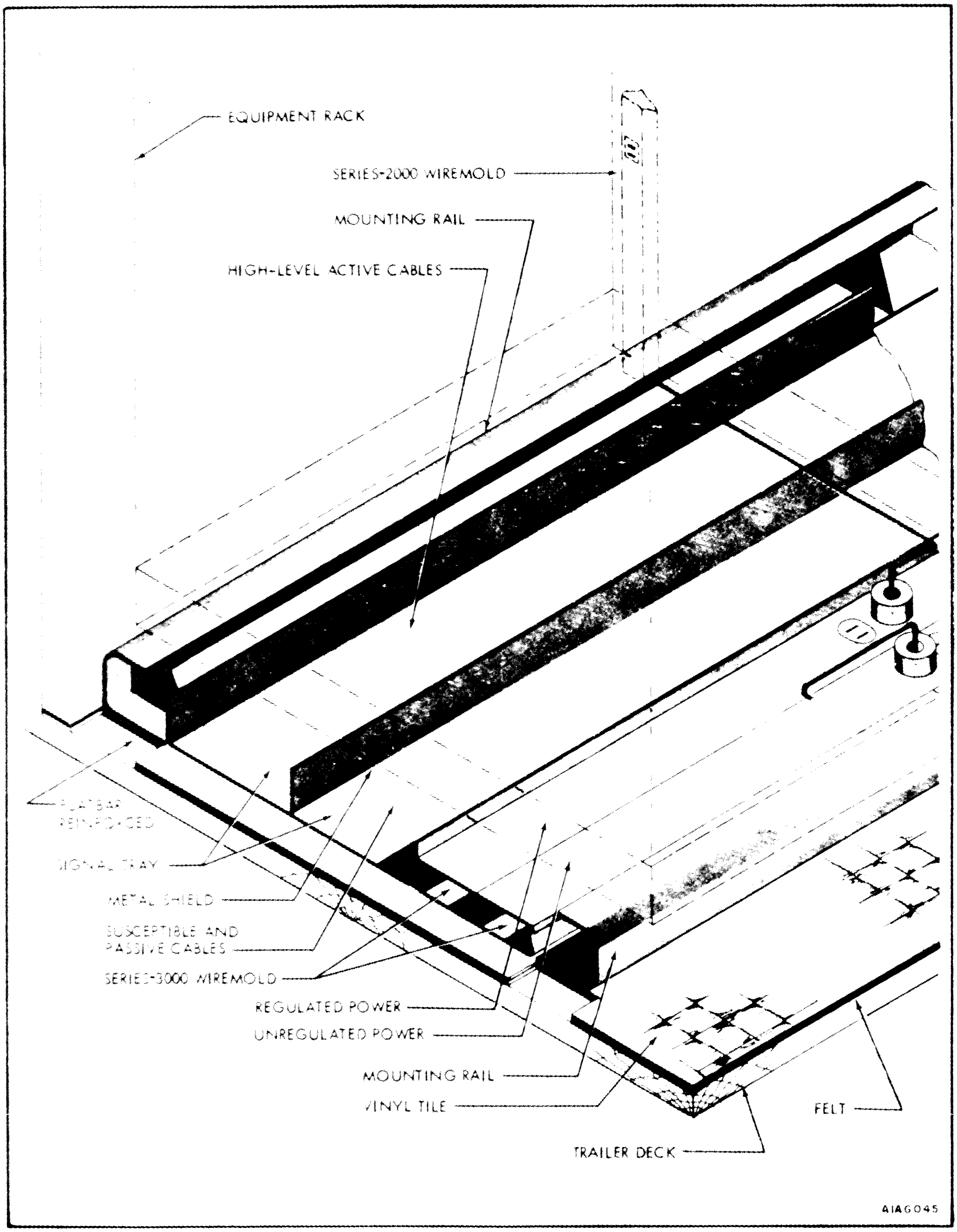


Figure 7-2. Typical Cable Tray Installation

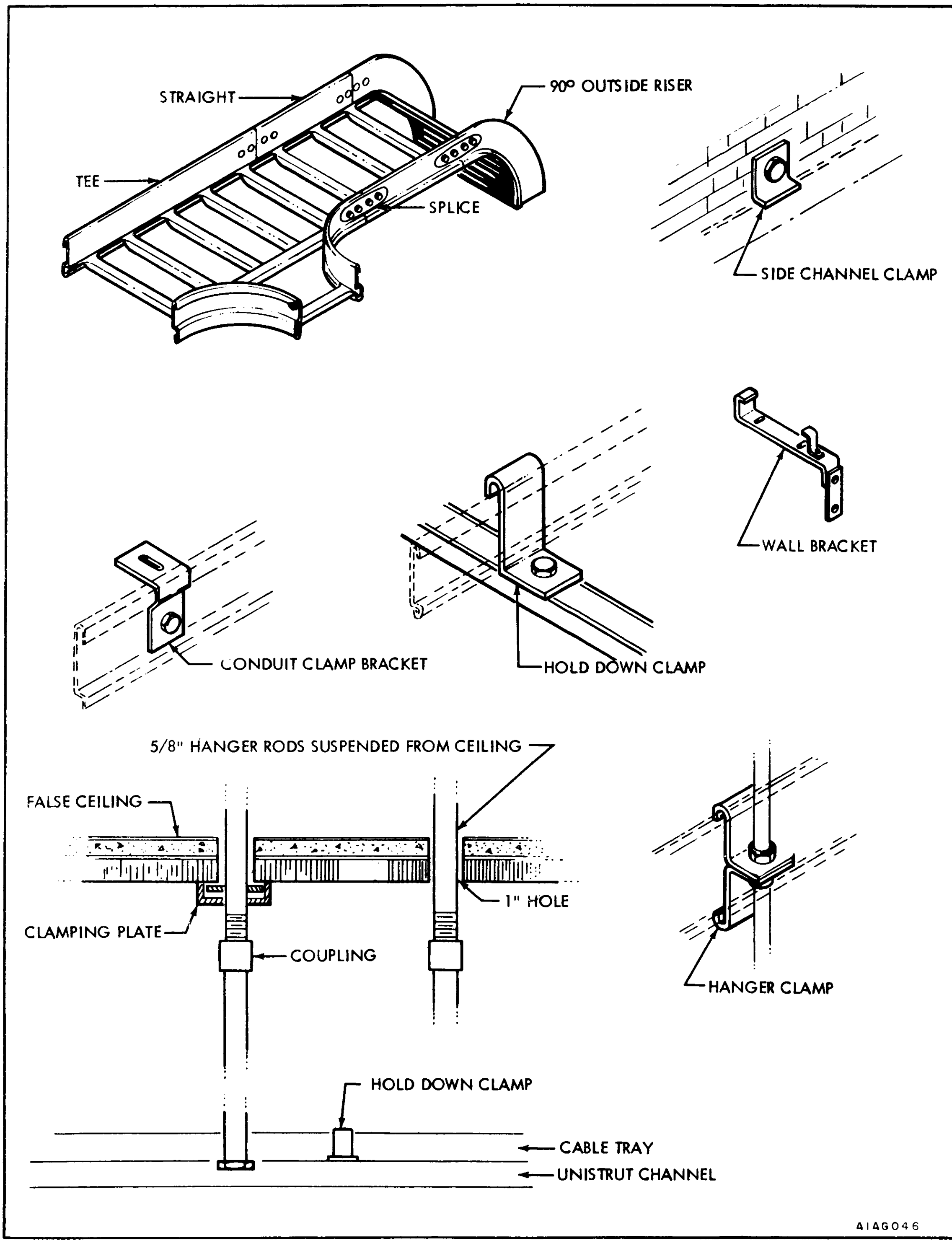


Figure 7-3. Typical Tray Fittings (Sheet 1 of 2)

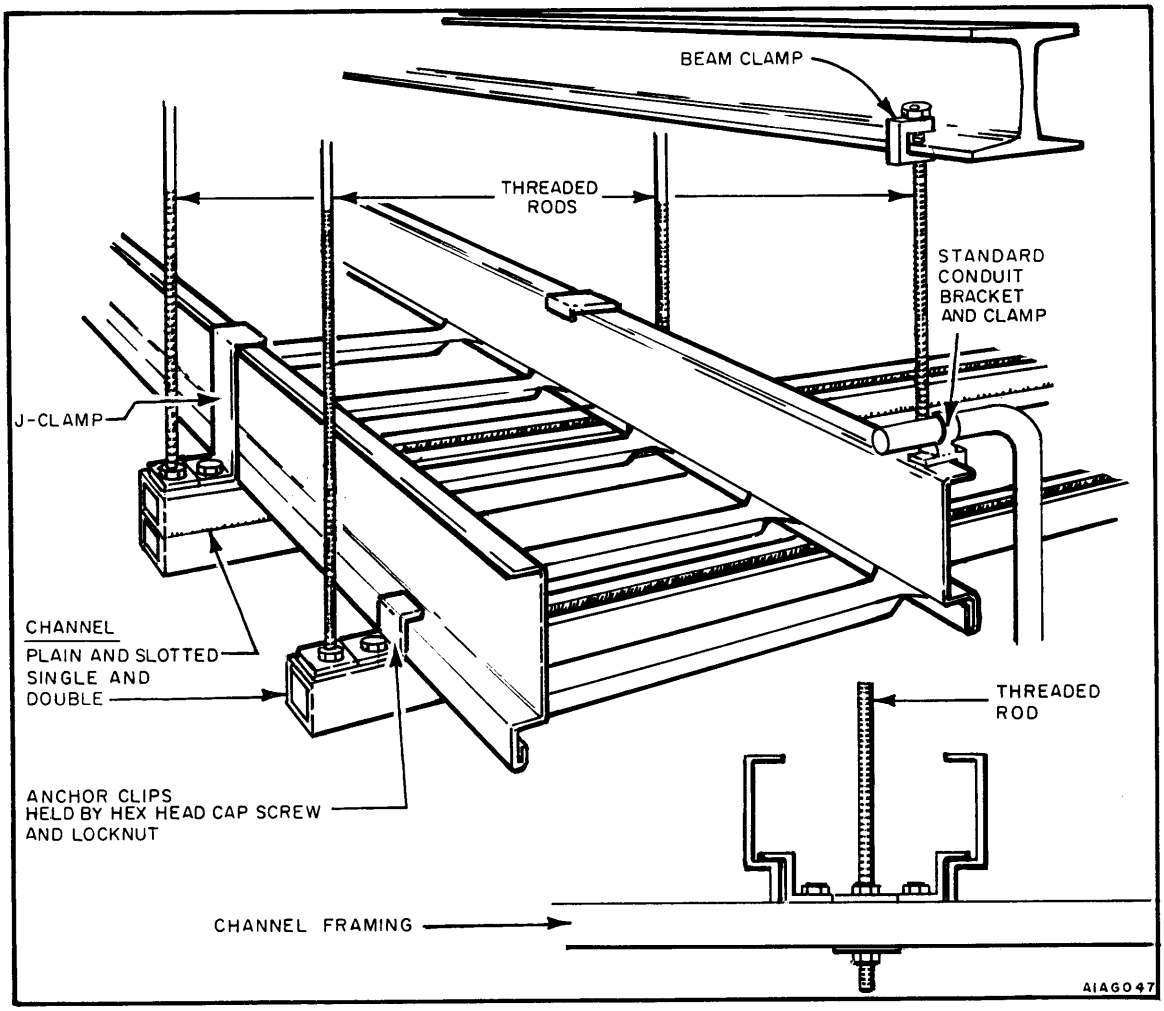


Figure 7-3. Typical Tray Fittings (Sheet 2 of 2)

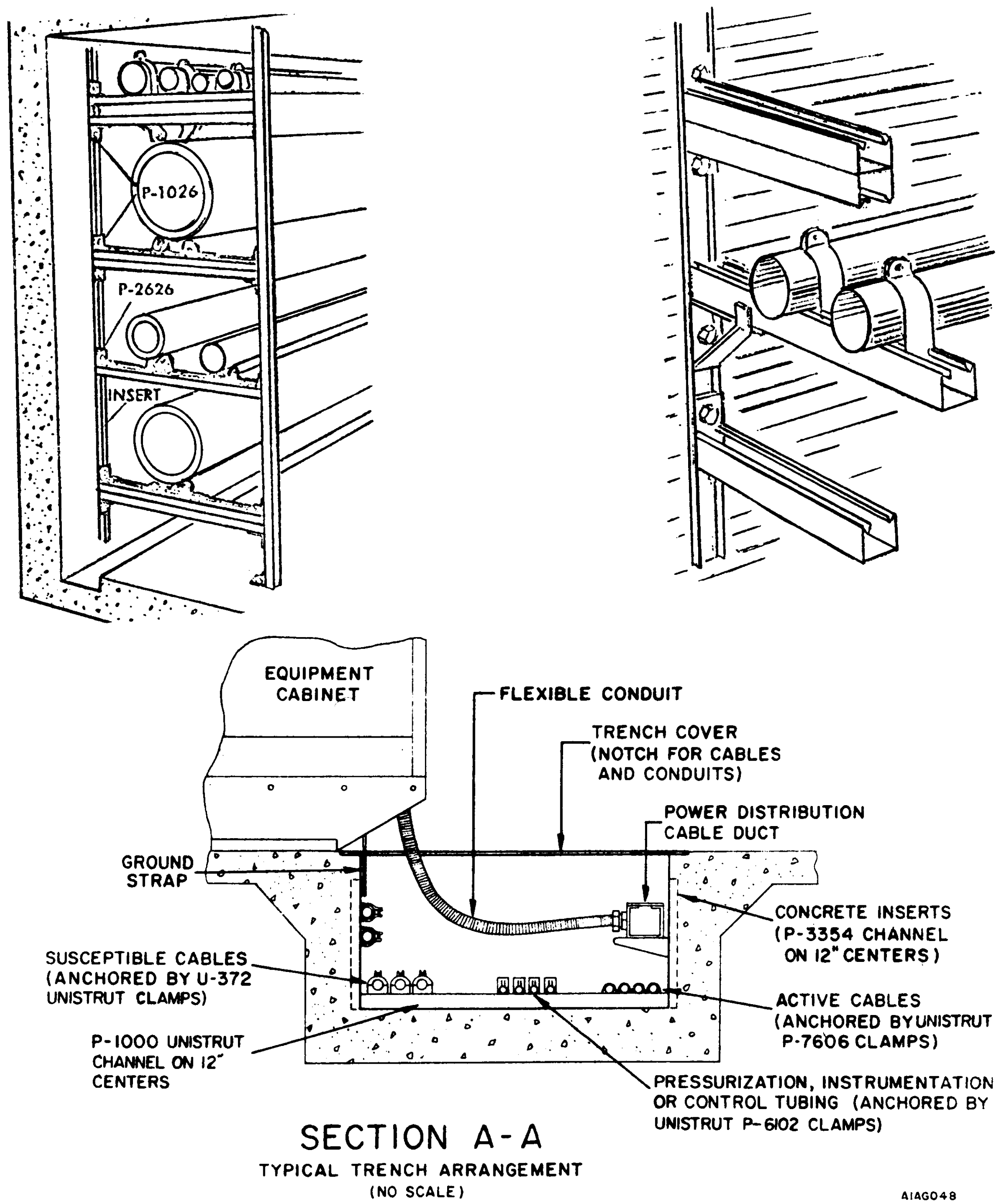


Figure 7-4. Typical Trench Arrangement (Sheet 1 of 2)

