

CHAPTER 9 - FORMING WIRES INTO CABLES AND HARNESSSES

9.1 General

Wiring shall be assembled in interconnecting cables or harnesses as described herein. Fabrication methods and assembly techniques that assure the production of high quality interconnecting cables and harnesses shall be used.

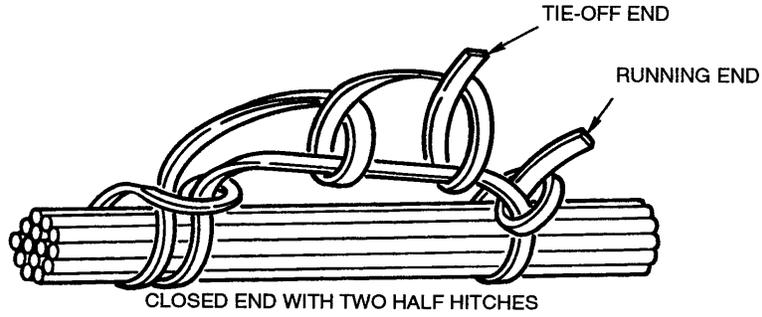
9.2 Lacing for Trunk, Branches, and Breakouts

When engineering documents specify the use and type of lacing, the following requirements shall apply. Lacing tie-ends shall be trimmed. When knots are staked (see Figure 9-7), the necessary compounds, as well as any special design requirements, shall be specified.

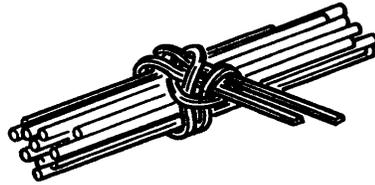
1. **Starting Stitch.** Harnesses laced with single tape shall initially be tied with a starting stitch. Single-tape starting stitches shall be the same as a spot tie with a running end (see item 2 of this paragraph), or as shown in Figure 9-1 View A. Starting stitches for double lacing shall be as shown in Figure 9-1 View B. Starting stitches shall not place stress on wire terminations.

2. **Spot Ties.** Spot ties shall consist of a clove hitch followed by a square knot as shown in Figure 9-2 or other non-slip knots. See Table 9-1 for spot tie spacing.

3. **Closing Stitch.** Single or double lacing tape shall be terminated with a closing stitch as shown in Figure 9-3. Lacing shall be terminated at every major breakout or branch and at the extremity of the harness. (Major breakouts normally contain a large percentage of the wire volume, such as 25 to 30 percent or more.) The stitching shall terminate close to the extremity of the harness but shall not stress the wire terminations. Closing and starting stitches at branches and breakouts shall be next to the breakout. An alternate closing stitch method is shown in Figure 9-4. Single or small multiple breakouts of two or three wires need not have closing and starting stitches, but may have running lockstitches on each side (Figure 9-5).

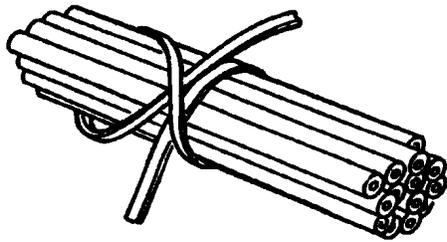


A. STARTING STITCH, SINGLE TAPE

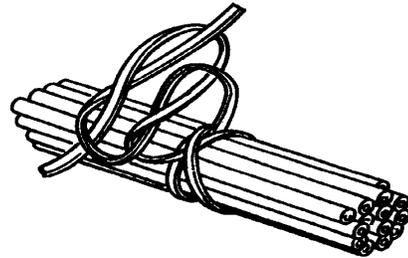


B. STARTING STITCH, DOUBLE TAPE

Figure 9-1. Starting Stitch



A. CLOVE HITCH



B. CLOVE HITCH AND SQUARE KNOT

Figure 9-2. Spot Tie (Typical)

Table 9-1. Spot Tie, Plastic Strap, and Stitch Spacing Dimensions

Harness Diameter mm (Inches)	Maximum Distance Between Harness Ties mm (Inches)
6.4 (0.25) or less	19.1 (0.75)
12.7 (0.50)	38.1 (1.50)
25.4 (1.00)	50.8 (2.00)
Larger than 25.4 (1.00)	76.2 (3.00)

