CHAPTER 5

ROPE AND CABLE TERMINATIONS

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1.0 INTRODUCTION

Selection of the proper type of wire or cable termination used in oceanographic applications is a key factor in the safe and effective utilization of the winch and wire system in the deep sea. The purpose of this section will describe the seven basic types of wire rope terminations, as well as those used with electromechanical cable. In particular, the characteristics, advantages, limitations, and assembly procedures for each type will be fully illustrated.

The selection of a wire or cable termination for a particular application should be considered carefully, bearing in mind that there are advantages and disadvantages to each termination type discussed in this section. To select the correct type of terminal for a particular application, the following factors should be carefully evaluated:

- Type and size of cable involved
- Corrosion potential
- Loading and cable fatigue
- Efficiency required
- Assembly requirements and cost

Primarily, seven basic types of wire rope terminations will be discussed as follows:

a. Wire rope clips - A U-bolt and saddle combination or a “fist-grip” nut and bolt arrangement used to fasten a loop of wire rope that is formed around a thimble.

b. <u>Open-wedge terminations</u> -- Also called “wedge sockets”; the cable is looped around a wedge, which is inserted into a socket or “basket” and held secure by tension on the line.

c. <u>Poured-socket termination</u> - - Also known as Spelter sockets; molten zinc or an epoxy compound is poured into the socket to bond the wire rope inside the fitting.

d. <u>Compressed sleeves</u> -- Also known as Nicopress terminations; sleeves are crimped or compressed around the cable, usually by use of hand tools.

e. Swaged terminations - - Attached by cold forming under high pressure so that the metal of the fitting flows around and between strands and wires of the rope.

f. Mechanical terminations - - Also known as Electroline fittings; these devices utilize wedge or plugs of various sizes and configurations to hold the cable inside a threaded lock sleeve.

g. Helical terminations - - Also known as Preformed Dyna-grip terminations. This device utilizes helical gripping wires, which wrap around the cable and are finished in a thimble or epoxy filled fitting.

2.0 SELECTION CRITERION

As mentioned in the introduction, a series of five criteria should be considered in the selection of a wire or cable termination. The following discussion of these criteria will provide insight into the problems, which can be encountered in the selection process.

2.1 Type and Size .of Wire or Cable

The terminations selected must be compatible with the type of cable being used and must result in the maximum effective holding strength. For example, swaged terminations, compressed sleeves and wire rope clips are not efficient terminals for hemp-core wire rope, armored electrical cables or synthetic cables. Application of such terminations requires squeezing them onto the cable, and “soft-core” cable material will give way under the pressure, thereby weakening the effectiveness of the termination. Mechanical, poured-socket and open-wedge terminations can be use effectively with these types of cables since they achieve their efficiency from bonding or compressing only the steel of the wire or cable.

Cable size is a major consideration because of the standard capacities of termination devices that are generally available. Compressed sleeves can be used on cables up to 5/8-inch diameter. Wire rope clips, open wedges and mechanical fittings are standard for cables up to 1-1/2 inches in diameter. Swaged terminals can be obtained as large as 2-1/2 inches and poured sockets up to 4 inches.

2.2 Corrosion Potential

The corrosion problems experienced in an oceanographic application, when wires and terminations are subjected to alternate immersion and drying cycles, is well known. Given this as an existing condition, it is important to consider the standard materials in which the various termination devices are available. In the main, poured sockets, helical terminations, wire rope clips, and open-wedge sockets are stocked only in stell, although zinc plating on these terminations is available. Compressed sleeves (Nicopress), swaged terminations, and mechanical fittings (Electroline), are available in a wide variety of materials ranging from steel to stainless steel. Compressed sleeves and the mechanical fittings are also produces, in certain sizes, in both bronze and aluminum for special applications. The variety of materials available in termination constructoin, make the matching of a specific fitting to a particular application a fairly simple process.

2.3 Loading and Cable Fatigue

All seven basic types of terminations are suitable for static and moderately cyclic loads such as those imposed by cranes, hoists, guy wires, tie downs, slings, etc. Only the mechanical and helical terminations, however, are designed to accommodate the shock and vibration loads imposed by winches, buoys and towed bodies in the marine environment.

The mechanical fittings have a “transition zone” in the nose where the cable enters the termination. In this “semi- loose” transition zone, the tension, compression and bending stresses in the rope strands are dissipated. Because of the ways in which other types of terminations are affixed to the cable, they have a hard transition from the cable to the terminal which can contribute to shorter cable fatigue life The helical type termination provides a long cable life by dissipating the shock and vibration loads in the spring action of the helical gripping wires.

2.4 Terminal Efficiency

The more efficient the terminal, the smaller and lower cost the cable may be. This also can affect the cost of winches and other handling equipment.

The swaged and helical terminals are rated for 100% of the cable's rated breaking strength. Poured sockets, compressed sleeves and mechanical fittings are rated at 95% to 100%, while wire rope clips and open-wedge terminations are rated at 75% to 85%. Wire rope clips tend to lose their holding strength with use and must be retightened from time-to-time. At the other end of the scale are the mechanical and open-wedge terminals in which the wedging action actually increases efficiency with loadings (Table I).

2.5 Assembly Requirements and Cost

Wire rope clips are both the least expensive and easiest termination that can be applied in the field. They require only attention to clip spacing, placement, and tightening torque to perform efficiently. The open-wedge termination is only slightly more expensive, but is just as simple to install, requiring only hand tools for the application. Although the simplest, they are also the least efficient of the six terminations discussed. The compressed sleeve (Nicopress) fitting represents another low cost, but highly efficient means of terminating a wire rope. Special tooling, which is available from the manufacturers, is available to ensure proper compression of the sleeve and the installer needs only to match the required number of compression to the sleeve size selected for use. Used in the proper situation, the compressed sleeve can be rapidly and efficiently reapplied in the field with no special training.

The swaged and poured socket (Spelter) terminations represent a moderately priced fitting with a high efficiency rating. Swaged terminations require large hydraulic presses for proper installation and do not readily lend themselves to reapplication in the field under most circumstances. The poured socket represents a highly efficient fitting, which can be reapplied in the field using either molten zinc or an epoxy resin to achieve wire bonding. This approach, however, requires careful attention to detail and the use of an aid to clean the wire ends prior to fitting installation.

The mechanical termination represents a more expensive fitting type discussed in this section due to the number of components involved in each assembly. Although it appears to be a complicated termination, it can be easily installed without special equipment and with only the training received from the manufacturers' literature. Attention to assembly detail and adequate proof loading are all that is required to produce a highly efficient termination using this fitting.

The helical terminal is the most expensive. Assembly can be accomplished easily in the field with no special training or equipment. However there is a 24-hour cure for the epoxy filling.

Inspection is another important assembly consideration. The swaged and compressed sleeve terminals can be inspected for effective assembly by measuring the final diameters. Wire rope clips can be inspected with a torque wrench. The poured socket cannot be inspected to determine if the assembly is proper. The mechanical terminal has an inspection hole built in to facilitate visual checking. The helical termination can be inspected to assure that no wires are crossing themselves and that the body is filled with epoxy.

Perhaps the single most important thing to remember in the selection of a termination for either wire rope or cable is that the fitting should be chosen at the same time as the cable is specified. A second major consideration is physical size of the termination relative to the instrument or device it will be attached to. This is especially important when the fitting is required to pass through an instrument as in the case of a piston-coring device or over a sheave. In these cases physical size and configuration of a fining will influence the type selected. Since the wire or cable termination is vital to the safe and efficient use of the wire or cable, it should be viewed as an integral part of the system and gives careful consideration then purchased.