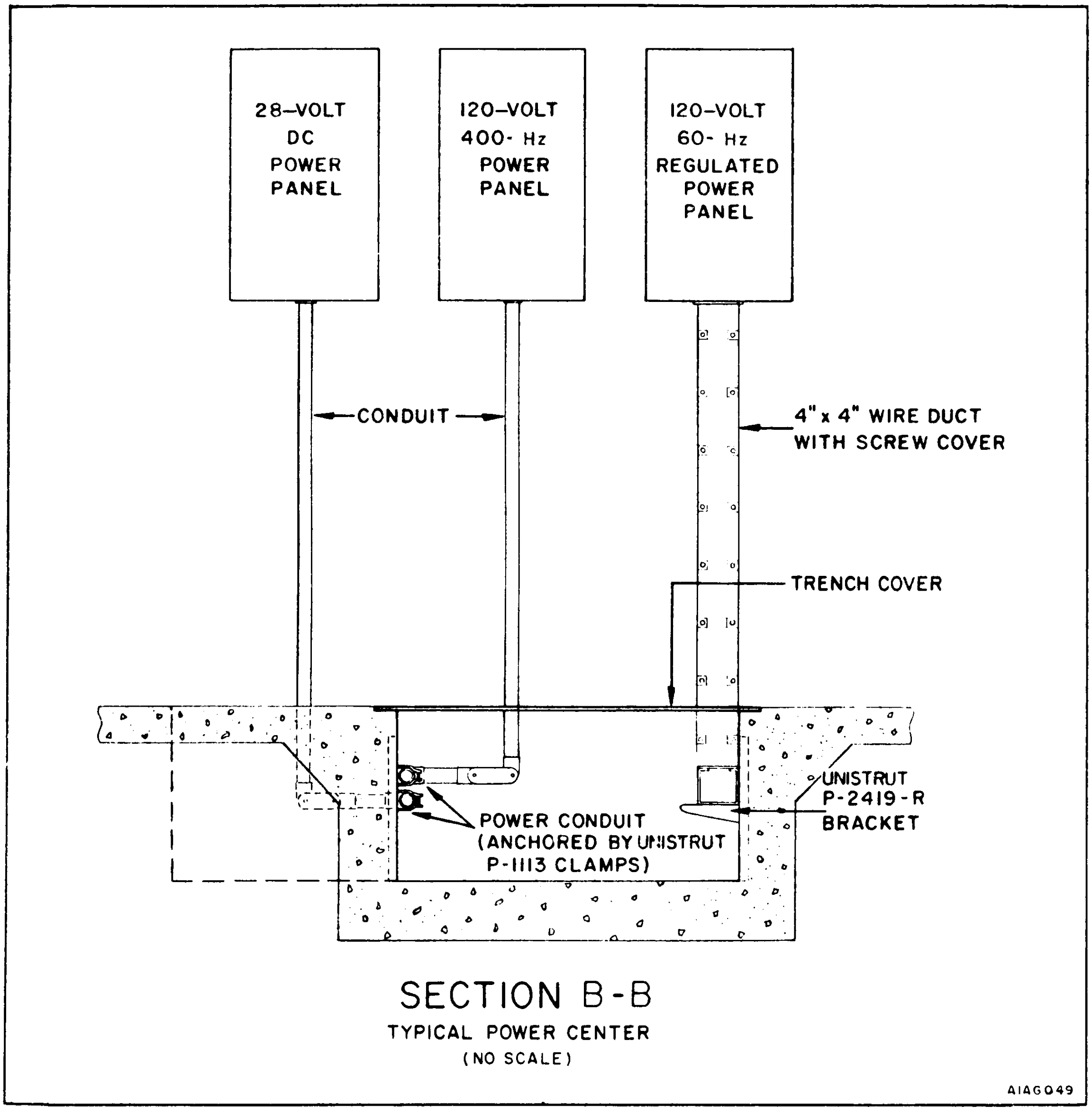


Figure 7-4. Typical Trench Arrangement (Sheet 2 of 2)