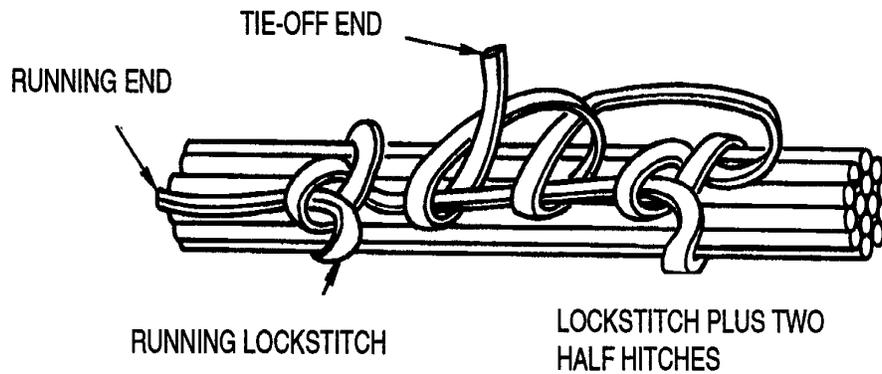


Figure 9-3. Closing Stitch and Single Tape--Illustration

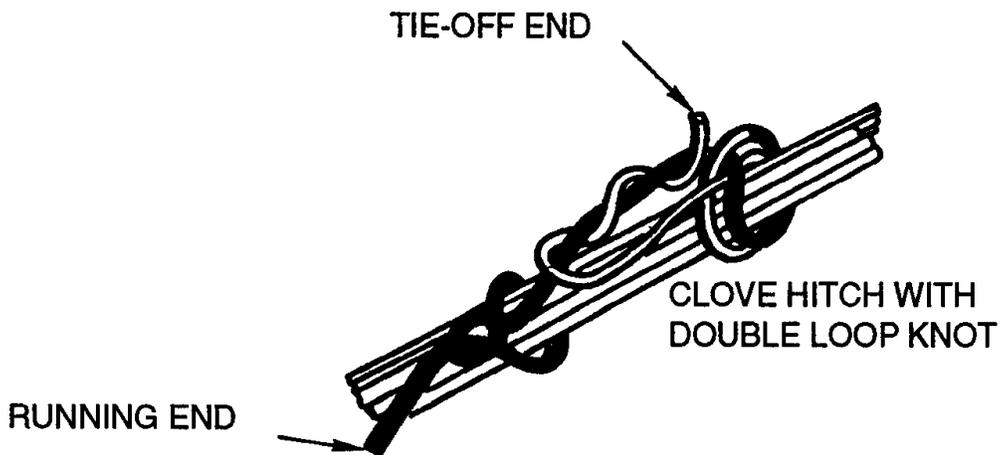


Figure 9-4. Alternate Closing Stitch and Single Tape--Illustration

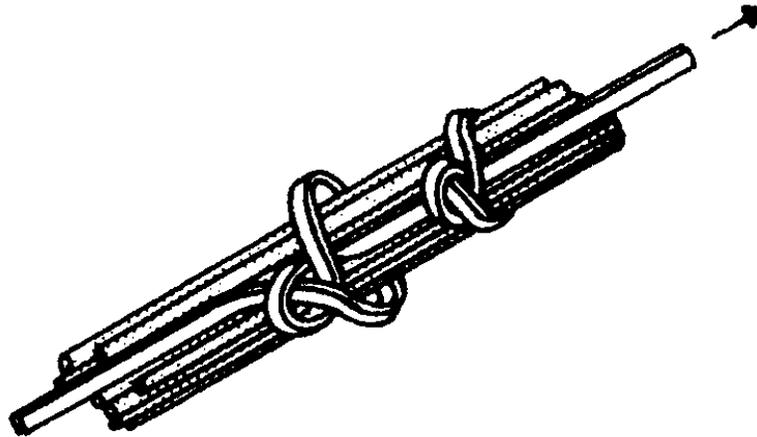


Figure 9-5. Running Lockstitch

4. **Running Lockstitch.** Continuous lacing shall be achieved using running lockstitches as shown in Figure 9-5.

5. **Stitch Spacing.** Lacing stitches and spot ties shall be placed as detailed in Table 9-1. A tie or stitch shall be placed immediately before and immediately after any breakout of the wire or cable from the harness. Dimensions from the connector or connector accessories to start of harness tie are given in Table 9-2.

Table 9-2. Distances From Connectors or Connector Accessories to Beginning of Harness Ties

Harness-Bundle Diameter mm (inches)	Distance From Connector or Connector Accessory to Start of First Tie mm (inches)
Less than 12.7 (.5)	25.4 - 50.8 (1 - 2)
12.7 to 25.4 (.5) (.5 to 1)	50.8 - 76.2 (2 - 3)
25.4 (1) or larger	76.2 - 101.6 (3 - 4)

6. **Flat Stitching.** Flat stitching shall utilize either of the stitches pictured in Figure 9-6.