In order to select the proper terminations for an application, the factors discussed here should be carefully considered as well as those presented in Table I.

3.0 INSTALLATION PROCEDURES

In order to ensure the highest possible reliability in applying the particular termination selected for use, the following procedures have been detailed, along with information, which affects long-term performance. For any type of termination there are “tricks of the trade” which assure the integrity of the fitting once applied, and which should not be deviated from if full reliability is to be achieved. The following procedures, if carefully followed, will assure the reliability required in an oceanographic application.

TABLE 1

CHARACTERISTICS OF SEVEN TYPES OF TERMINALS FOR WIRE ROPE AND CABLE

TYPE OF TERMINAL	TYPE OF ROPE/CABLE	ROPE SIZE	STANDARD MATERIALS	DESIGN LOADING	EFFICIENCY % OF RBS	CABLE LIFE	ASSEMBLY	COST
Wire Rope Clips	IWRC Strand	3/16 - 1 1/2	Steel	Static Cyclic (needs re-adjustment)	75% - 85%	Short	No training needed. No special tools. Fast field assy and disassembly, Reuseable. Torque inspection.	Low
Open Wedge	IWRC Hemp Center Strand Synthetic	3/8 - 1 5/8	Steel	Static Cyclic (effectiveness increases with load)	75% - 85%	Short	No training needed. No special tools. Fast field assy and disassembly, Reuseable. Visual Inspection.	Medium
Poured Socket	IWRC Hemp Center Strand	3/16 - 4	Steel	Static Cyclic	95% - 100%	Long	Training required. Special tools and equipment req'd. Difficult field Assy. Not reuseable. No visual inspection of acceptable assy.	Medium
Compressed Sleeve (Nicopress)	IWRC Strand	1/16 - 5/8	Steel Stainless Aluminum Bronze	Static Cyclic	95% - 100%	Short	No training req'd. Special tools req'd. Field assy on only smaller sizes. Not reuseable. Dimensional Inspection.	Low
Swaged Socket	IWRC Strand	1/8 - 2 1/2	Steel Stainless	Static Cyclic	100%	Medium	Training needed. Tools and Equipment req'd. No field assy. Not reuseable. Dimensional Inspection	Medium
Mechanical (Electroline Fiege)	IWRC Strand Hemp Center Double-armored Synthetic	1/16 - 1 1/2	Steel Stainless Aluminum Bronze	Static Cyclic Shock Vibration (effectiveness increases w/load)	95% - 100%	Long	No training needed. No special tools. Fast field assy, reuseable. Visual inspection.	High
Mechanical (Preformed Dyna-Grip)	IWRC Hemp Center Strand Double-armored	1/8 - 3/4	Steel	Static Cyclic Shock Vibration	100%	Long	No training needed. No special tools. 24 hour cure for the epoxy. Not reuseable No method of inspection.	High

3.1 Wire Rope Clips

Wire rope clips (Figure 5-1) are sized and marked on the body of the clip with the wire diameter that they are to be used. It is important that the clip be matched to the diameter wire that is in use, as mismatches will result in a drastic reduction in termination holding power and efficiency. Placement of the wire rope clip is of prime importance to achieve maximum holding power. It should be noted that most available wire rope clip data sheets specify only a minimum number of clips needed for ordinary loads. Where heavy loading is anticipated, it is strongly recommended that two additional clips be added to each installation.

The recommended procedure for applying wire rope clips to achieve the maximum termination holding power is as follows:

-- Turn back the amount of wire required based on Table 2. This distance is measured from the thimble to the bitter end of the wire.

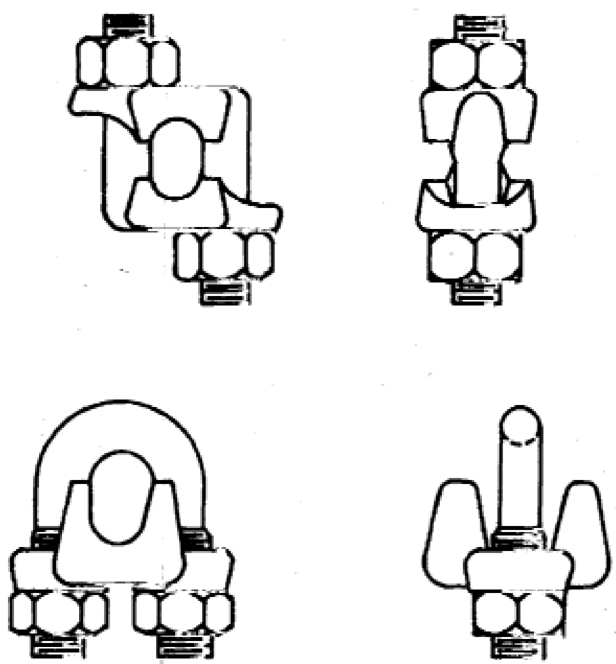


FIGURE 5-1

WIRE ROPE CLIPS

-- The U-Bolt portion of the clip must be placed over the bitter end of the wire while the saddle of the clip is placed on the standing part of the wire. Any reversal of this procedure or a staggering of the clips will result in reduced efficiency of the termination.

TABLE 2

Wire Rope Clip Assembly Data **

ROPE DIA	NO. CLIPS REQ NORM	H.D.	CENTER TO CENTER CLIP SPACING	LENGTH OF ROPE TURNBACK-INCH NORM	H.D.	TIGHTENING TORQUE FT. LBS.
1/8'	2	2	1 3/8"	3 1/4"	6"	5
3/16'	2	4	1 7/16"	3 3/4"	6 5/8"	9
1/4'	2	4	1 7/8"	4 3/4"	8 1/2"	18
5/16'	2	4	1 7/8"	5 1/4"	9	30
3/8"	2	4	2 5/8"	6 1/2"	11 3/4"	42
7/16'	2	4	2 7/16"	7"	11 7/8"	70
1/2'	3	5	3 15/32"	11 1/2"	14 31/3"	75
9/16'	3	5	3 1/2"	12"	19"	100
5/8'	3	5	3 1/2"	12"	19"	100
3/4'	4	6	4 1/4"	18"	27"	150
7/8'	4	6	4 1/4"	19"	27 1/2"	240
1'	5	7	4 3/4"	26"	35 1/2"	250
1 1/8'	6	8	5 3/8"	34"	37 5/8"	310
1 1/4'	6	8	5 3/4"	37"	48 1/2"	460
1 3/8'	7	9	5 15/16"	44"	55 7/8"	520
1 1/2'	7	9	6 1/2"	48"	60 7/8"	590
1 5/8'	7	9	6 29/32"	51"	64 27/3	730
1 3/4'	7	9	7"	53"	66 1/2"	980
2'	8	10	8 15/32"	71"	87 31/32"	1340
2 1/4"	8	10	8 5/8"	73"	90 13/32"	1570
2 1/2'	9	11	8 27/32"	84"	101 11/16"	1790
2 3/4'	10	12	9 9/16"	100"	118 15/16"	2200
3'	10	12	10"	106"	125 1/4"	3200

** Table based on Crosby Group Data

-- The first clip should be installed within one saddle width of the end of the turned back wire and the nuts evenly tightened. The second clip should be installed as near the thimble or loop as is possible with nuts firmly installed, but not tightened.