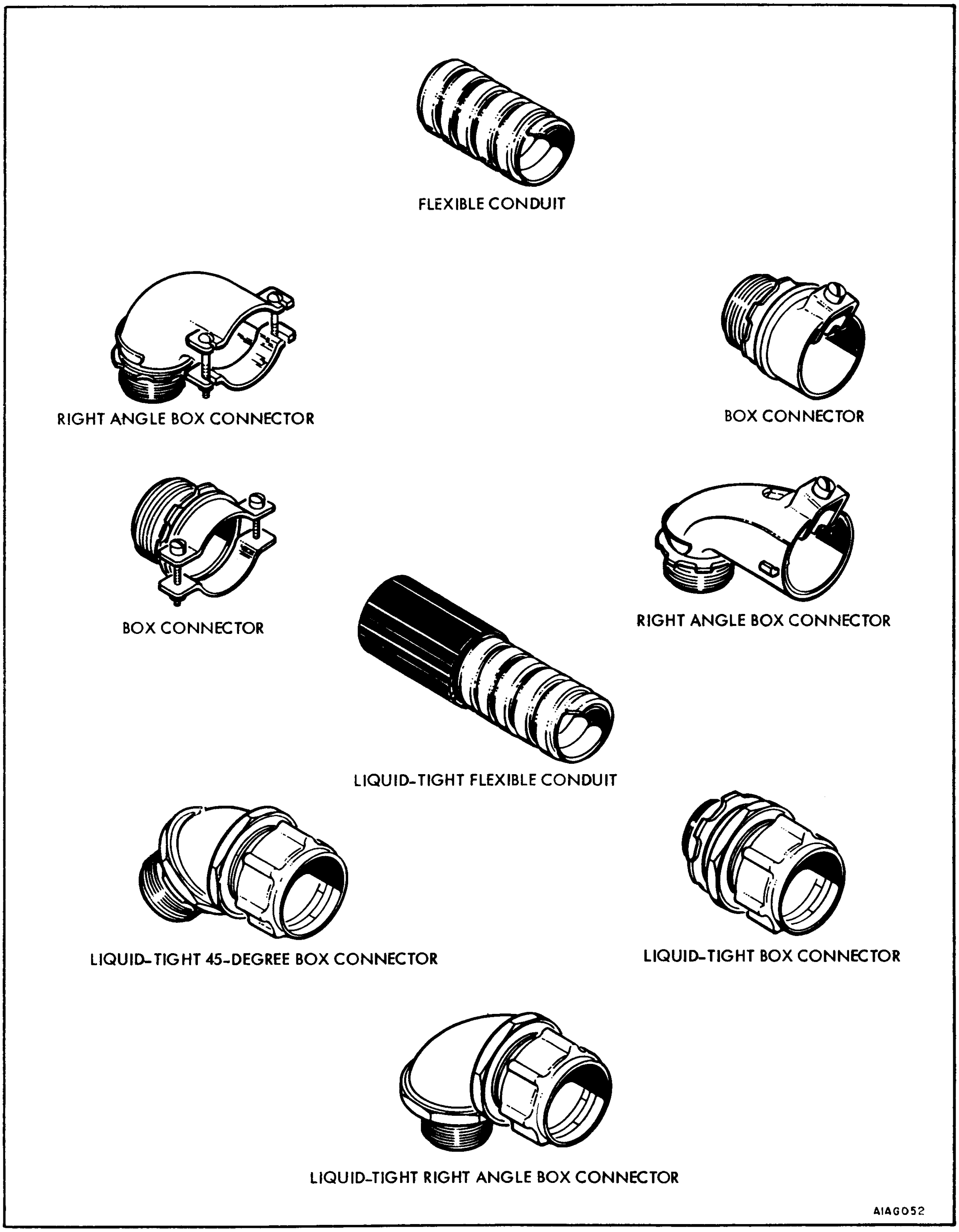


Figure 7-5. Flexible Conduit and Fittings

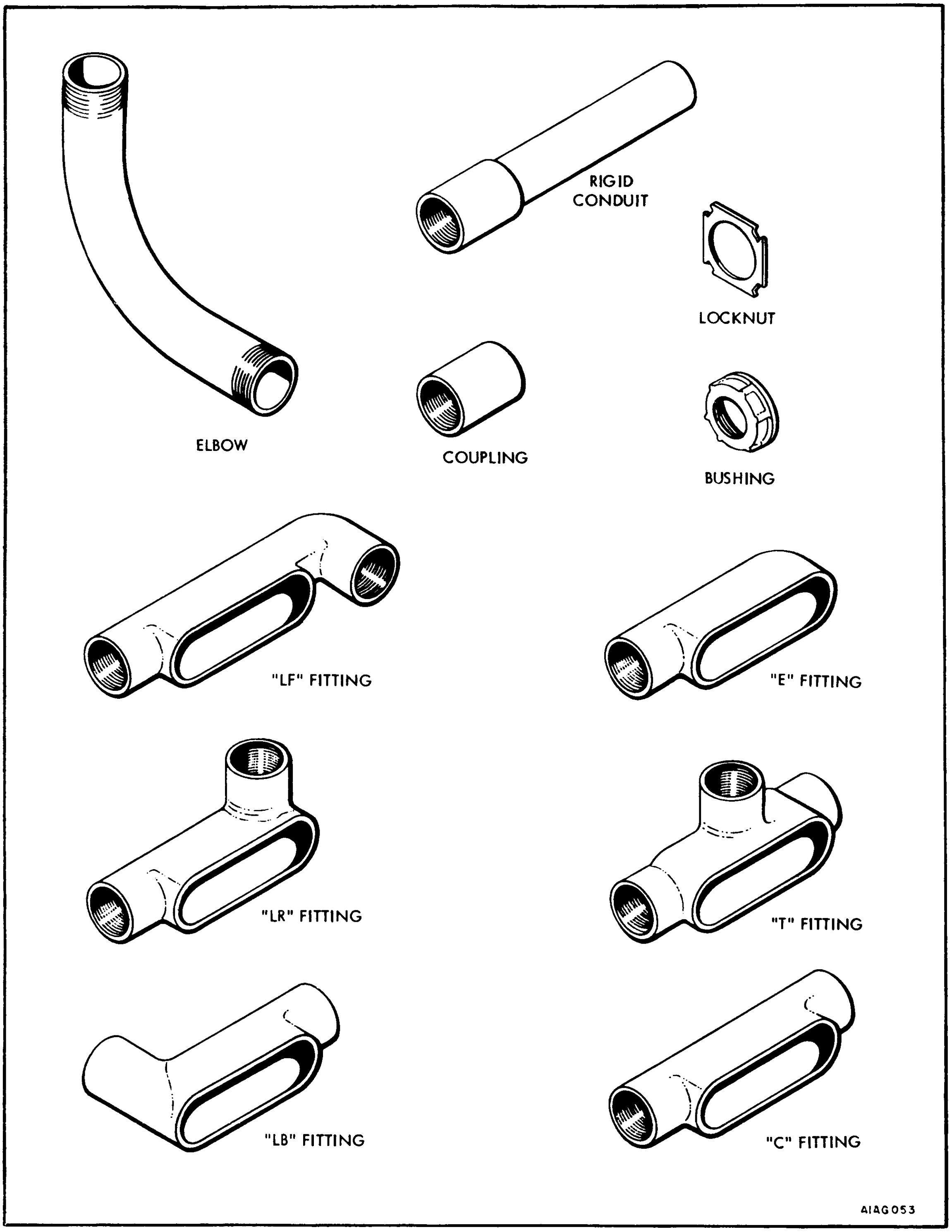


Figure 7-6. Rigid Conduit and Fittings

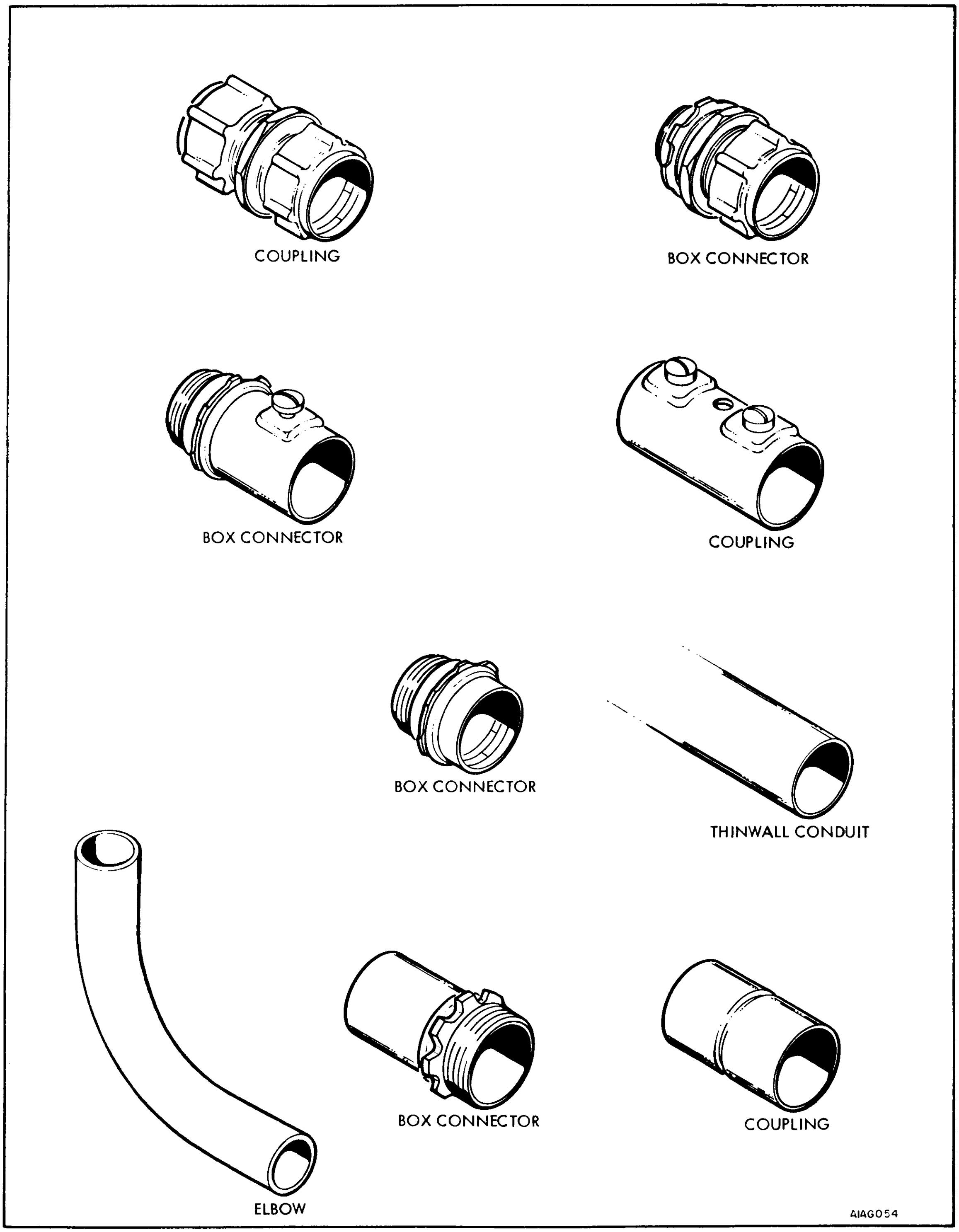


Figure 7-7. Thinwall Conduit and Fittings

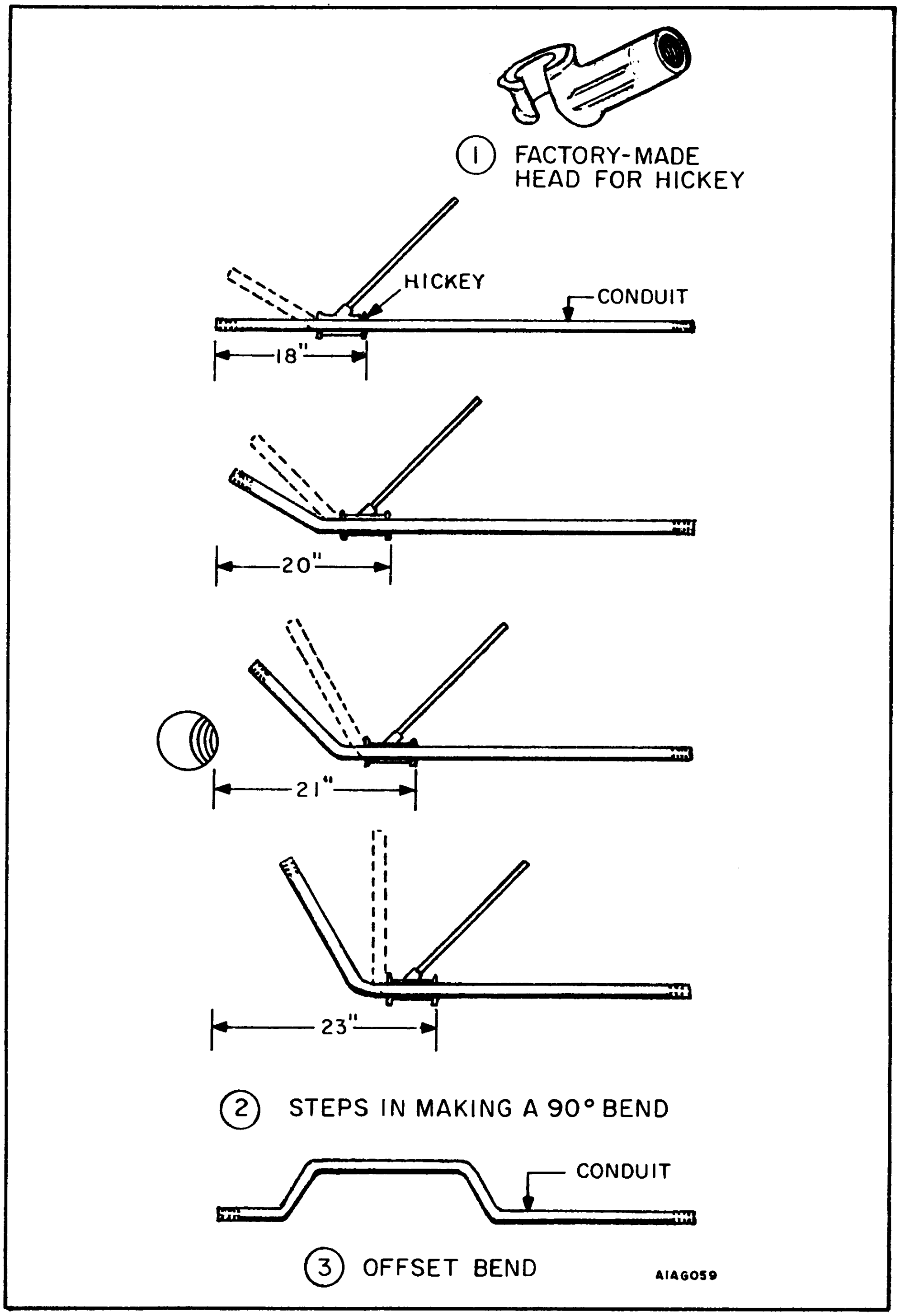


Figure 7-8. Bending Rigid Conduit

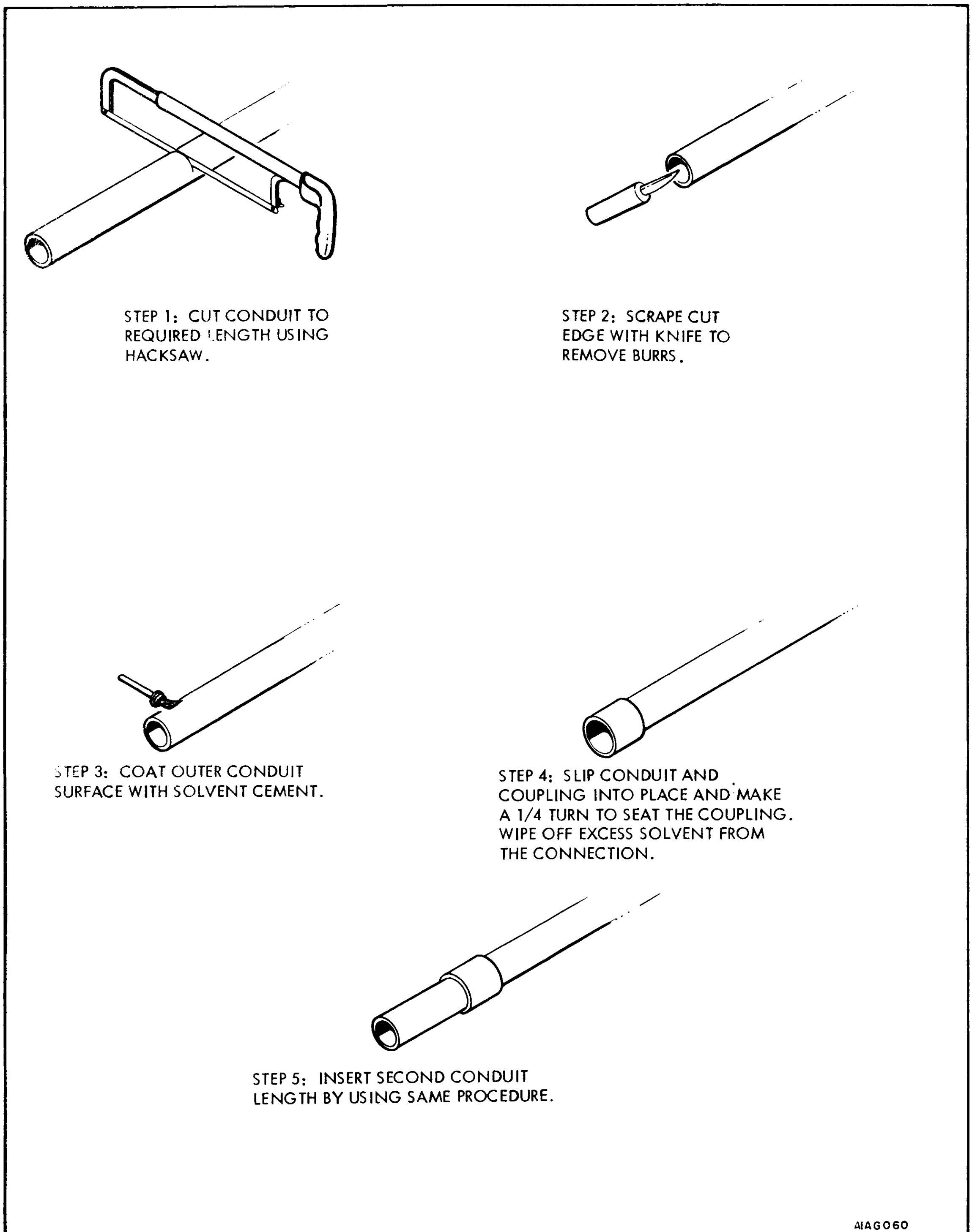


Figure 7-9. Connection of Plastic Conduit

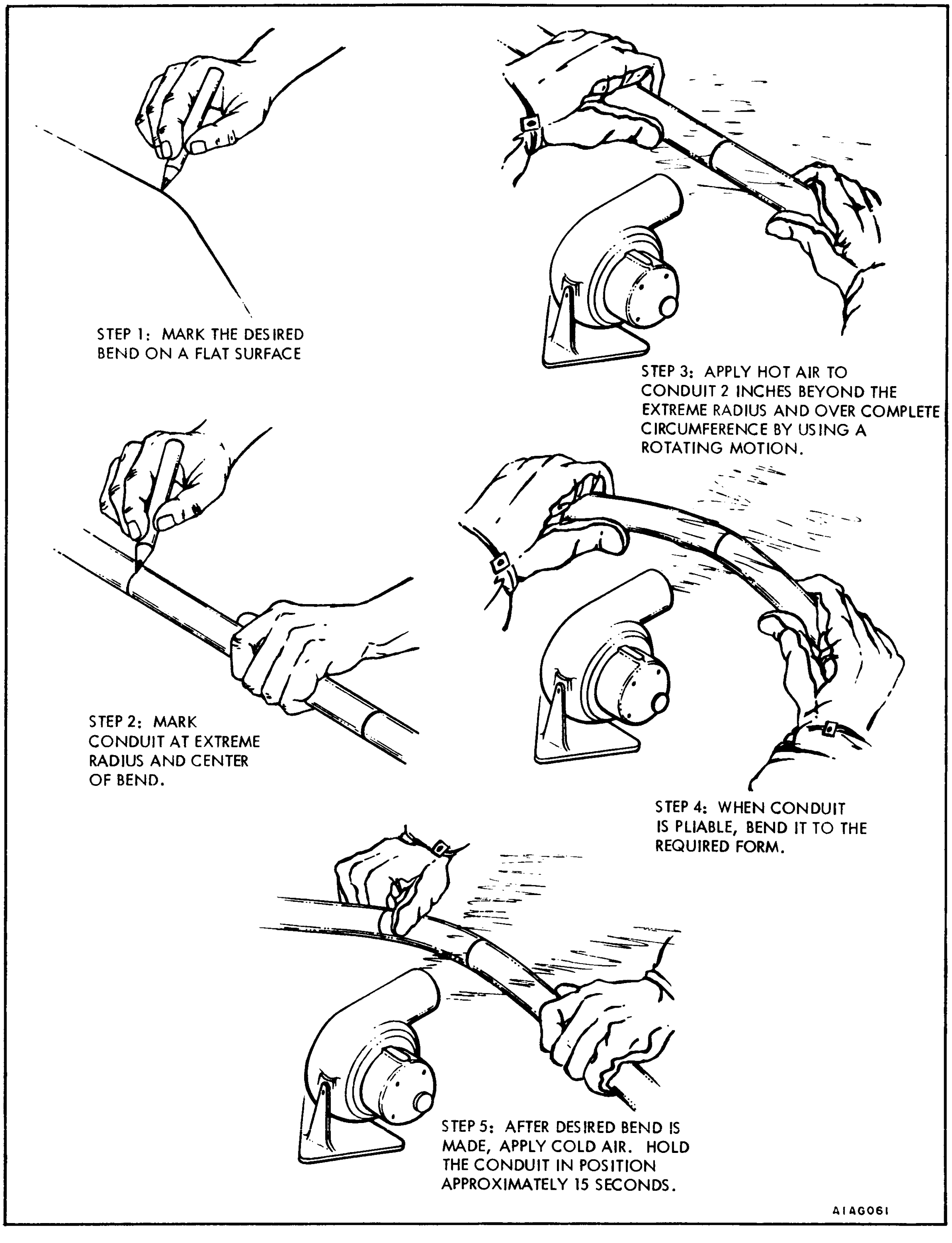


Figure 7-10. Bending Plastic Conduit

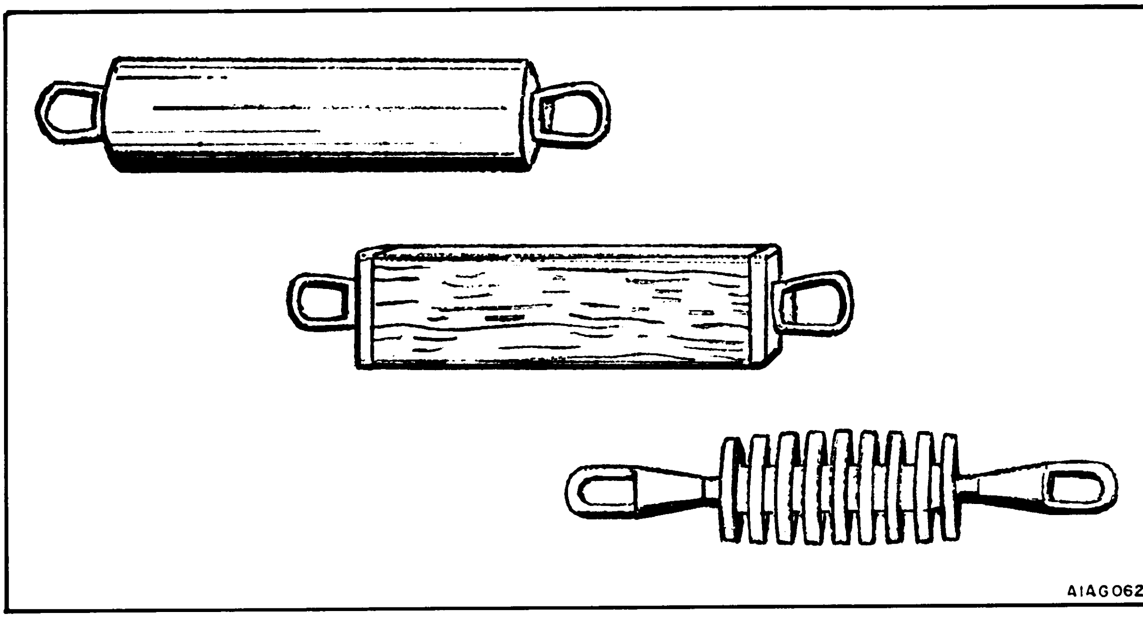