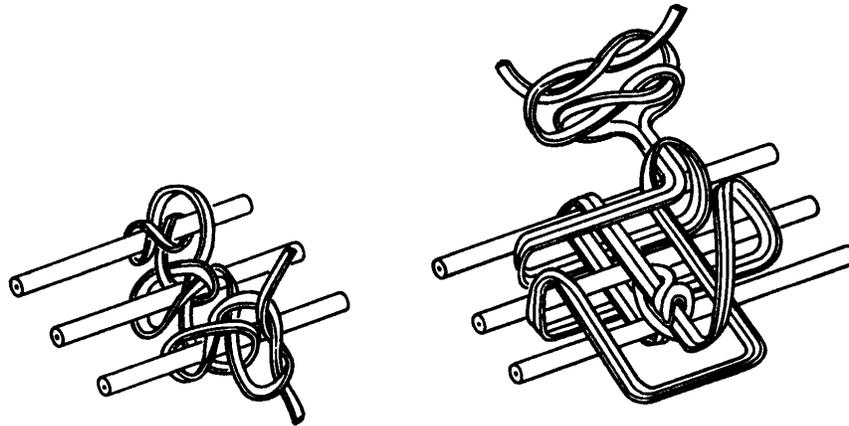


Figure 9-6. Flat Lacing Stitches

7. **Large Breakouts.** Lockstitching shall terminate with a closing stitch before each large breakout or branch of the harness. The lacing shall start anew with a starting stitch on the opposite side of the breakout on each branch.

9.3 Fabric Braid Sleeving (Prewoven)

Prewoven fabric (unvarnished) braid sleeving to be installed over the wire harness shall be slightly oversized so that it can be slid over the bundle. Braided sleeving shall be snugly dressed down over the wire bundle. Continuous braid sleeving shall be secured at the ends by plastic cable straps, spot ties, clamps, heat shrinkable sleeving, or a potting material. When secured, the covering shall not slide freely. Sleeving shall be trimmed and terminated at a breakout but shall not be punctured or slit to provide openings for breakout. After installation, braided sleeving shall be secured or treated in one of the following ways to eliminate fraying or unraveling.

1. Braided sleeving may be secured by a spot tie or plastic cable strap. The end of the braid shall be tucked under and secured with a spot tie or plastic strap (Figure 9-7).

BRAID END TUCKED UNDER

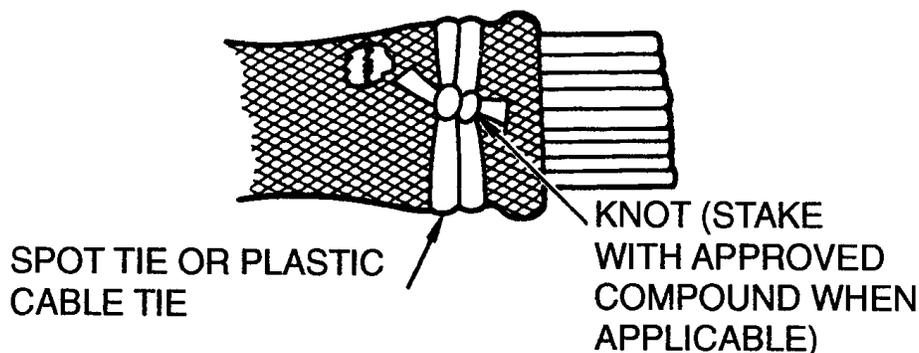
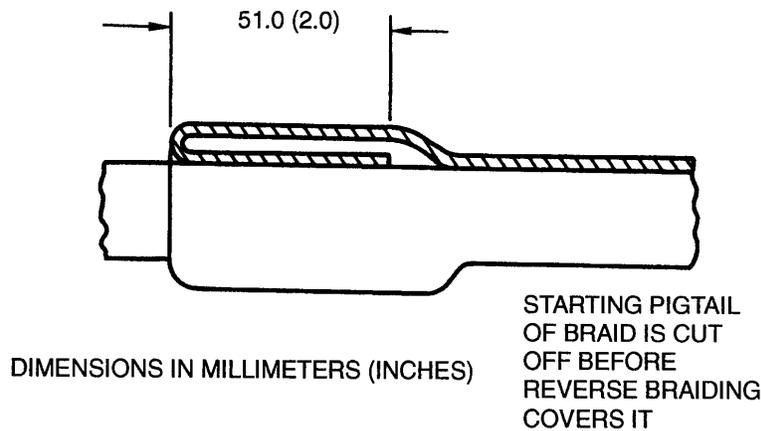