-- Space additional required clips evenly between the two clips already on the wire. Light tension should be applied between the terminal loop and the standing part of the cable before tightening all clips to their recommended torque. This process will eliminate stack occurring in the bitter end of the cable and produce a more uniform application.

-- An initial load should be applied to the termination and all nuts retightened to their recommended torque prior to use of the termination. Once applied in accordance with the above procedures, the resulting termination will have an efficiency rating of 75-85% of the breaking strength of new wire.

-- When a wire rope clip type of termination is used, it is advisable to periodically tighten the nuts to their recommended torque since wire vibration can result in a loosening of the U-bolt nuts.

3.2 Wire Rope Thimbles

The use of a thimble is highly recommended with this type of termination and some discussion of thimble styles is necessary at this point. Essentially, thimbles fall into three broad categories: I) Standard Wire Rope Thimbles, 2) Extra Heavy Thimbles, and 3) Solid Thimbles. Specific data relating to each style discussed will be found in the Useful Information section at the end of this handbook.

a. Standard Wire Rope Thimbles -- This class of thimble is designed primarily for use in light duty situations where loading is minimal. Their use in heavy-duty situations will result in a complete deformation of the thimble and the placing of excessive stress on the wire at the head of the loop. Under this situation, a failure of the wire can be expected, which will occur below the rated strength of both the termination and the wire.

b. Extra Heavy Wire Rope Thimble -- This style of thimble has been designed for heavy-duty service where high loading conditions are expected to Occur. They are far more resistant to deformation due to loading and work to maintain an even wire loading condition in the loop of the termination. As in all thimbles under load, the size of the pin used to attach the toad to the cable is critical. Its diameter should be closely matched to the internal diameter of the thimble in order to reduce point loading.

c. Solid Thimble - This thimble is designed as the ultimate in crush-proof thimbles due to its solid steel construction. Primarily a unit for very heavy load conditions, it has a single disadvantage in that the hole-sizes available are more limited than those found in the extra-heavy thimble. Where heavy loading situations are anticipated on a regular basis, it is recommended that a solid thimble be considered.

3.3 Open-Wedge Termination

Although this type of termination is typically found on crane cables, it has occasionally been used for limited trawl wire operations. Because of its diverse usage in the field, it is felt prudent to provide proper assembly instructions for this type of fitting.

The open wedge termination (Figure 5-2), although a simple style of fitting to install, should be approached with a certain amount of caution during installation of the wire. Improper placement of the wire can result in excessive wire stress at the termination resulting in a reduction of wire loading potential.

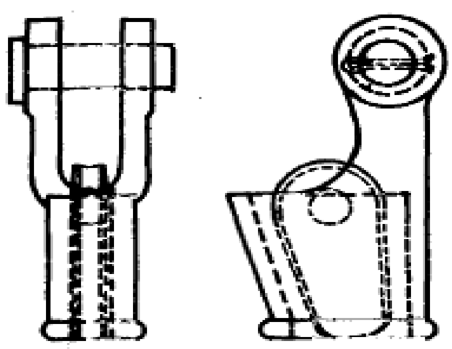


FIGURE 5-2

OPEN WEDGE TERMINATION

a. Installation Procedure - The simplicity and rapid installation potential of the open-wedge can be further enhanced by attention to a few details calculated to produce the maximum efficiency from this style of termination. The proper installation procedure is as follows:

-- An inspection of both the socket and wedge should be made to identify any rough or burred surfaces on the wire path, which could damage the wire under load. If irregularities are discovered, they should be removed, if possible, or the socket or wedge replaced.

-- The bitter end of the wire should be clean cut and served in order to prevent unlaying. It is important that the bitter end be clean cut rather than fused due to cutting with a torch in order to allow the individual wire strands to adjust around the sharp bend of the wedge. If the wire end is fused on installation, the movement of individual wire strands will be translated to the standing part of the wire causing irregularities in shape and unequal loading.

-- To install the wire in the socket, the socket must be in an upright position (ears downward). The wire is then brought into the socket to form a large, easily handled loop. Care should be taken to ensure that the standing part of the wire is in line with the sockets ear (Figure 5-2).

-- The bitter end of the wire should extend above the socket for a distance equal to nine (9) times the diameter of the wire used. At this point the wedge is placed in the socket and a wire rope clip placed around the bitter end of the wire by clamping it around a short length of wire, which has been attached to the bitter end to provide the mass required for the wire clips seating. The U-bolt of the wire clip should bear on the bitter end and the saddle on the added short piece of wire.

-- By securing the fitting to a convenient pad eye or bit, a load should be placed on the standing part of the wire. This load is steadily applied until the wedge and wire are pulled into position with enough strain to hold them in place when the load is released. During the seating of the wedge, sudden surge or shock loading should be avoided.

3.4 Poured or Spelter Sockets

The spelter socket (Figure 5-3) represents a highly reliable termination with 100% efficiency, when properly applied. The key factor in achieving the 100% efficiency of this termination is careful cleaning of the wire ends with a solvent solution and the positioning of the socket on the wire prior to the pouring of either the zinc or resin used to hold it in place. The cleaning of the wire ends allows for the maximum bonding action of the filler chosen while exact positioning of the socket on the wire ensures an even loading of the wire strands in the field.

A certain amount of caution should be used when dealing with this style of termination. The rigidity, which is caused by the bonding action of the zinc or resin on the end of the wire, causes a sudden dampening of wire vibration at the point where the wire enters the fitting. This dampening of vibration can lead to fatiguing of the wires at this point and frequent, careful inspection of the area for broken wire should be made. The detection of any broken wires should dictate the immediate replacement of the fitting.

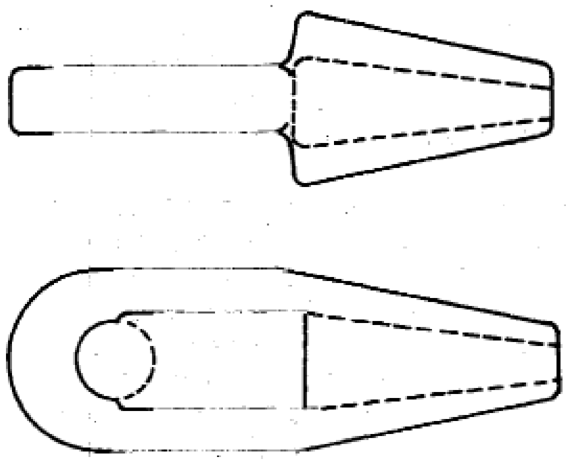


FIGURE 5-3

POURED SOCKET

a. Zinc Socketing Procedures (Figure 5-4) - The procedures for applying zinc-pouted sockets is as follows:

-- Measure the rope ends for socketing and apply serving at the base of the socket. As indicated in Figure 5-4a, the length of the rope end should be such that the ends of the wires when un-laid from the strands will be at the top of the socket basket. Apply a tight wire-serve band for a length of two, rope diameters begin-fling at the base of the socket and extending away from it.

-- Broom out strands and wires in the strands (Figures 5-4b and 5.4c). Un-lay and straighten the individual strands of the rope and spread them evenly so they form an included angle of approximately 60°. If the rope has a fiber core, cut out and remove the core as close to the serving band as possible. Un-lay the wires from each individual strand for the full length of the rope end, being careful not to disturb or change the lay of the wires and strands under the serving band. If the rope has an independent wire rope core (IWRC), un-lay the wires of the IWRC in the same manner.