Figure 7-11. Typical Testing Mandrels

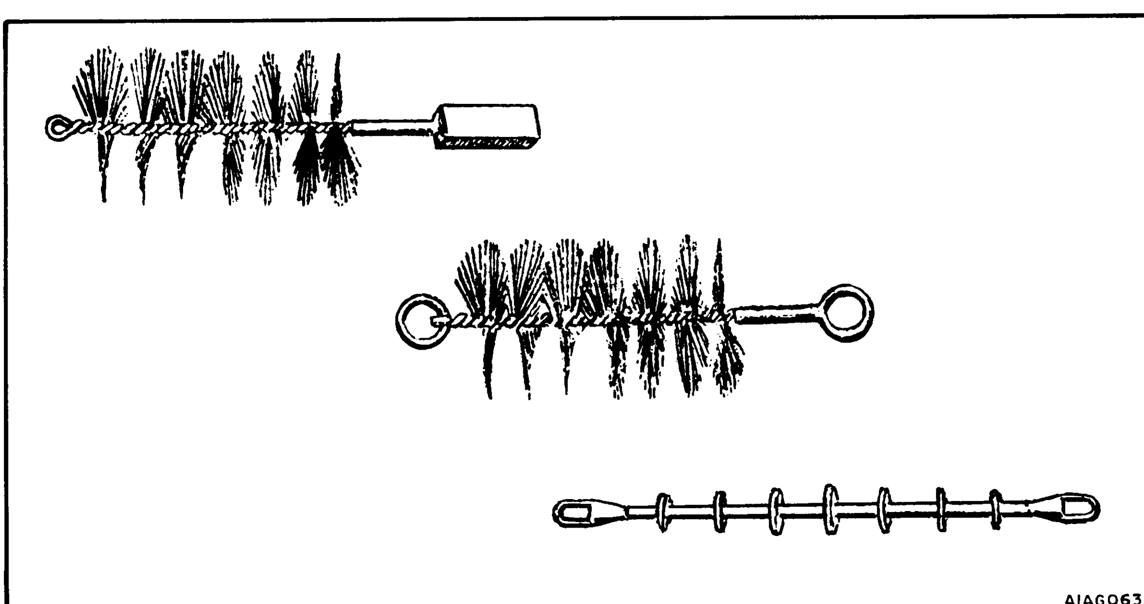


Figure 7-12. Typical Conduit Cleaners

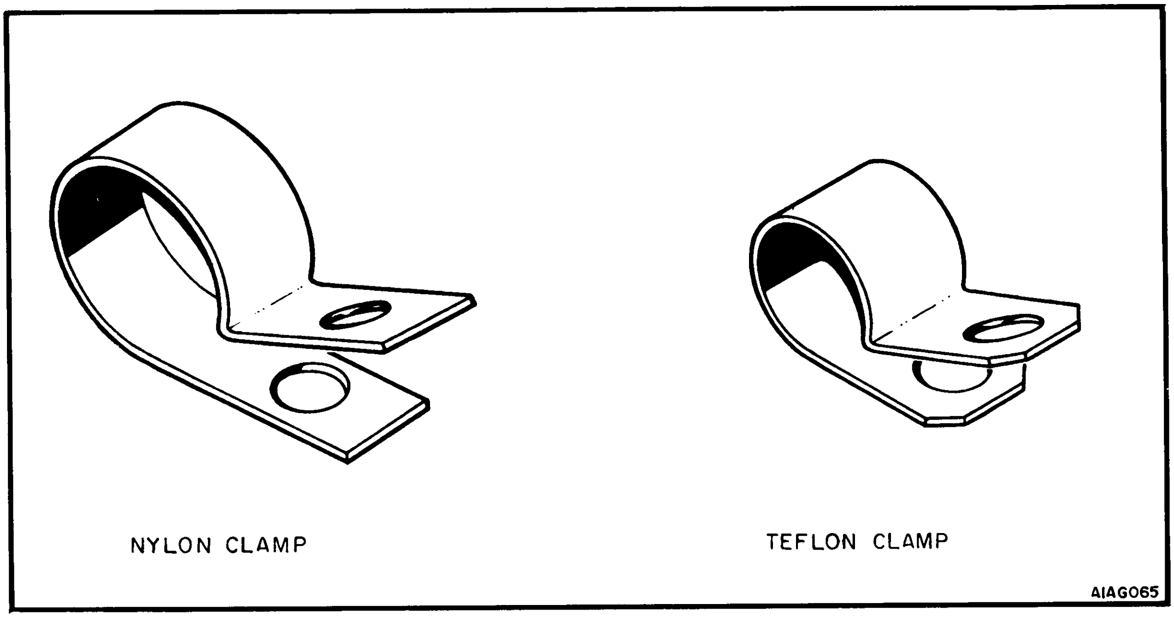


Figure 7-13. Typical Plastic Clamps

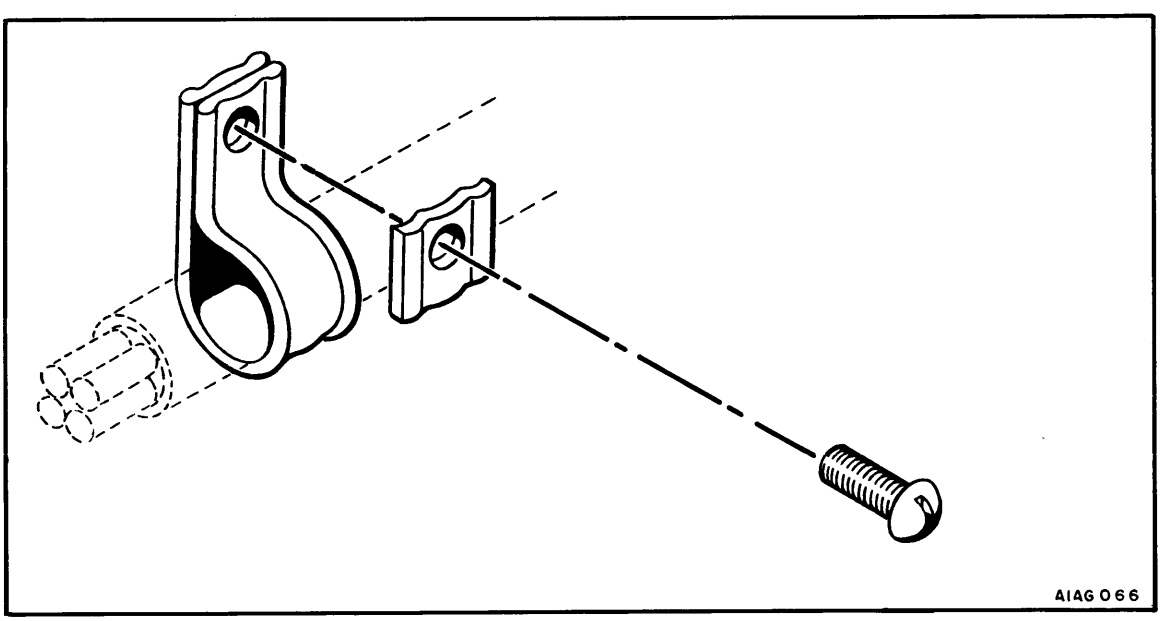


Figure 7-14. Reinforcing Washers

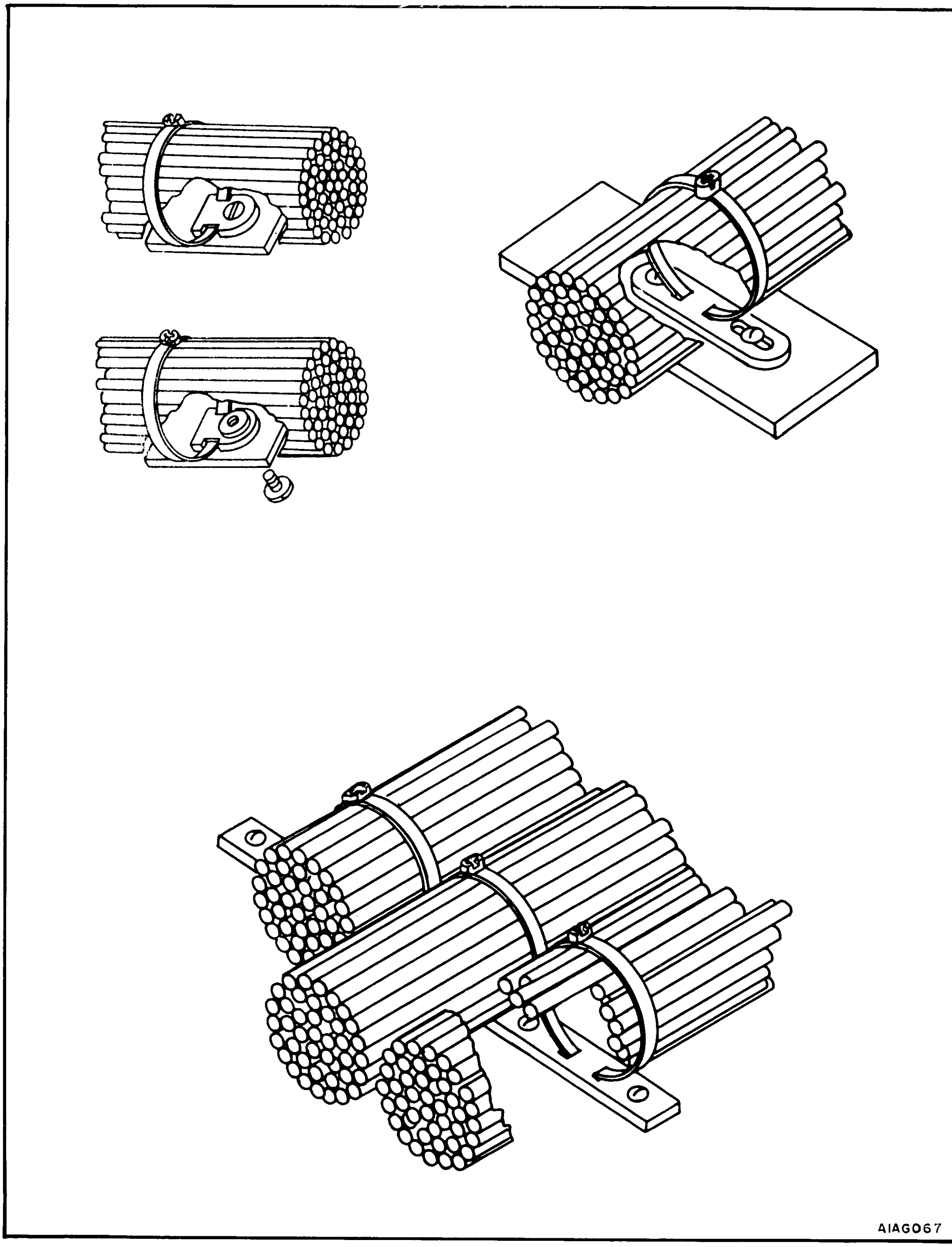
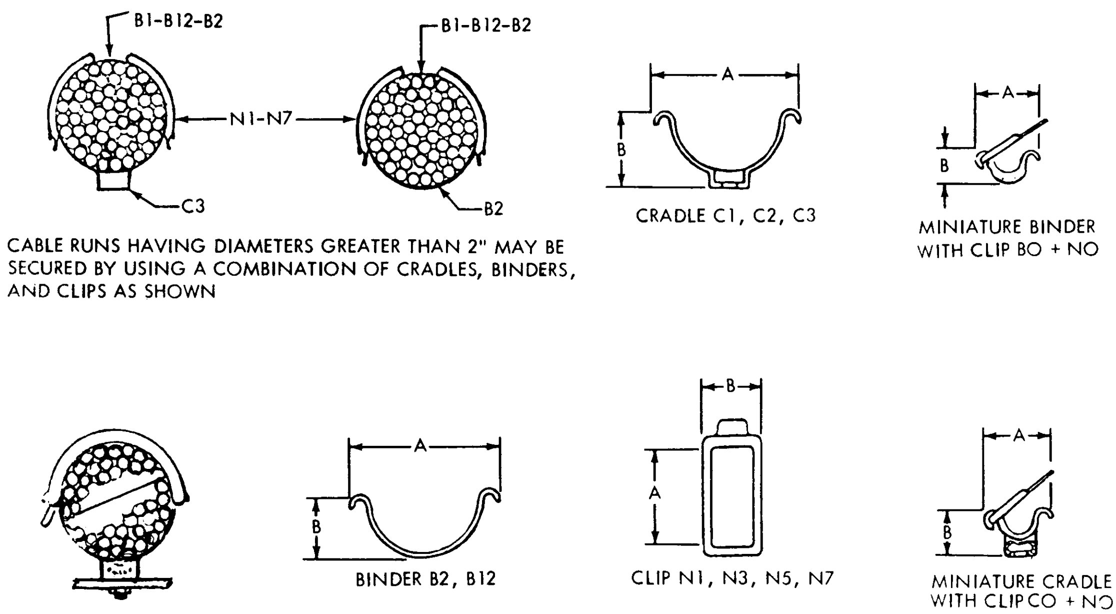
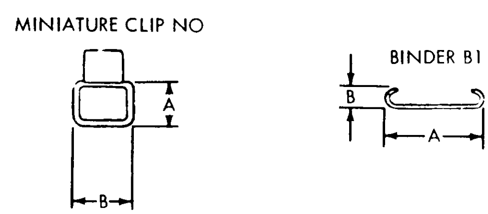


Figure 7-15. Typical Clamping Pads and Bars





DIMENSIONS

TYPE and USE	DIMENSION In Inches A	B
CO	.500	.335
C1	.937	.562
C2	1.375	.750
C3	1.875	1.000
BO	.500	.250
B1	.875	.187
B12	.937	.400
B2	1.875	.812
NO	.340	.500
N1	.500	.937
N3	1.000	1.000
N5	1.750	1.000
N7	2.562	1.000

RECOMMENDED DIMENSIONS

DIAMETER OF CABLE FORM In Inches	USE FOR SUPPORTED WIRING		USE FOR UNSUPPORTED WIRING	
	Cradle	Clip	Binder	Clip
1/8" - 5/16"	CO +	NO	BO +	NO
1/4" - 5/8"	C1	N1	B1	N1
1/2" - 11/16"	C1	N3	B1	N5
11/16" - 15/16"	C2	N3	B12	N3
15/16" - 1-1/16"	C2	N5	B12	N5
1" - 1-1/4"	C3	N3	B2	N3
1-1/4" - 1-1/2"	C3	N5	B2	N5
1-1/2" - 2"	C3	N7	B2	N7

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Figure 7-16. Cradle Clamp Information