Figure 9-7. Securing Fabric Braid Sleeving

2. The end of the braid may be secured by connector clamps, other hardware, or potting.
3. The ends of glass braids may be bonded using an adhesive. Excessively frayed material shall be trimmed away prior to application of the adhesive. When the adhesive is dry, the braid shall be secured by spot tying or other means so that it does not slip on the wire bundle.
4. Polyamide (nylon) braids (for use on ground service equipment) may have their ends sealed by use of a "hot knife" or similar instrument.

9.4 Fabric Braid Directly Woven on Interconnecting Harness or Cable

Fabric braids woven directly on interconnecting harnesses or cables may be loose or tight, as necessary to produce the degree of flexibility required. The braid shall be smooth and shall provide coverage that leaves no gaps through which the wires can be seen. No frayed ends shall be visible. All pigtails shall be secured. Braids applied tightly shall not terminate so close to connectors that they stress wires attached to solder cups. Spot ties, plastic straps, lacing, and other temporary holding means shall be removed from wire bundles prior to braid application. Flat tapes may be left under braid if the tape has a low profile. Typical braiding techniques are shown



in Figures 9-8, 9-9, and 9-10.

Figure 9-8. Starting Lock

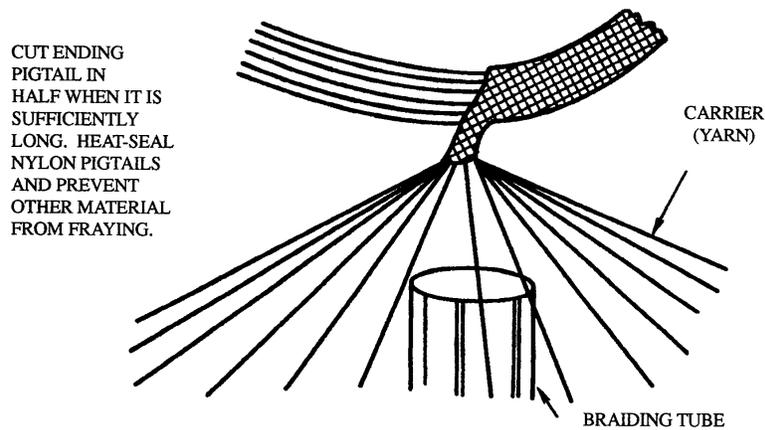


Figure 9-9. Forming Ending Pigtail

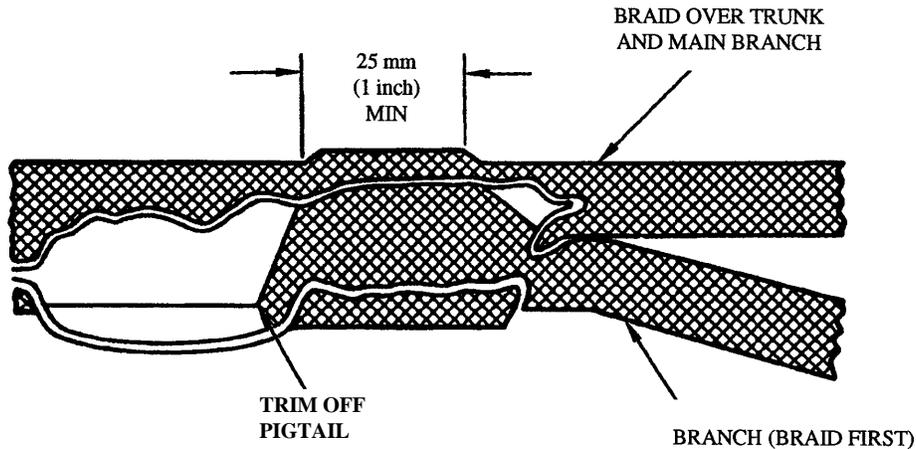


Figure 9-10. Braiding at a Breakout or Y Intersection

9.5 Spiral Wrap Slewing

Spiral wrap slewing shall be installed to make firm contact with the wire bundle. The ends of the spiral wrap shall be trimmed to eliminate sharp edges or points that might damage the insulation. The slewing may be butted or applied as an open spiral, but shall not be overlapped (Figure 9-11). When spiral slewing is applied, the ends of the wire bundle shall be secured by the tie wraps or by other means (see paragraphs 9.2 and 9.3-2).