-- Clean the broomed-out ends (Figure 5-4d). A suggested solvent for cleaning is SC-5 Methyl Chloroform. This solvent is also known under the names of Chlorothane VG or 1,1,1-trichloroethane.

CAUTION: Breathing the vapor of chlorinated solvents is harmful; use only with adequate ventilation. Follow the solvent manufacturer's instructions; observe the label instructions.

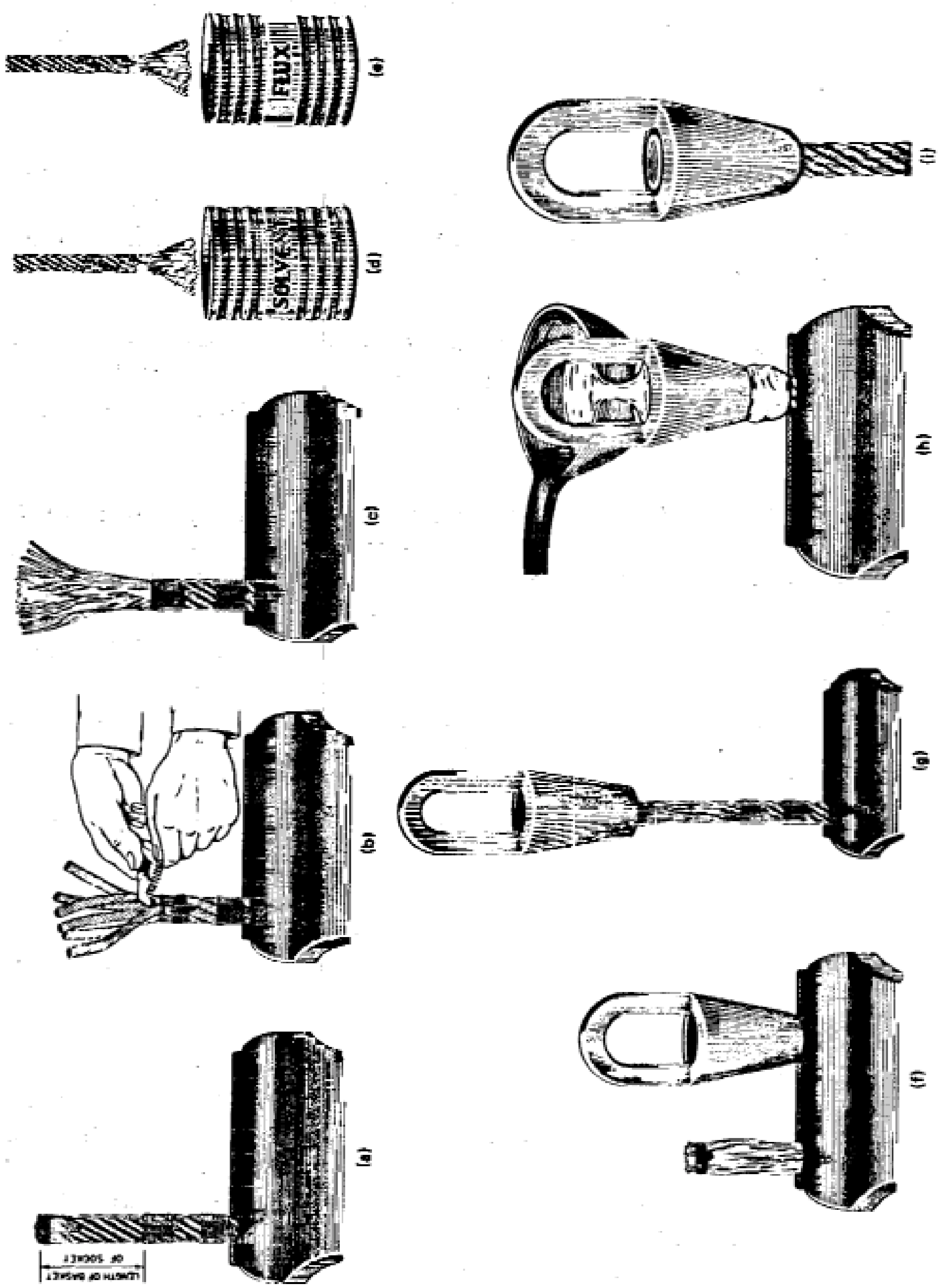
When using a solvent, swish the broomed-out rope end in the solvent and vigorously brush away all grease and dirt making sure to clean all the wires of the broomed-out portion to a point close to the Serving band. A solution of hydrochloric (muriatic acid) may be used for additional cleaning. However, if acid is used, the broomed-out ends of the rope should be subsequently rinsed in a solution of bicarbonate of soda to neutralize any acid that may remain on the rope. Care should also be exercised that acid does not enter the core, particularly if the rope has a fiber core. Ultrasonic cleaning is a preferred method for cleaning rope ends for socketing.

After cleaning, put the broomed-out ends upright in a vise until it is certain that all the solvent has evaporated and the wires are dry.

- Dip the broomed-out rope ends in flux (Figures 5-4e). Make a hot solution of zinc-ammonium chloride flux such as Zalcon K. Use a concentration of one pound of zinc-ammonium chloride in one gallon of water and maintain the solution at a temperature of 180° to 200°F. Swish the broomed-out end in the flux solution, put the open end upright in the vise, and permit all wires to dry thoroughly.

FIGURE 5-4

ZINC SOCKETING



-- Close rope ends and install the socket (Figures 5-4f and 5-4g). Use clean wire to compress the broomed-out rope end into a tight bundle so that the socket can be slipped over the wires. A socket should always be cleaned and heated before placing it in the rope. The heating is necessary to dispel any moisture and to prevent premature cooling of the zinc.

CAUTION: Never heat a socket after it has been placed on the rope because of the hazard of heat damage to the wire rope.

When the socket has been put on the rope end, the wires should be evenly distributed in the socket basket so that zinc can surround every wire. Use utmost care to align the socket with the centerline of the rope and to ensure that there is a vertical, straight length of rope exiting the socket that is equal to a minimum of 30 rope diameters. Seal the base of the socket with fire clay or putty, but be sure this material is not inserted into the base of the socket; if this were done, it would prevent the zinc from penetrating the full length of the socket basket and would, create a void, which would collect moisture when the socket is placed into service.

-- Pour the zinc (Figure 5-4h). Use zinc that meets the requirements in ANSI/ASTM B6-70, Specification for Zinc Metal (Slab Zinc), for "high grade" or Federal Specification QQ-Z351-a Amendment I, and Interim Amendment 2. Pour the zinc at a temperature of approximately 95O~F to 975°F making allowances for cooling if the zinc pot is more than 25 feet from the socket.

CAUTION: Do not heat zinc above 1100°F or its bonding properties will be lost.

The temperature of the zinc may be measured with a portable pyrometer or a Templistik. Remove all dross before pouring. Pour the zinc in one continuous pour to the top of the socket basket so that all the wire ends are covered; there should be no "capping" of the socket.

-- Remove the serving band (Figure 5-4i). Remove the serving band from the base' of the socket and check to see that zinc has penetrated to the base of the socket.