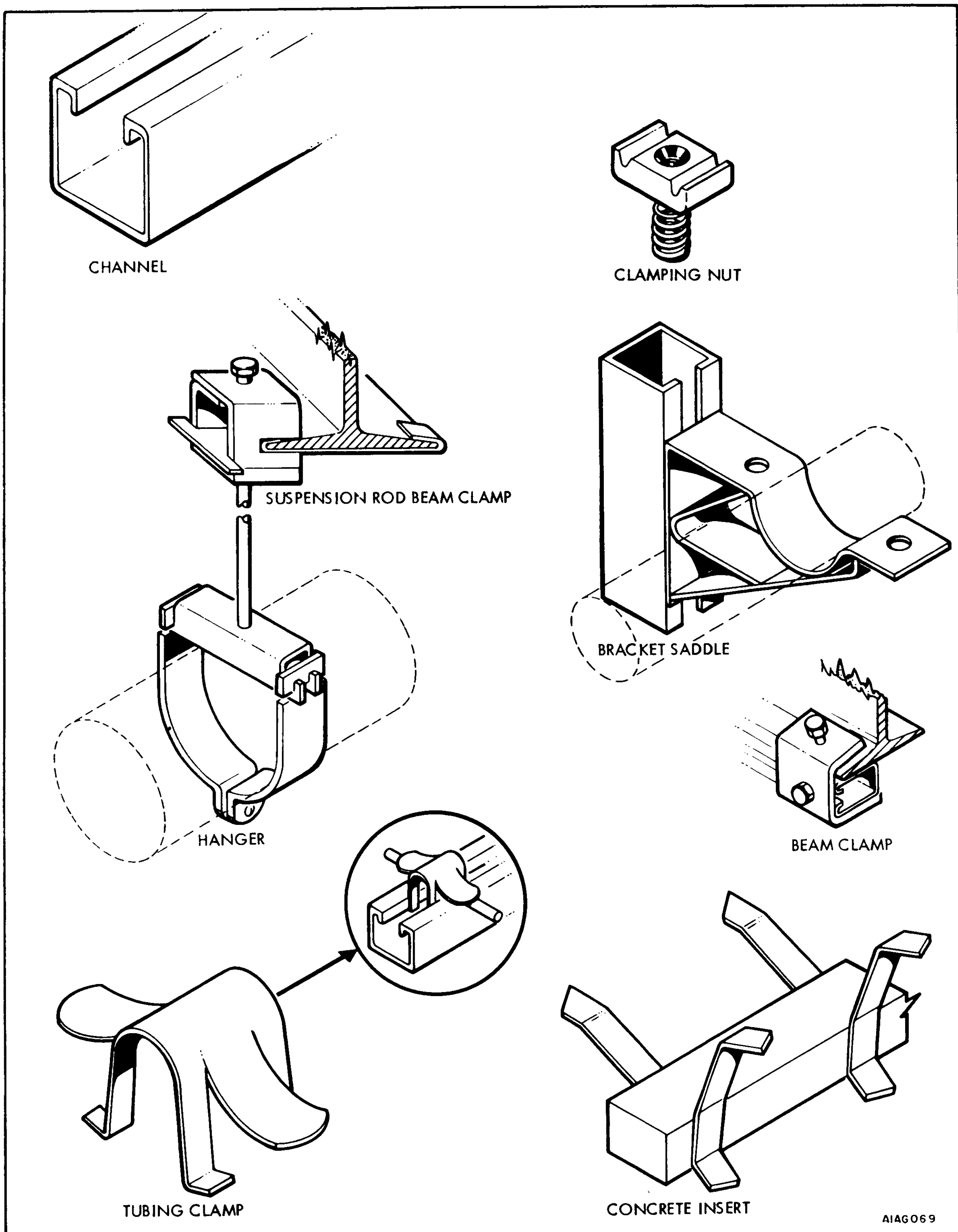


Figure 7-17. Typical Unistrut Type Fittings

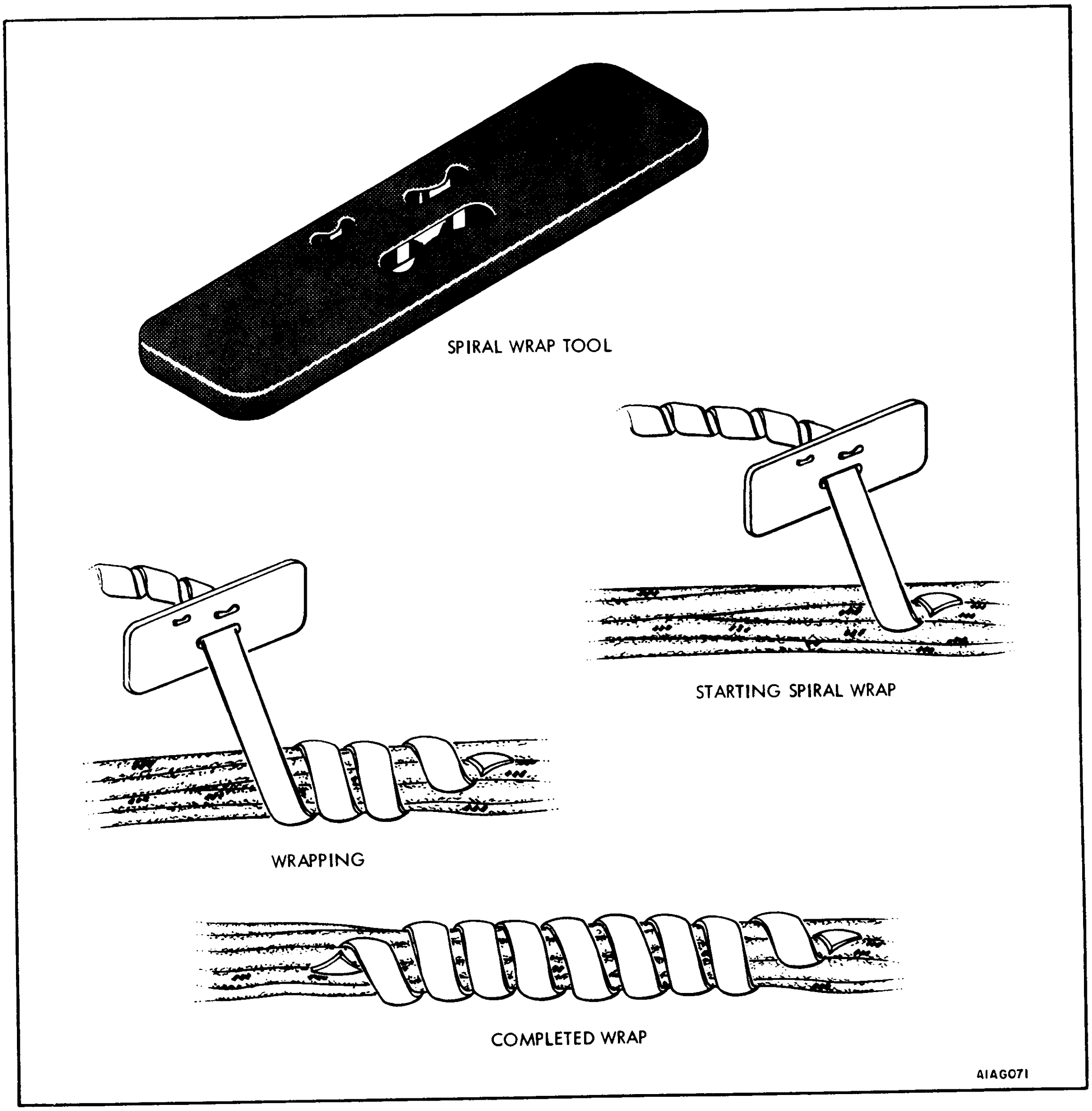


Figure 7-18. Spiral Wrap Installation

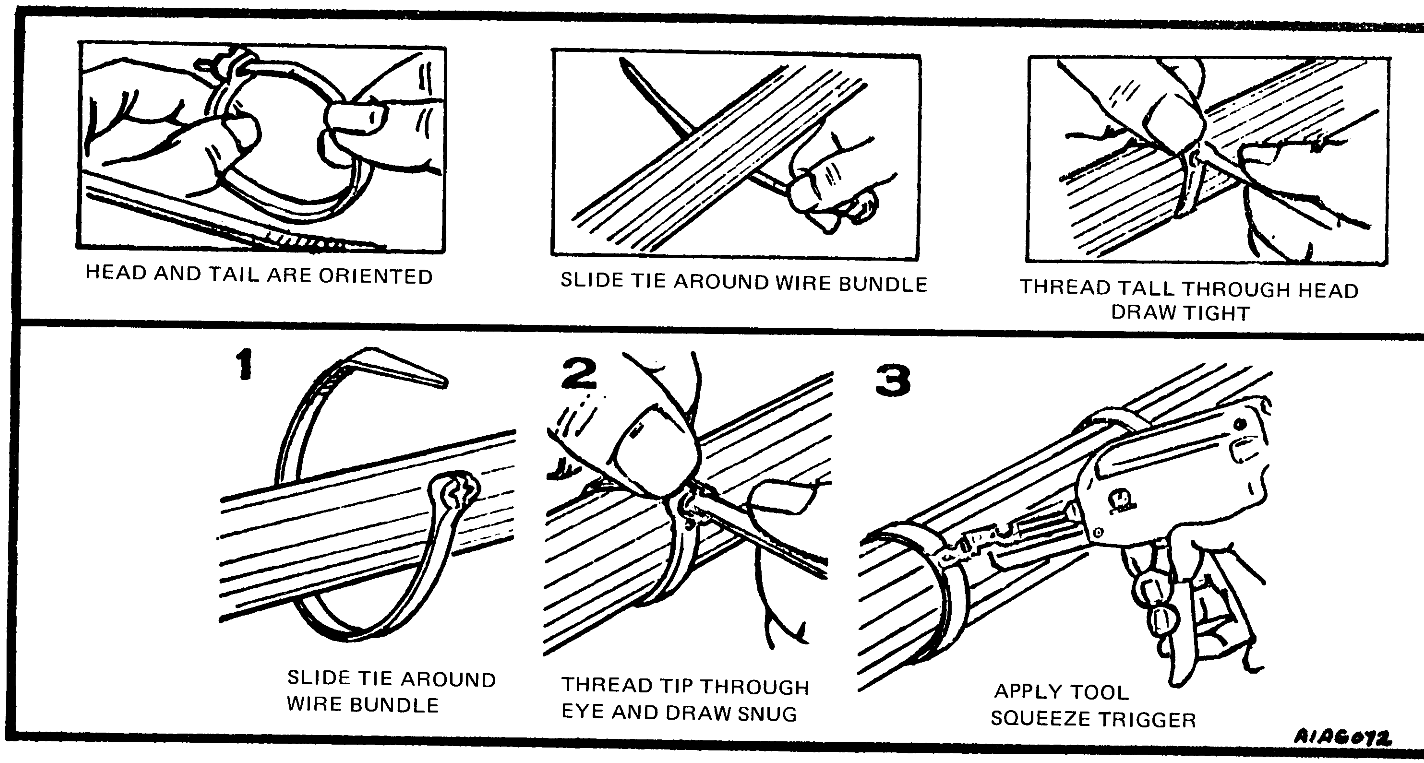


Figure 7-19. Manual and Special Tool Banding Strap Installation

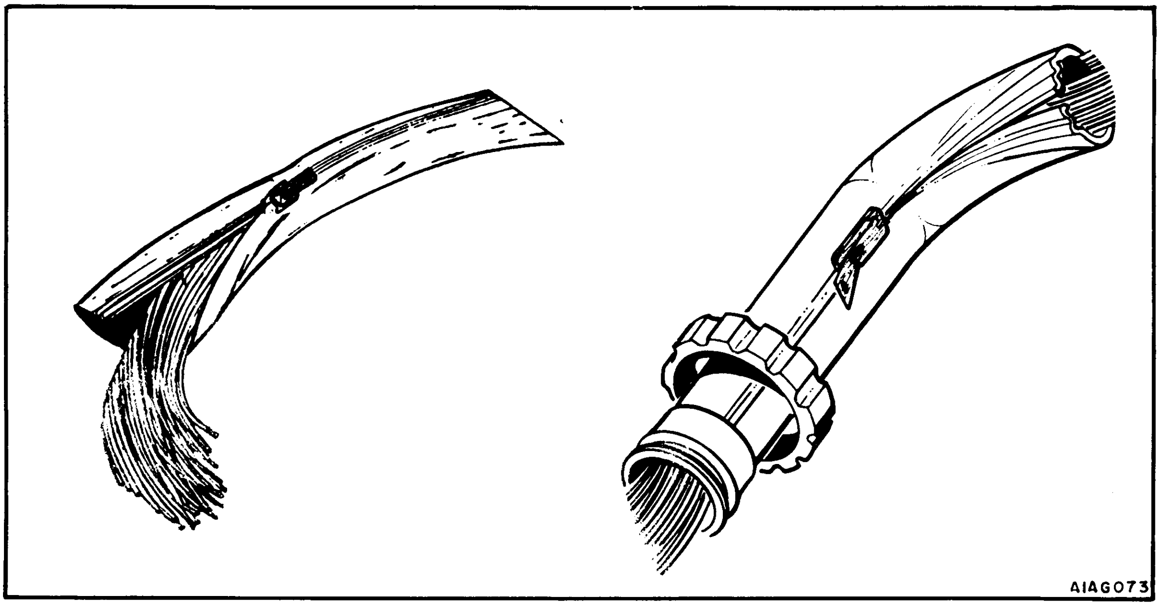


Figure 7-20. Zippered Tubing

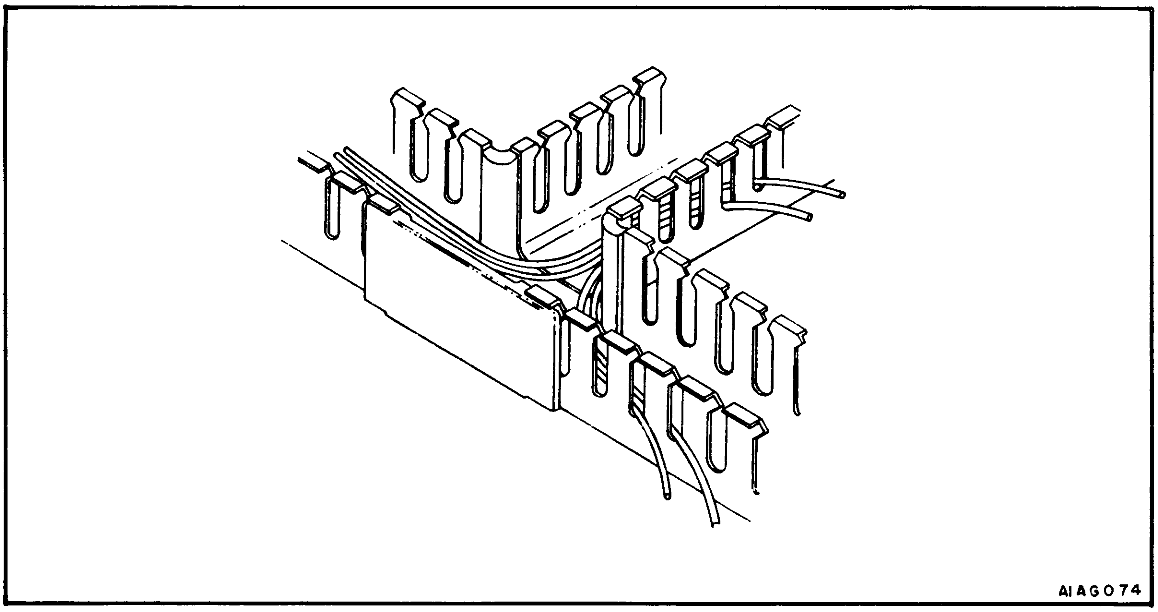
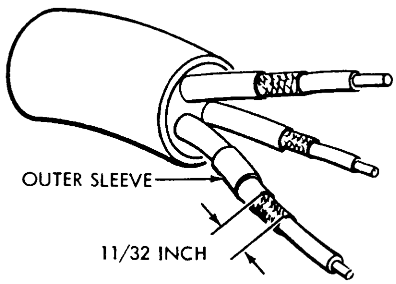
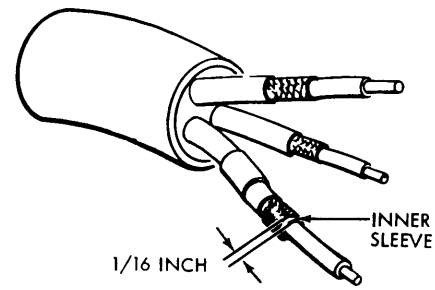


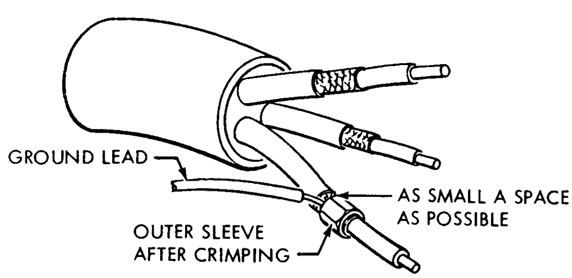
Figure 7-21. Typical Plastic Wiring Duct



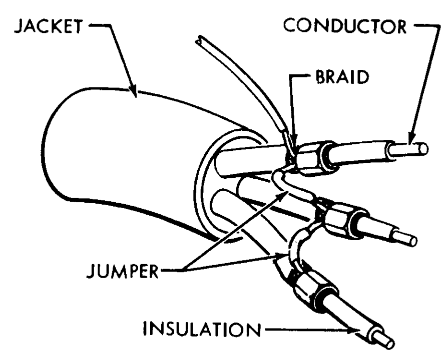
STEP 1: A. - TRIM OUTER JACKET TO DESIRED LENGTH.
B. - CUT BRAID APPROXIMATELY 11/32 INCH PAST END OF JACKET.
C. - SLIDE OUTER SLEEVE OF GROUNDING SHEATH OVER JACKET.



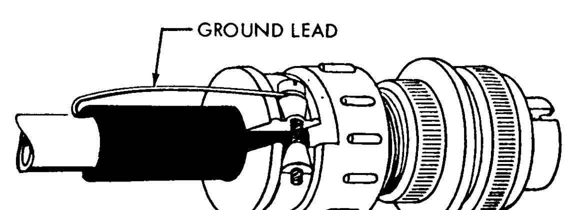
STEP 2: FAN OUT BRAID AND SLIDE INNER SLEEVE UNDERNEATH UNTIL APPROXIMATELY 1/16 INCH OF SLEEVE IS LEFT EXPOSED.



STEP 3: A. - INSERT GROUND LEAD BENEATH OUTER SLEEVE AND EVEN WITH EDGE OF BRAID.
B. - SLIDE OUTER SLEEVE OVER BRAID UNTIL IT IS EVEN WITH EDGE OF INNER SLEEVE.
C. - CHECK THAT NO PART OF BRAID OR GROUND LEAD IS EXPOSED.
D. - SELECT PROPER TOOL AND CRIMP OUTER SLEEVE.



STEP 4: CONNECT OTHER END OF GROUND LEAD TO NEXT SHIELDED CONDUCTOR IN ADDITION TO ITS OWN GROUNDED LEAD. DO THE SAME FOR ALL SHIELDED CONDUCTORS IN CABLE.



STEP 5: A. - SLIDE A LENGTH OF VINYL SLEEVING ON THE FINAL GROUND LEAD AND BRING THE LEAD OUT THROUGH THE BACK OF THE CONNECTOR.
B. - ATTACH A TERMINAL TO THE LEAD AND, WHEN THE CONNECTOR IS ASSEMBLED, FASTEN THE TERMINAL TO ONE OF THE CABLE CLAMP SCREWS.