NOTE: DO NOT USE SPIRAL WRAP SLEWING ON SPACECRAFT OR LAUNCH VEHICLES.

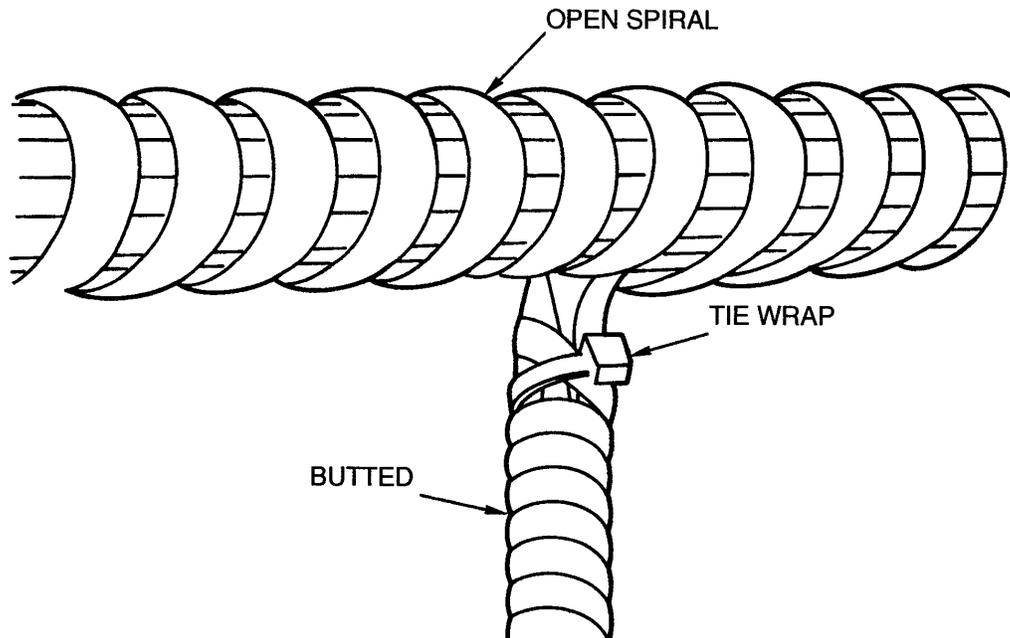


Figure 9-11. Spiral Wrap Sleeveing

9.6 PLASTIC STRAPS

1. Installed straps shall be locked to prevent them from loosening or opening. Straps shall be placed on both sides of a breakout; otherwise, spacing between straps shall be as required by Table 9-1. The "ribbed" side of a strap shall always be placed against the wires. Straps shall be tightened so that they do not slide back and forth on the assembly; however, they shall not be so tight as to cause noticeable indentation or distortion of the wires in the harness. Proper strap orientation is shown in Figure 9-12.

2. Plastic straps are usually installed by tooling. Tooling shall be tension-controlled to meet the strap-tightening requirements previously stated. Surplus strap ends shall be trimmed flush at the back end of the strap head (this is done automatically by most tooling).

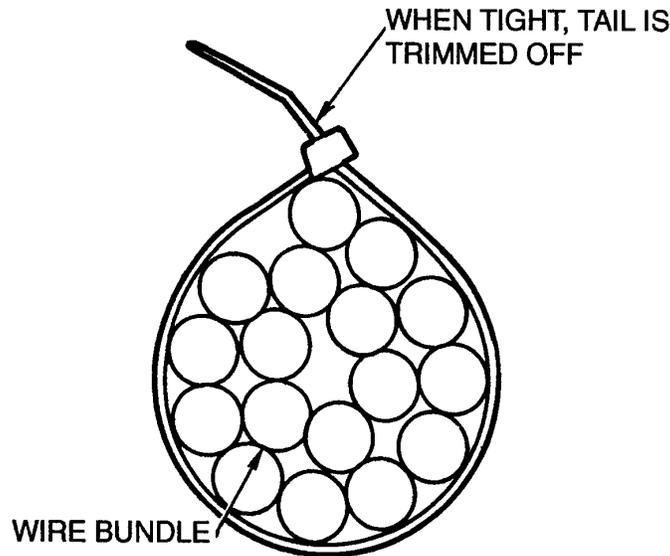


Figure 9-12. Plastic Strap Orientation

9.7 Metal Braid Shielding

Metal braid shielding can either be woven directly over a core or obtained in prebraided form and installed by sliding it over the wire bundle. To prevent potential damage (cold flow) of the underlying wire insulation, a separator (e.g., a tape) may be applied over the wire bundle to give the wire continuous protection. Prewoven braiding shall be tightened down to contact the wire bundle. Braids shall be terminated as specified by the engineering documentation. Prewoven metallic braid shall be cleaned in a suitable solvent to remove contamination prior to installation over the harness (see Chapter 15).