-- Lubricate the rope. Apply a wire rope lubricant to the rope at the base of the socket and on any section of the rope from which the original lubricant has been removed.

b. Procedure for Thermoset Resin of Wire Rope

-- General -- Before proceeding with thermoset resin socketing, the manufacturers instructions for using this product should be carefully read. Particular attention should be given to sockets that have been designed specifically for resin socketing.

-- Seizing and Cutting the Rope - - The rope manufacturer's directions for a particular size or construction of rope should be followed with regard to the number, position length of seizing, and the seizing wire size to be used. The seizing which will be located at the base of the installed fitting, must be positioned so that the ends of the wires to be embedded will be slightly below the level of the top of the fitting's basket. Cutting the rope can best be accomplished by using an abrasive wheel.

-- Opening and Brooming the Rope End - - Prior to opening the rope end, place a short temporary seizing directly above the seizing that represents the base of the broom. The temporary seizing is used to prevent brooming the wires the full length of the basket and also to prevent the loss of lay in the strands and rope outside the socket. Then move all seizings between the end of the rope and the temporary seizing. Un-lay each of the strands that make-up the construction of the rope. Open each strand of the rope and broom or un-lay the individual wires.

When the brooming is completed, the wire should be distributed evenly within a cone so that they form an included angle of approximately 60°. Some types of sockets require a different brooming procedure and the manufacturers instructions should be followed.

-- Cleaning the Wires and Fittings - Different types of resin with different characteristics require varying degrees of cleanliness. For some, the use of soluble oil for cleaning wires has been found to be effective. For one type of polyester resin on which over 700 tensile tests on ropes in sizes 1/4 to 3-1/2 inches in diameter were made without experiencing any failure in the resin socket attachment, the cleaning procedure is as follows:

Thorough cleaning of the wires is required to obtain resin adhesion. Ultrasonic cleaning in recommended solvents such as trichloroethylene or I-I-I trichloroethane or other nonflammable grease-cutting solvents is the preferred method of cleaning the wires in accordance with OSHA Standards. Where ultrasonic cleaning is not available, brush or dip cleaning in trichloroethane may be used; but fresh solvent should be used for each rope and fitting and discarded after use. After cleaning, the broom should be dried with clean compressed air or in some other suitable fashion before proceeding to the next step. The use of acid to etch the wires before resin socketing is unnecessary and not recommended. Since there is a variation in the properties of different resins, the manufacturer's instructions should be carefully followed.

-- Placement of the Fitting - Place the rope in a vertical position with the broom up. Close and compact the broom to permit insertion of the broomed rope end into the base of the fitting. Slip on the fitting, remove any temporary banding or seizing as required. Make sure the broomed wires are uniformly spaced in the basket with the wire ends slightly below the top edge of the basket; make sure that the axis of the rope and the fittings are aligned. Seal the annular space between the base of the fitting and the existing rope to prevent leakage of the resin from the basket. A non-hardening butyl rubber-base sealant gives satisfactory performance. Make sure that the sealant does not enter the base of the socket so that the resin may fill the complete depth of the socket basket.

-- Pouring the Resin - Controlled heat curing (but without open flame) at a temperature range of 250° to 300°F is recommended -- and is essential if ambient temperatures are less than 60°F. When controlled heat curing is not available and ambient temperatures are not less than 60°F, the attachment should not be disturbed and tension should not be applied to the socketed assembly for at least 24 hours.

-- Lubrication of Wire Rope after Socket Attachment - After the resin has cured, re-lubricate the wire rope at the base of the socket to replace the lubricant that was removed during the cleaning operation.

c. Description of the Resin

-- General - Resins vary considerably according to the manufacturer; it is important to refer to the manufacturer's instructions before using resins as no general rules about them can be established.

Properly formulated thermoset resins are acceptable for socketing. These resin formulations, when mixed, form a pourable material that hardens at ambient temperatures or upon the application of moderate heat. No open-flame or molten-metal hazards exist with resin socketing since heat-curing, when necessary, can only be carried out at a relatively low temperature (250° to 300°F) that can be supplied by electric-resistance heating.

Tests have shown satisfactory wire rope socketing performance by resins having the properties of a liquid thermoset material that hardens after mixing with the correct proportion of catalyst or curing agents.

-- Properties of Liquid (Uncured) Material - Resin and catalyst are normally supplied in two separate containers, the complete contents of which, after thorough mixing, can be poured into the socket basket. Liquid resins and catalyst should have the following properties:

1) Viscosity of Resin-Catalyst Mixture - - The viscosity of the resin-catalyst mixture should be 30,000 to 40,000 CPS at 75°F immediately after mixing. Viscosity will increase at lower ambient temperatures and resin may need warming prior to mixing in the catalyst if ambient temperatures drop below 40°F.

2) Flash Point - Both resin and catalyst should have a minimum flash point of 100°F.

3) Shelf Life – Resin and catalyst should have a minimum of one-year shelf life at 70° F.

4) Pot Life and Cure Time - After mixing, the resin-catalyst blend should be pourable for a minimum of eight minutes at 60°F and should harden in 15 minutes. Heating of the resin in the socket to a maximum temperature of 250°F is permissible to obtain full cure.

-- Properties of Cured Resin

1) Socket Performance - Resin should exhibit sufficient bonding to solvent-washed wire in typical wire rope end fittings to develop the nominal strength of all types and grades of rope. No slippage of wire is permissible when testing resin-filled rope socket assemblies in tension; however, after testing, some "seating" of the resin cone may be apparent and is acceptable. Resin adhesion to wires shall also be capable of withstanding tensile shock loading.

2) Compressive Strength - The minimum compressive strength for fully cured resin should be 12,000 lb/in^2.

3) Shrinkage - - Fully cured resin may shrink a maximum of 2%. The use of an inert-filler in the resin is permissible to control shrinkage, if the viscosity provisions specified for the liquid resin are met.

4) Hardness - A desired hardness of the resin is in the range of Barcol 40-55.

-- Resin Socketing Compositions - Manufacturers directions should be followed in handling, mixing, and pouring the resin composition.

-- Performance of Cured Resin Sockets - - Poured resin sockets may be moved when the resin is hardened. After the ambient or elevated temperature cure recommended by the manufacturer, resin sockets should develop the nominal strength of the rope, and should also withstand shock loading sufficient to break the rope without cracking or breakage. Resin socketing materials that have not been tested to these criteria by the manufacturer should not be used.

3.5 Compressed Sleeves (Nicopress)

The compressed or Nicopress sleeve (Figure 5-5) represents a style of wire and cable termination which has been available for the past thirty years. Its high efficiency, 95% - 100% of the breaking strength of the wire, and its simplicity of installation have made it an ideal type of termination for general field use. The success of the compressed sleeve is dependent upon the selection of the proper sleeve to match the wire to be terminated and matching the compression requirements of the sleeve. Specialized tooling is produced which will ensure proper compression to achieve the maximum holding power of the fitting.

When terminating a rope or cable, both the sleeve and tool should match the requirements of the cable size. Table 3 provides a guide to this selection as well as the recommended compressions needed for maximum efficiency.