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Figure 7-22. Termination of Shielded Conductors With Grounding Sheaths

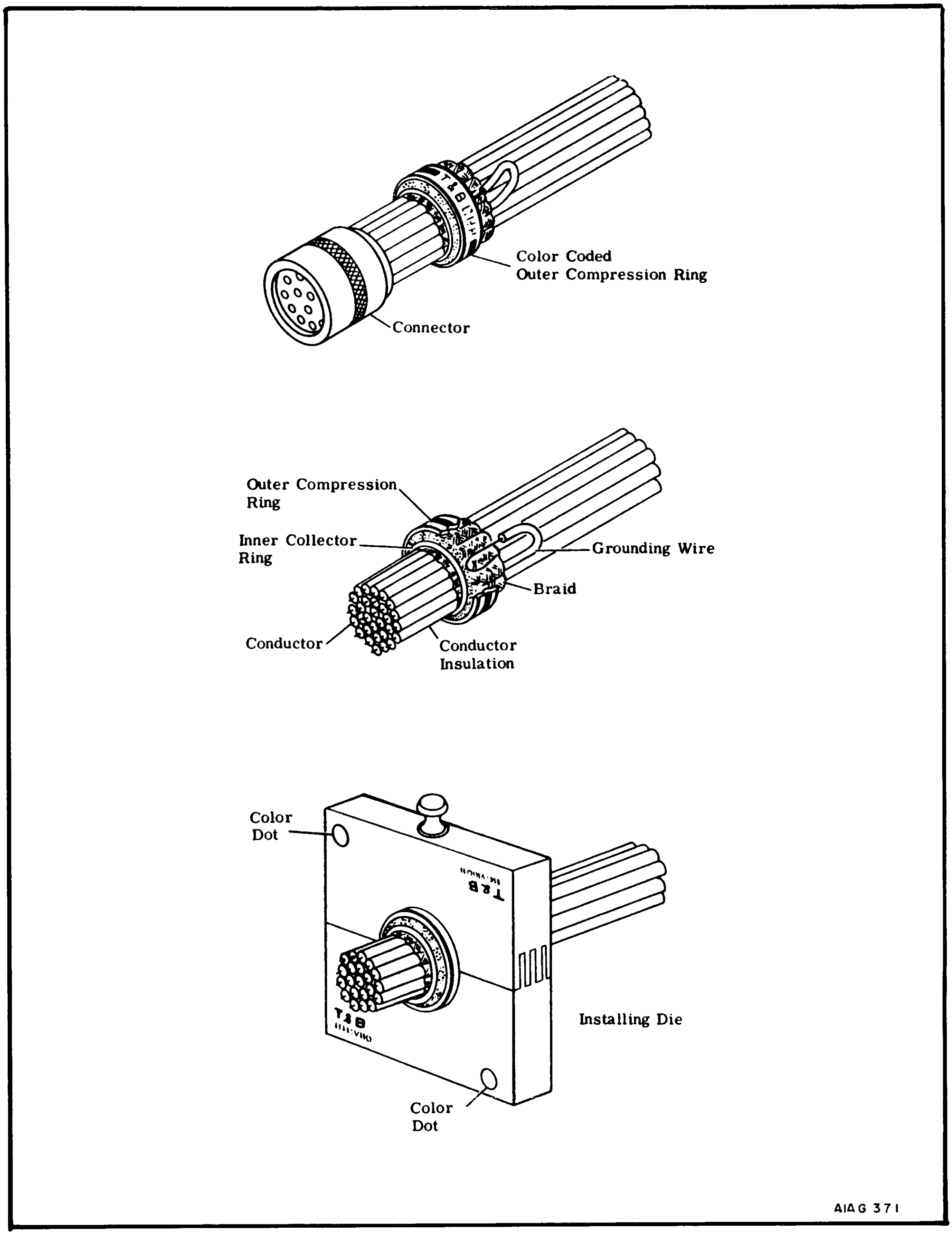


Figure 7-23. Multi-Conductor Shielded Cable Connector

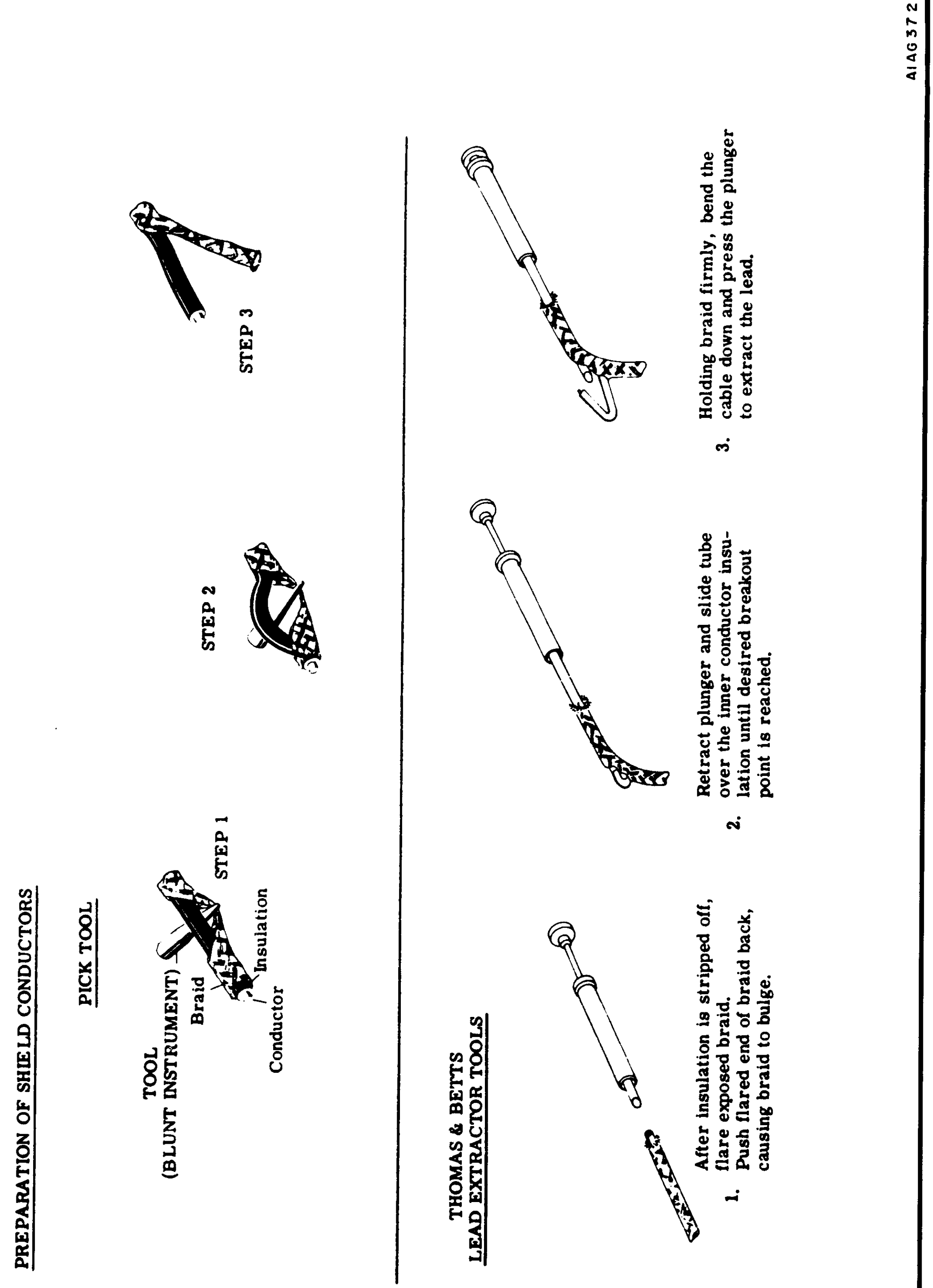
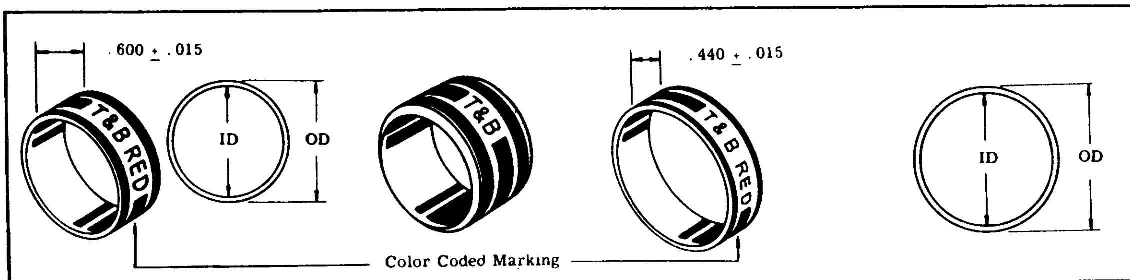
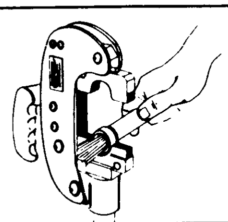


Figure 7-24. Preparation of Shield Conductors



Inner Collector Ring			Cushioned Inner Collector Ring			Outer Compression Ring			Installing Die	Color Code	* Max. No. Braided Shields
Cat. No.	I. D.	O. D.	Cat. No.	I. D.	O. D.	Cat. No.	I. D.	O. D.	Cat. No.		
GSB430	.430	.500	GSK363	.363	.500	GSC590	.590	.670	GS590	Red	15
GSB550	.550	.620	GSK483	.483	.620	GSC710	.710	.790	GS710	Blue	19
GSB670	.670	.750	GSK602	.602	.750	GSC840	.840	.920	GS840	Gray	22
GSB810	.810	.880	GSK742	.742	.880	GSC1010	1.010	1.090	GS1010	Brown	25
GSB920	.920	1.000	GSK852	.852	1.000	GSC1130	1.130	1.210	GS1130	Green	28
GSB1040	1.040	1.120	GSK972	.972	1.120	GSC1250	1.250	1.330	GS1250	Pink	32
GSB1122	1.122	1.192	GSK1054	1.054	1.192	GSC1332	1.332	1.412	GS1332	Orange	35
GSB1224	1.224	1.294	GSK1156	1.156	1.294	GSC1440	1.440	1.520	GS1440	Purple	38
GSB1353	1.353	1.423	GSK1285	1.285	1.423	GSC1563	1.563	1.643	GS1563	Yellow	41
GSB1425	1.425	1.545	GSK1357	1.357	1.545	GSC1670	1.670	1.750	GS1670	Red	44
GSB1550	1.550	1.670	GSK1482	1.482	1.670	GSC1795	1.795	1.875	GS1795	Blue	47
GSB1675	1.675	1.795	GSK1607	1.607	1.795	GSC1920	1.920	2.000	GS1920	Gray	51
GSB1800	1.800	1.920	GSK1732	1.732	1.920	GSC2045	2.045	2.125	GS2045	Brown	55
GSB1925	1.925	2.045	GSK1856	1.856	2.045	GSC2170	2.170	2.250	GS2170	Green	60
GSB2050	2.050	2.170				GSC2295	2.295	2.375	GS2295	Pink	Consult factory
GSB2175	2.175	2.295				GSC2420	2.420	2.500	GS2420	Orange	
GSB2300	2.300	2.420				GSC2545	2.545	2.625	GS2545	Purple	
GSB2425	2.425	2.545				GSC2670	2.670	2.750	GS2670	Yellow	
GSB2530	2.530	2.670				GSC2795	2.795	2.875	GS2795	Red	
GSB2655	2.655	2.795				GSC2920	2.920	3.000	GS2920	Blue	
GSB2780	2.780	2.920				GSC3045	3.045	3.125	GS3040	Gray	
GSB2905	2.905	3.045				GSC3170	3.170	3.250	GS3170	Brown	

*Typical Maximum Fill Using 1/8" x .020 Braid with Two (2) #20 Ground Leads.



Installing Head—Cat. No. 13640 (order dies separately)
Hand-Foot-Pump—Cat. No. 13586 (MS-25494)
Electric Hydraulic Pump—Cat. No. 13594
Hand Switch—Cat. No. 13595
Foot Switch—Cat. No. 13596
Hydraulic Hose—Cat. No. 21006 (6ft.)
21010 (10ft.)

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Figure 7-25. Selection of Ring Size