9.8 Insulation Sleeving/Tubing

Insulation sleeving shall be installed on all terminations that are not otherwise insulated or potted, except those at ground potential (e.g., overall shield and coaxial cable terminations). Sleeving shall be installed to meet the dimensional requirements of the applicable drawing or specification.

1. **Heat-Shrinkable Sleeving.** The heat-shrinkable sleeving selected shall be larger than the maximum diameter of the object being covered, and after shrinking it shall provide a tight fit over the object in the area of maximum diameter. This will cause the sleeving to have a tight mechanical grip on the item it covers. A guide for selecting sleeving sizes is given in Table 9-3. There shall be no partially or incompletely shrunken areas. Sleeving may have a slight surface crazing, but it shall be free of cracks, punctures, and charred or burned areas.

2. **Tubing.** Tubing shall be secured by spot ties or otherwise restrained to prevent them from sliding back and forth over the wire bundle.

Table 9-3. Selection Guide for Use of Polyolefin and Polyvinylidene Fluoride Sleeving $\frac{1}{mm}$ (inches)

I.D. As Supplied	I.D. Recovered (After Heating)	Cable Diameter	Sleeving Size
1.2 (0.046)	0.6 (0.023)	0.30 to 0.70 (0.01 to 0.026)	1.2 (3/64)
1.6 (0.063)	0.8 (0.031)	0.71 to 1 (0.028 to 0.038)	1.6 (1/16)
2.4 (0.093)	1.2 (0.046)	1.01 to 1.40 (0.039 to .054)	2.4 (3/32)
3.2 (0.125)	1.5 (0.061)	1.41 to 2.00 (0.055 to 0.077)	3.2 (1/8)
4.7 (0.187)	2.4 (0.093)	2.01 to 2.80 (0.078 to 1.109)	4.8 (3/16)
6.4 (0.250)	3.2 (0.125)	2.81 to 4.00 (0.110 to 0.156)	6.4 (1/4)
9.5 (0.375)	4.7 (0.187)	4.01 to 5.50 (0.157 to 0.218)	9.5 (3/8)
12.7 (0.500)	6.4 (0.250)	5.51 to 7.90 (0.219 to 0.312)	12.7 (1/2)
19.1 (0.750)	9.5 (0.275)	7.91 to 11.10 (0.313 to 0.437)	19.1 (3/4)
25.4 (1.000)	12.7 (0.500)	11.11 to 15.90 (0.438 to 0.625)	25.4 (1)
38.1 (1.500)	19.1 (0.750)	15.91 to 22.2 (0.626 to 0.875)	38.1 (1-1/2)
50.8 (2.000)	25.4 (1.000)	22.21 to 31.80 (0.876 to 1.250)	50.8 (2)
76.2 (3.000)	38.1 (1.500)	31.81 to 44.50 (1.251 to 1.750)	76.2 (3)
101.6 (4.000)	50.8 (2.000)	44.51 to 63.5 (1.751 to 2.500)	101.6 (4)

1/ The 2 to 1 shrink ratios shown apply to commonly used polyolefin sleeving (MIL-DTL-23053/5 and /6) and polyvinylidene fluoride sleeving (PVDF) (MIL-DTL-23053/8). Other shrink sleeving such as fluorinated ethylene propylene (FEP) (MIL-DTL-23053/11), polyethylene terephthalate (PET) (MIL-DTL-23053/7), and extruded polytetrafluoroethylene (PTFE) (MIL-DTL-23053/12) have different shrink ratios, and the applicable specification should be consulted.

9.9 Installation of Heat-Shrinkable Sleeving

After the sleeving has been placed over the object to be covered, it shall be heated and shrunk using a hot air gun, an oven, or radiant heating. The degree of heat used and the exposure time will depend on the size and type of sleeving. A typical shield termination is shown in Figure 9-13. Sleeving coverage dimensions are given in this figure. If a tight fit is required for the minimum diameter, additional sleeving may be required.

CAUTION: EXTREME CARE SHALL BE EXERCISED TO ASSURE THAT THE AMOUNT OF HEAT APPLIED IS NOT DETRIMENTAL TO THE OBJECT BEING COVERED. WHEN OTHER TEMPERATURE-SENSITIVE MATERIALS AND PARTS ARE IN THE VICINITY, THEY SHALL BE PROTECTED FROM EXPOSURE TO DIRECT HEAT.