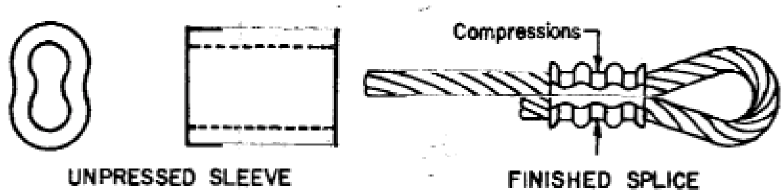


FIGURE 5-5

COMPRESSED SLEEVE (NICOPRESS)

It should be noted that in Table 3 the number of sleeves, required per installation, to achieve the maximum holding power is the same for all wire sizes. The manufacturer recommends a single sleeve per termination and the addition of more sleeves in no way increases the ultimate holding power of this type of termination. One factor, which can affect the efficiency of the compressed sleeve, is excessive compression. The recommended compressions shown in the table and in Figure 5-5, allow for ultimate holding while providing an adequate stress relief at both ends of the sleeve. This factor can become extremely important when Stainless steel sleeves are used in the termination of a wire.

As with other types of terminations, which require the wire to be looped at the termination point, it is necessary to use a properly sized thimble to protect the wire. The discussion found in Chapter 6, Section 3.2, also applies to the use of compressed sleeves.

3.6 Swaged Terminations

The swaged style of wire termination, possesses a 100% efficiency rating when compared to the breaking strength of the wire being

TABLE 3

CABLE SIZE	SLEEVE STOCK NO.		TOOL STOCK NO.	LENGTH BEFORE COMPRESSION	LENGTH AFTER COMPRESSION
	PLAIN	PLATED			
1/16"	18-1-C	28-1-C	51-C-887	3/8"	7/16"
1/8"	18-3-M	28-3-M	51-M-850	9/16"	3/4"
3/16"	18-6-X	28-6-X	51-X-850	15/16"	1-3/16"
1/4"	18-10-F6	28-10-F6	3-F6-950	1-1/8"	1-1/2"

CABLE SIZE	SLEEVE STOCK NO.		DIE STOCK NO.	WIDTH OF PRESS	NUMBER OF PRESSES	GAUGE
	PLAIN	PLATED				
5/16"	18-13-G9	28-13-G9	OVAL-G9	1-5/16"	1	.730
3/8"	18-23-H5	28-23-H5	OVAL-H5	1-5/16"	1	.795
7/16"	18-24-J8	28-24-J8	OVAL-J8	7/8"	2	.915
1/2"	18-25-K8	28-25-K8	OVAL-K8	13/16"	2	1.000
9/16"	18-27-M1	28-27-M1	OVAL-M1	9/16"	3	1.125
5/8"	18-28-N5	28-28-N5	OVAL-N5	5/8"	3	1.285

terminated. Its high efficiency is achieved through the use of large hydraulic presses, which exert a uniform compressive force on the fitting (Figure 5-6).

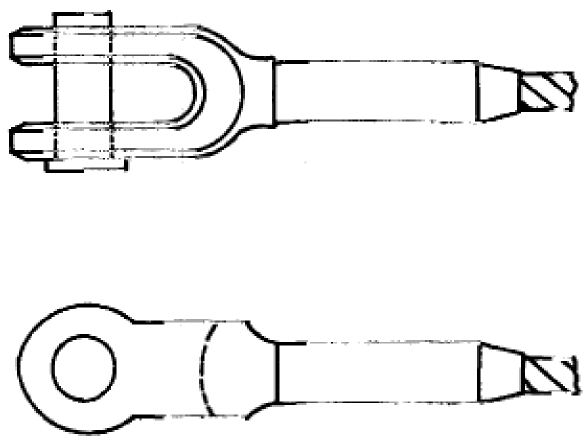


FIGURE 5-6

SWAGED TERMINATION

When swaged sockets are used with 3 x 19 wire rope, it is necessary to insert filler pieces into the spaces between the strands, inside the socket, prior to compression of the fitting. The soft wire fillers serve to increase the effective surface area of the 3 x 19 rope and allow a more uniform compression and holding power to be achieved (Figure 5-7).

The specialized nature of the swaged termination does not lend itself easily to field applications due to operate the equipment. The frequent re-termination of both trawl and hydrographic wires that is required at sea also precludes the use of this particular type of fitting for working cable applications. In addition, the corrosion potential within the swaged socket occurs in an area, which is impossible to inspect. Corrosion of the filler wire can occur over time and eventually result in a failure of the termination without prior warning or evidence of weakening.

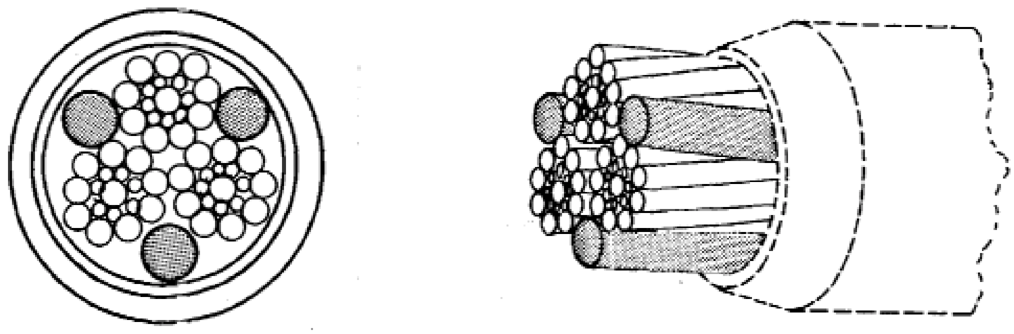


FIGURE 5-7

FILLER WIRES FOR SWAGED TERMINATION

3.7 <u>Mechanical Terminations (Electroline or Fiege)</u>

Perhaps the most common fitting used to terminate the deep-sea trawl wire is the Electroline eye socket assembly or "Fiege fitting" as it is frequently called. The Electroline termination (Figure 5-8), is a three component device consisting of a threaded sleeve, socket assembly and a plug which, when properly assembled, will result in a termination strength equal to 95%-100% of the ropes' breaking strength. The high level of fitting efficiency is achieved through the use of the plug as a wedge and by carefully following the assembly instructions.

Although this type of fitting can be used with all styles of wire rope construction, only three-strand, torque balanced wire rope will be discussed here. Changes in wire construction will require changing the style and possibly the material used to construct the plug (Photograph I). The particular plug we are interested in for the purpose of this discussion is a triangular plug specifically designed for three-strand wire rope (Figure 5-9).

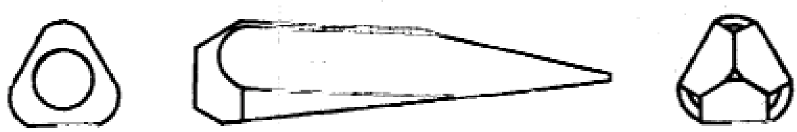


FIGURE 5-9

3 x 19 WIRE ROPE TRIANGULAR PLUG

The following assembly procedures have been developed to detail the application of the Electroline mechanical termination for 3 x 19 torque-balanced wire rope. It should be remembered that this application requires that an oversized fitting and special plug be used.