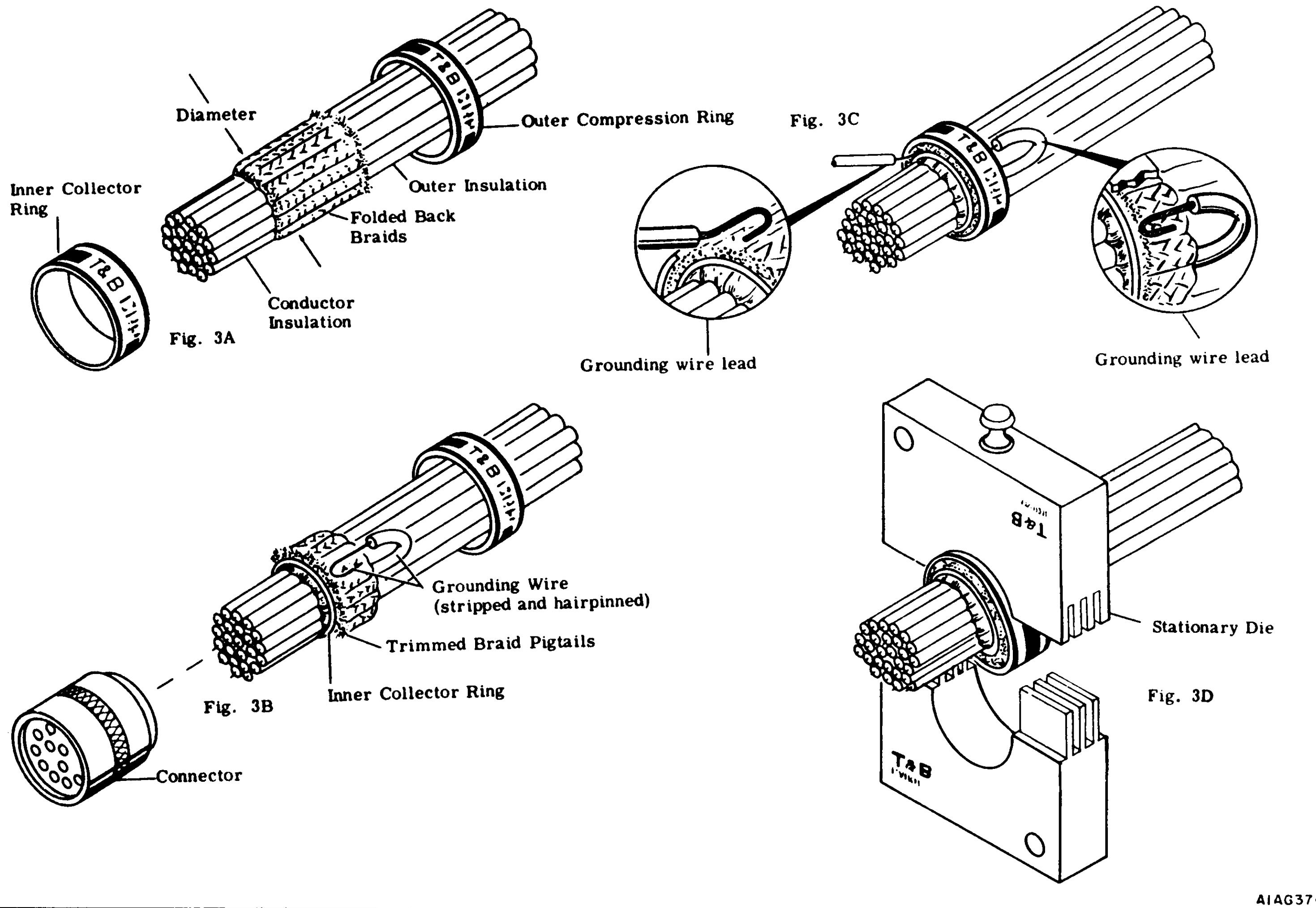

Figure 7-26. Double Fold Shield Method

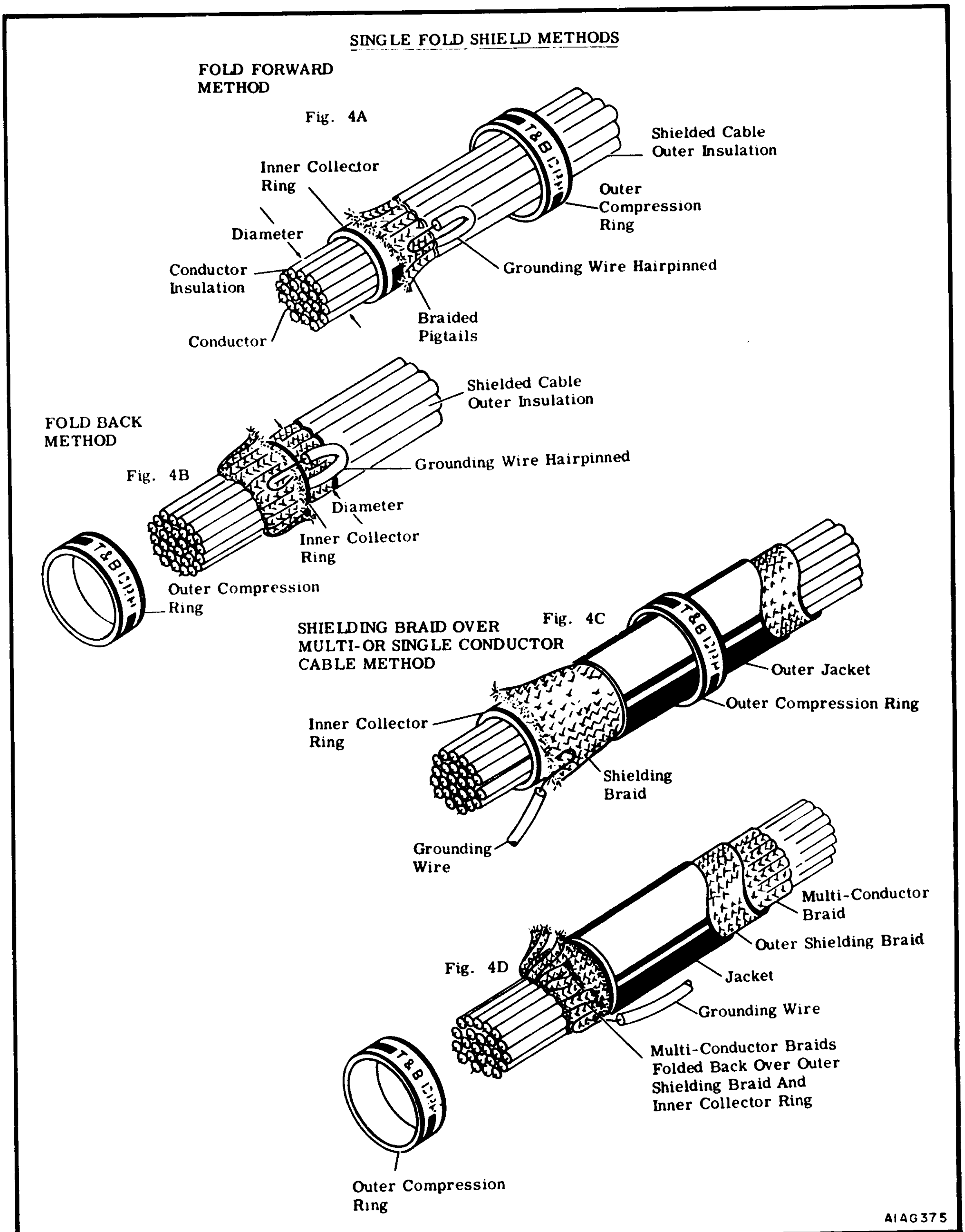

Figure 7-27. Single Fold Shield Methods

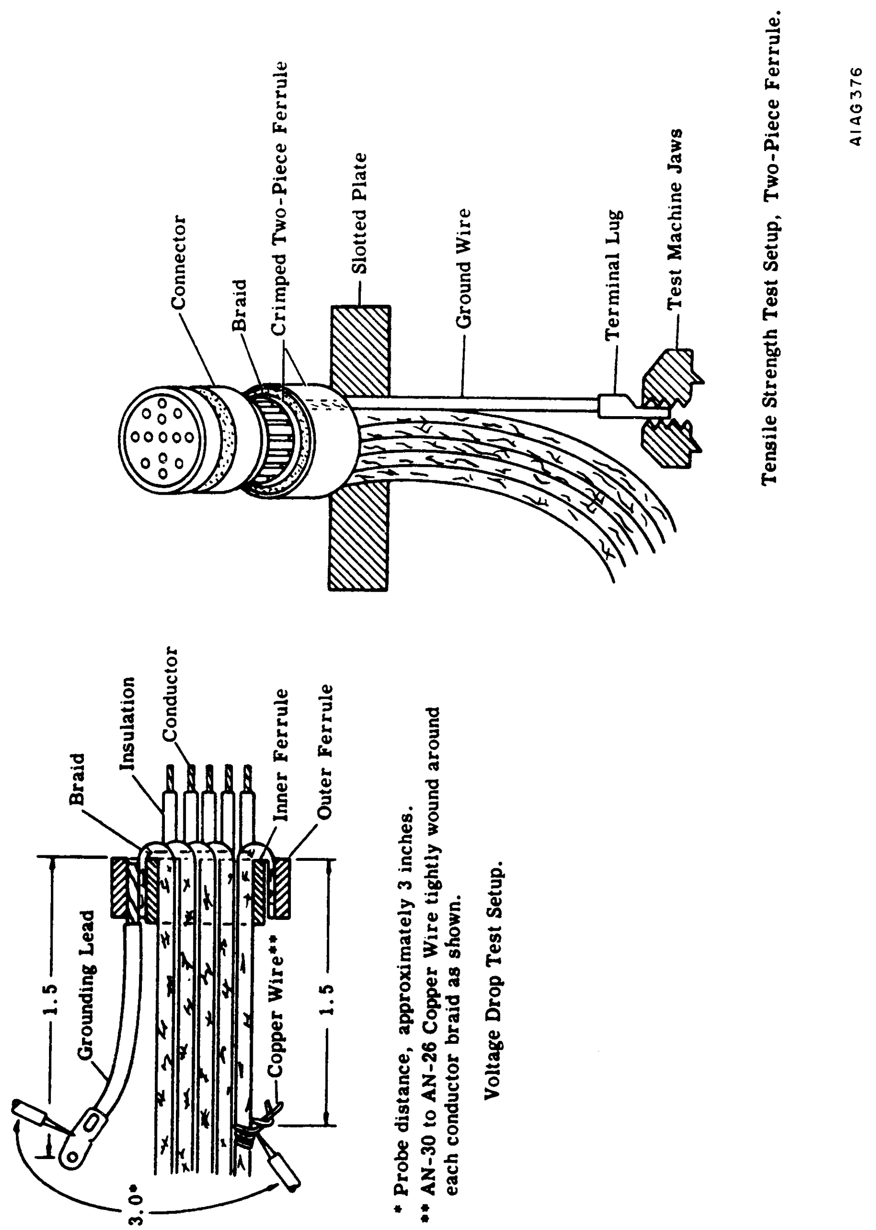

Figure 7-28. Typical Test Methods Setup

Collector Ring Cat. No.	Compression Ring Cat. No.	1/8" Braid Approx. No. Braids	No. Grd. Leads	Average M. V. Drop 1 Amp.	Average Tensile Strength Lbs.
GSB430	GSC590	5 to 14	2 #20 Str.	1.03	39.6
GSB550	GSC710	5 to 17	2 #20 Str.	1.04	33.9
GSB670	GSC840	5 to 20	2 #20 Str.	0.77	35.9
GSB810	GSC1010	5 to 23	2 #20 Str.	0.86	38.6
GSB920	GSC1130	5 to 27	2 #20 Str.	0.89	30.0
GSB1040	GSC1250	5 to 30	2 #20 Str.	0.83	39.0
GSB1122	GSC1332	5 to 34	2 #20 Str.	0.82	36.0
GSB1224	GSC1440	5 to 37	2 #20 Str.	0.90	36.5
GSB1353	GSC1563	5 to 41	2 #20 Str.	0.87	35.4
GSB1425	GSC1670	5 to 43	2 #20 Str.	0.73	31.0
GSB1550	GSC1795	5 to 47	2 #20 Str.	0.70	31.0
GSB1675	GSC1920	5 to 52	2 #20 Str.	0.71	30.0
GSB1800	GSC2045	5 to 56	2 #20 Str.	0.71	30.0
GSB1925	GSC2170	5 to 62	2 #20 Str.	0.69	29.0
GSB2050	GSC2295	For Test Information Consult Factory			
GSB2175	GSC2420				
GSB2300	GSC2545				
GSB2425	GSC2670				
GSB2530	GSC2795				
GSB2655	GSC2920				
GSB2780	GSC3040				
GSB2905	GSC3170				AIAG377

Figure 7-29. Average Millivolt Drop and Tensile Strength

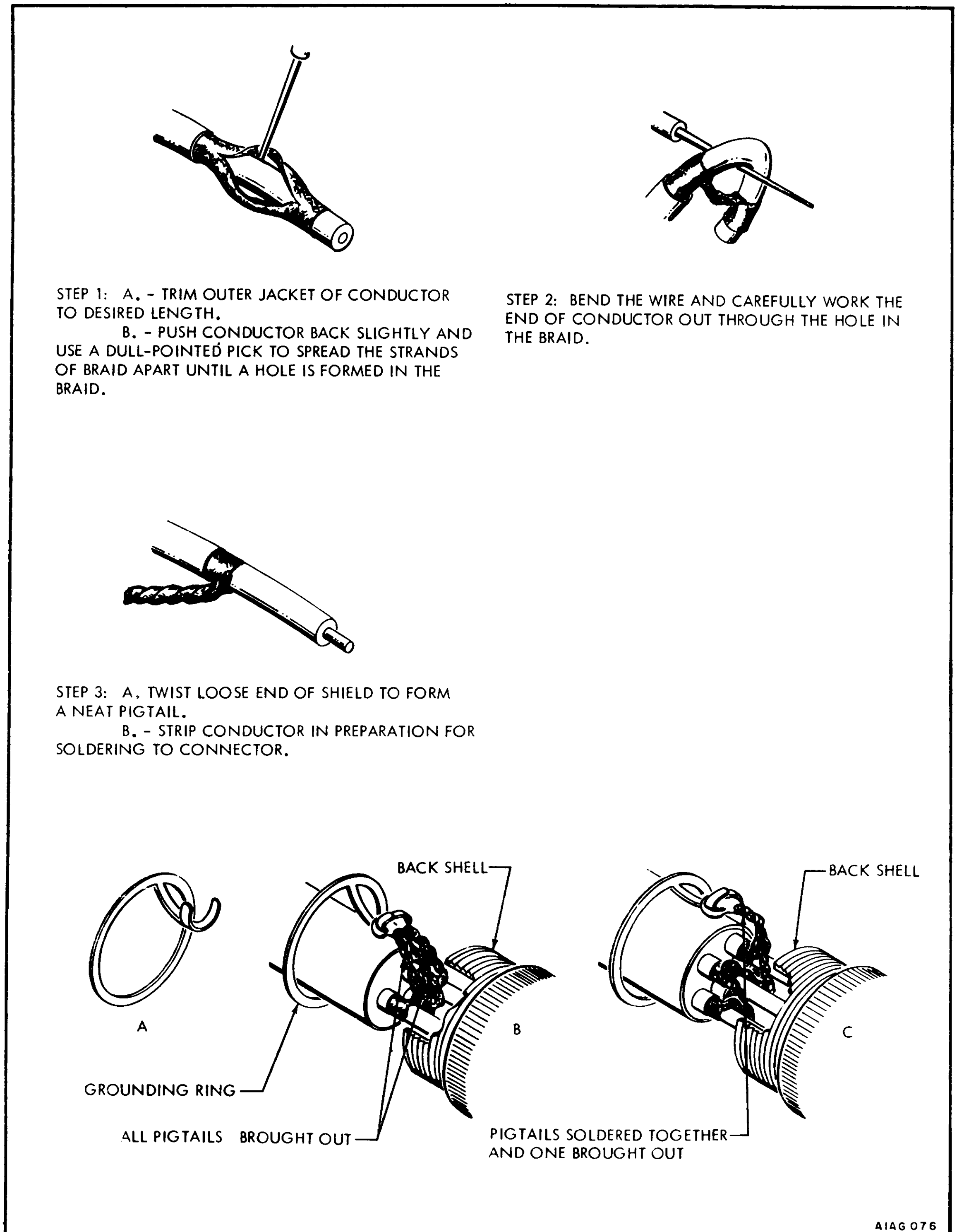

Figure 7-30. Termination of Shielded Conductors With a Grounding Ring