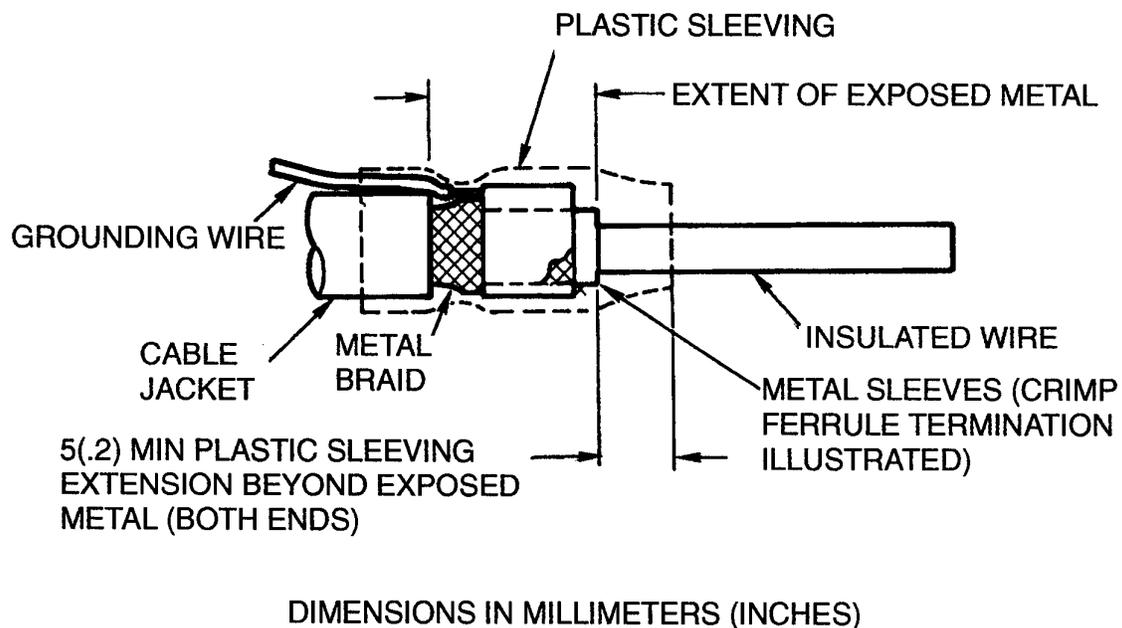


Figure 9-13. Illustration of Shrink Sleeve Installation (Typical)

9.10 Long Lengths of Shrinkable Sleeving

Long lengths of shrinkable sleeving installed over interconnecting harnesses and cables shall provide protective coverage of the designated area without leaving residual stress in the material. The sleeving shall be in contact with the interconnecting harness or cable along its length. One method of controlling endwise shrinkage (reduction in length) of the sleeving during installation is shown in Figure 9-14.

NOTE: MEDIUM TO LONG LENGTHS OF HARNESSSES/CABLES WITH SHRINK SLEEVING ARE EXTREMELY DIFFICULT TO BEND AND COIL WITHOUT DAMAGE.