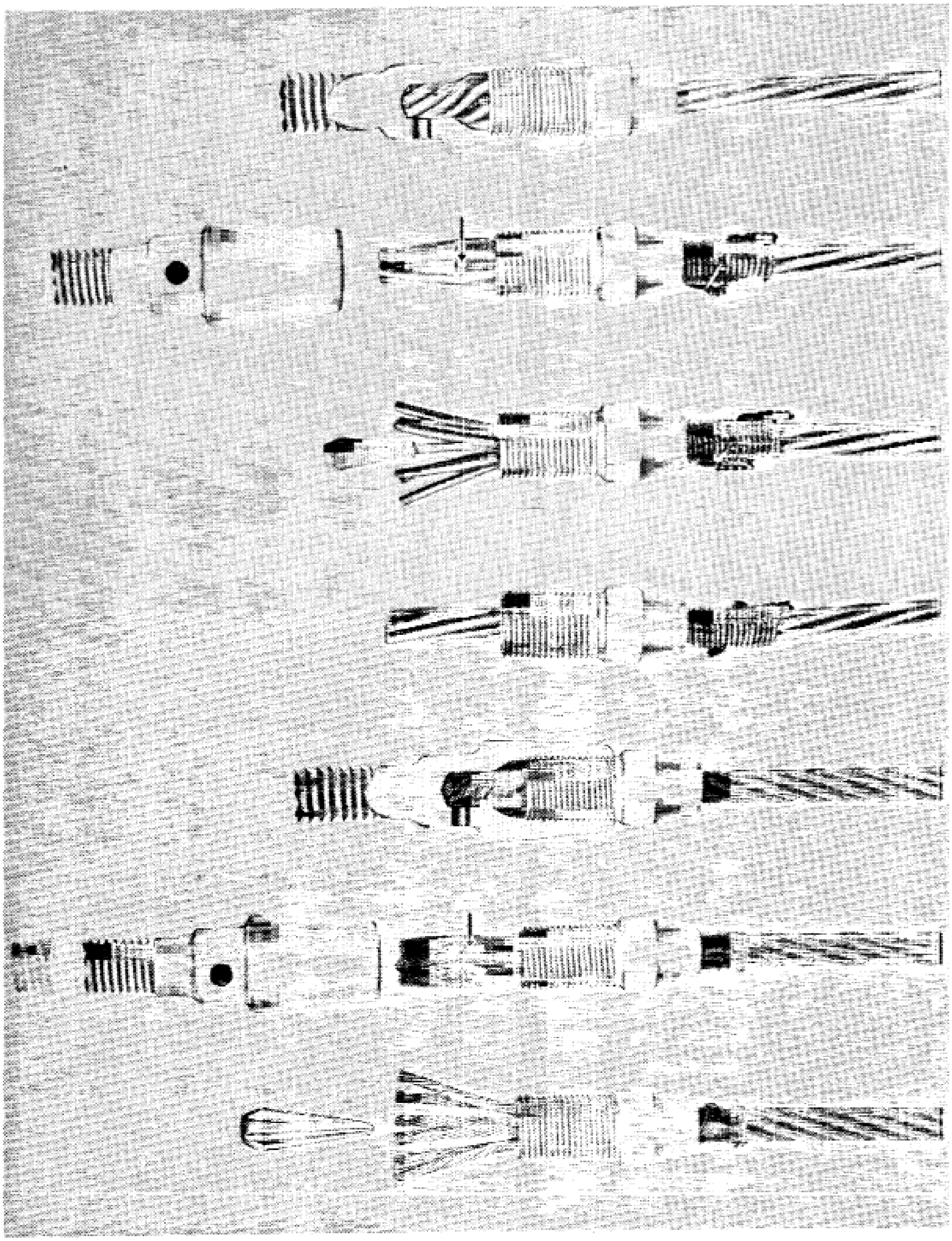
1. When assembling Electroline fittings on wire rope it is recommended, that assembly blocks be used to prevent the rope from being nicked by the jaws of the vise, to protect the lay of the rope, and to hold all wires in the strands firmly so the plug can be driven to a solid seat.

Assembly kits are available in the following three sizes:

Part No.	For Rope Sizes
SP-307A	1/8” thru 9/16”
SP-307B	5/8” thru 1”
SP-307C	1-1/8” thru 1-1/2”

2. The bitter end of the wire to be terminated should be carefully cut to insure a 90° surface. Prior to cutting, the wire

PHOTOGRAPH 1



should be seized with light wire to prevent unraveling of the rope when cut.

3. Place the Assembly blocks on the rope and place blocks in vise. If the assembly blocks are missing or unavailable, two short pieces of wood strapping can be used between the vise jaws. The wire length should be carefully measured (Table 4) before securing the wire between the wooden blocks in the vise.

4. Position end of rope to dimension “A” as shown on the chart for the size rope being assembled. Tighten vise firmly. This position of the assembly procedure should be carefully checked with a good ruler to ensure that the exact measurements specified in the chart are met. In addition, care should be taken to ensure that the wire is perpendicular to the assembly block, before tightening vise.

5. Remove seizing on end of rope.

6. Twist threaded end of sleeve over end of rope. Twist in direction of rope lay. Check dimension “B” as shown on Table 4.

7. Un-lay one of the three strands. If rope has a right lay, un-lay each of the other two strands in counter-clockwise order. If rope has a left lay, un-lay each of the other two strands in clockwise order. When done correctly, the three outer strands form a symmetrical basket. Do not attempt to straighten the spiral lay of the three strands.

8. Place the plug in the center of the three strands. Drive the plug downward with a hammer while making certain that each of the strands is positioned properly along the sides of the plug.

9. Once the plug is in position it should be driven to a solid seat using a hammer and draft pin of at least V2” diameter. When seated, the top of the plug should be well below the tops of the wires.

10. Remove assembly from vise, remove assembly blocks, and clamp the hex of the sleeve in vise. At this time wrap a layer of tape around the wire where it exits the sleeve. The tape should be as close to the base of the sleeve as possible.

11. With a piece of tubing (1.0. of tubing should be 1/32” to 1/16” larger than 0.0. of each strand of rope), bend each of the three strands in toward the center of the plug. Tubing is furnished in each of the three assembly kits.

    As an alternative to using the tubing, a small 2” hose clamp can be used to squeeze the ends of the wires toward the center of the plug, allowing the socket to slide over the wire ends and mate with the threaded sleeve.

12. Place socket over ends of strands, twist on in the direction of the lay of the rope. Engage threads of sleeve and tighten socket securely on sleeve.

    During the tightening of the fitting it is recommended that a pair of large crescent wrenches (20”) be used instead of a bar through the eye of the socket. The reasoning behind this is that the bar can and will deform the eye of the socket making insertion of a bushing or screw pin difficult.

13. If assembled correctly, the end of the rope will be visible in the inspection hole. Several threads will be visible on the sleeve below the eye socket after tightening. The best method for checking the visibility of the wires through the inspection hole is with the use of a flashlight. If the ends of the wires are not visible the fitting should be removed, the wire cut, and the termination installed again.

    At this time it would pay to check the tape on the wire below the fitting sleeve to determine the amount of slippage that has occurred. The average amount allowable is approximately 1/2”.

14. After a proof load is applied to the assembly, the plug will seat further in the sleeve and the rope will not be visible in the inspection hole. This final seating of the plug insures an assembly of maximum strength. After the proof loading of the fitting has been accomplished the fitting should tightened again to recover any exposed threads. The recommended proof load should be 8,000 lbs. for 1/2-9/16’, 5/8 wire ropes.