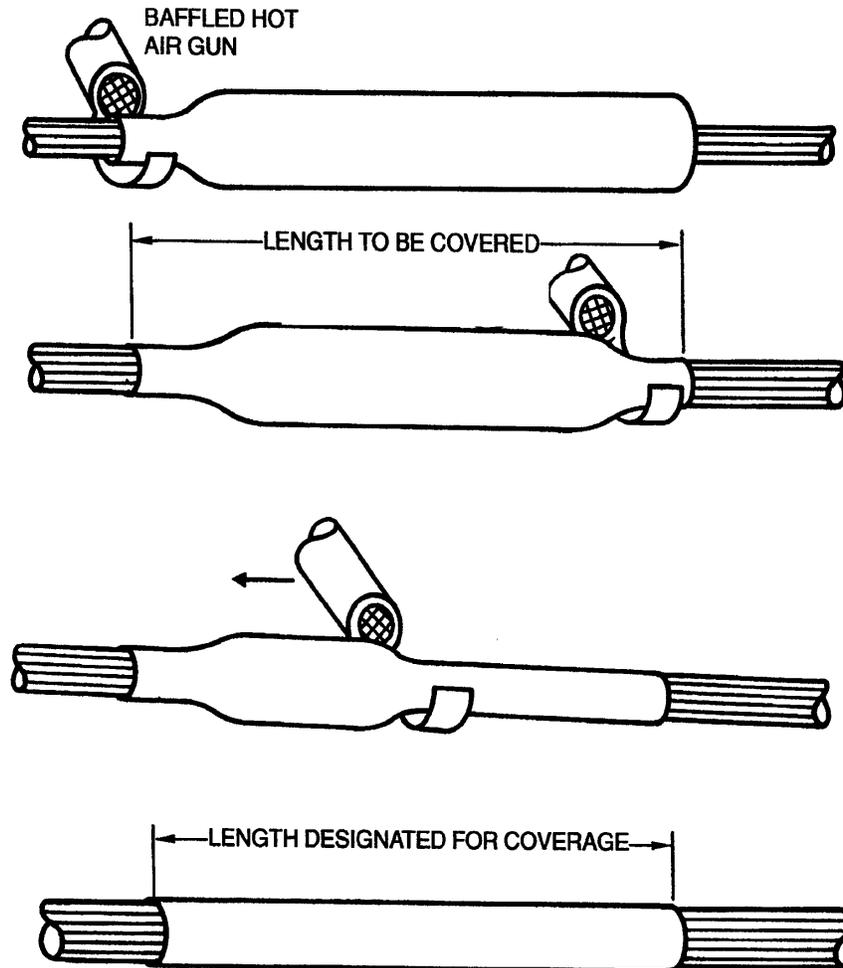


Figure 9-14. Installation of Long Lengths of Sleeving to Achieve Controlled Dimensions

9.11 SHRINKABLE PART REQUIREMENTS AND INSTALLATION

1. Shrinkable parts shall meet the following requirements (see Figure 9-15 for typical sleeving installation):

- a. They shall be uniformly shrunk to assure a tight fit where required.
- b. The part shall be positioned according to drawing or specification requirements.
- c. The shrinkable sleeving shall firmly grip the item over which it has been installed.
- d. The shrinkable part shall be free of cracks, punctures, blisters, and burned areas.

2. When shrinkable parts are installed, the gripping section of the part is shrunk first. (For example, the gripping-end section of a connector backshell boot is shrunk over the connector before the smaller cable-gripping end is heated.)

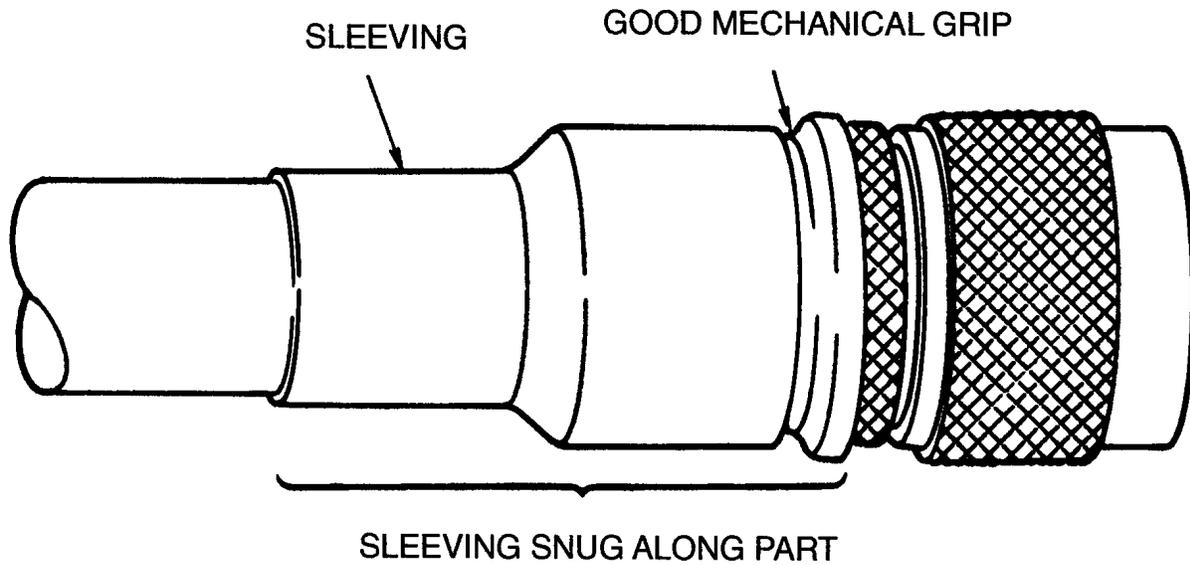


Figure 9-15. Sleeving Installation (Typical)