TABLE 4

Rope Size	Fitting Rope Size	Sleeve Rope Size	Plug No. -MZ	Dimensions A+l/8 -0	Dimensions B+1/8 -0
1/16	1/8	1/8	MZ 1606	1-9/16	5/8
1/8	3/16	3/16	“1612	1-31/32	3/4
3/16	1/4	1/4	“1618	2-1/4	13/16
1/4	5/16	5/16	“1625	2-3/4	1
5/16	3/8	3/8	“1631	3-1/8	1-1/8
3/8	7/16	7/16	“1437	3-5/8	1-5/16
7/16	1/2	1/2	“1443	4-1/8	1-1/2
1/2	9/16	9/16	“2250	4-3/4	1-5/8
9/16	5/8	5/8	“2250	4-3/4	1-5/8
5/8	3/4	3/4	“ 1462	5-1/2	1-7/8
3/4	7/8	7/8	“2275	6-1/2	2-1/4
7/8	1	1	“2287	7-7/8	2-3/4
1	1-1/8	1-1/8	“2299	9-3/8	3-1/8

ELECTROLINE TERMINATION ASSEMBLY DIMENSIONS

MISCELLANEOUS

The following items are not recorded in any of the literature available to date, but constitute a series of points that can help in detecting or preventing failure, etc.

A. Eye Socket Hole

It has proven to be a good idea to accurately measure the hole diameter of each new fitting prior to its first use and again at the end of each cruise. In this way elongation of the hole due to applied stresses can be detected and the fitting discarded prior to a failure.

Some form of indexing and logging of this data should be established. It is also recommended that when the hole is measured, at least three separate readings be taken to determine an average.

B. Eye Socket Bushing

It is recommended that a bushing be used inside the eye socket hole when the pin passing through the eye is smaller than the opening. This approach will lessen the point load exerted on the fitting during periods of high stress.

C. Removal of Fitting and Plug

When a termination is to be removed it is suggested that the wire be cut off as close to the sleeve as possible. The fining is then disassembled, the sleeve with plug clamped in a vise with the sawn off section of wire uppermost, and the plug and wire driven out with a 1/2" drift pin. It will be noted that a considerable amount of force will be required to accomplish this task.

D. Re-use of Triangular Plug

It is in no way recommended that the triangular plug be reused after it has been removed from the sleeve. The potential for damage to the plug is very high and re-use can only jeopardize the equipment deployed on the next lowering. Also a careful inspection of the sleeve and eye socket should be made prior to their re-use or storage. Items to look for are broken threads, elongated holes, and cracks in either the sleeve or eye socket.

4.0 ELECTRO-MECHANICAL TERMINATIONS

Since it would he impractical to discuss fully all of the available styles of electro-mechanical terminations this chapter will, instead, concentrate on three specific types of terminations. Specifically these will include: 1) straight mechanical fittings; 2) combination mechanical and epoxy terminations; and 3) helical terminations. It is felt that other termination styles, which are available lie somewhere within the range of those, discussed in this chapter.

One factor, which cannot be stressed often enough, is the need to carefully follow the recommended installation procedures for the fitting selected. If the termination is to perform as it is advertised, it is necessary for the individual installing of the fitting to understand that recommended procedures should not be compromised by a lack of attention to detail. Required wire lengths should not be estimated and the necessary curing times for epoxies must not be disregarded in an attempt to re-deploy an instrument. The result of such careless practices is usually the loss of an expensive piece of equipment.

4.1 Electroline E-M Cable Terminations

This style of termination, like its wire rope counterpart, relies on the use of a series of plugs to achieve its holding power. Because this is a purely mechanical termination it can be used immediately after assembly and testing. Other terminations, which combine an expoxy filler in the mechanical fittings are restricted by the curing time of the epoxy and therefore have a relatively long time period between assembly and use.

The purely mechanical termination is quite simple to install in the field requiring only basic hand tools and no special technical training on the part of the installer. The only critical aspect of assembling this style of fitting is close attention to the installation instructions. By carefully following the Instructions detailed below the maximum efficiency of the fitting can be assured.

4.2 Installation Procedures

The following procedures have been developed for the termination of double armor electro-mechanical cable. The success of this termination rests on the proper installation of two hollow plugs (Figure 5-10) and the careful measurement of the wire lengths required in Table 5.

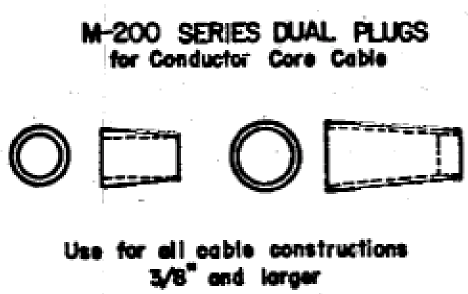


FIGURE 5-10

TABLE 5

E.M. FITTING ASSEMBLEY DIMENSIONS

FITTING SIZE	CABLE SIZE	NO. WIRES PER. LAYER	CONDUCTOR HOLE SIZE	PLUG PART NO.	DIMENSIONS		
					A	B	C
1/8"	1/8"	12 x 18	3/32"	ME-212	1-3/8"	CUT TO REQUIRED LENGTH PLUS 1" TO 1-1/2" ADDITIONAL SPACE TO ALLOW FOR SEATING OF PLUG	7/16"
3/16"	3/16"	18 x 18	1/8"	ME-218	1-23/32"		1/2"
1/4"	1/4"	15 x 15 18 x 18	3/16"	ME-225	1-15/16"		9/16"
5/16"	5/16"	15 x 15 18 x 18 18 x 24 24 x 24	3/16"	ME-231	2-5/16"		5/8"
3/8"	3/8"	18 x 18	1/4"	ME-237	2-5/8"		3/4"
7/16"	7/16"	18 x 18	5/16"	ME-243	3-5/16"		3/4"
1/2"	1/2"	18 x 18 24 x 24	3/8"	ME-250	3-1/2"		15/16"
9/16"	9/16"	24 x 24	7/16"	ME-256	4-1/4"		1-1/8"

Installation of the fitting can be accomplished using the following procedure:

1. The cable to be terminated should have the better end seized and the cable cut off square. Once this is accomplished place the cable in the assembly block, position the end of the strand to dimension A and B for the size cable being terminated and clamp the assembly block in a vise (Figure 5-11). When the cable is clamped in the vise the seizing can be removed.

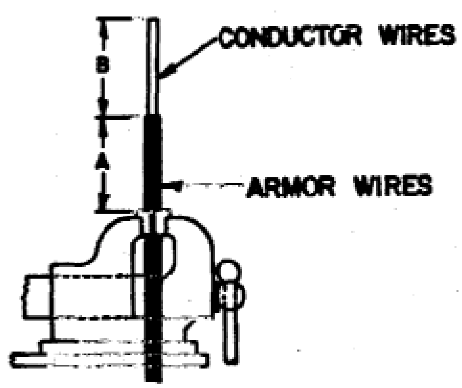


FIGURE 5-11

2. Twist the threaded sleeve over the end of the cable and check the length of the exposed armor strand against dimension C in Table 5. If this length is compatible with the table proceed to un-lay the outer armor wires. However, if this dimension is not met reposition the cable in the blocks before continuing. Place the large hollow plug over the center wires of the cable and carefully drive it to a solid seat (Figure 5-12). Once seated the inner armor wires should be un-laid and the small hollow plug slipped over the conductor wires and driven to a solid seat.

3. Remove the assembly blocks from the vise and the cable and clamp the threaded sleeve in the vise as shown in Figure 5-13. The broomed-out armor wires can now be bent inward around the conductor wires. In order to protect the conductor wires during the process, a piece of tubing should be slipped over the conductors prior to bending the armor wires inward.

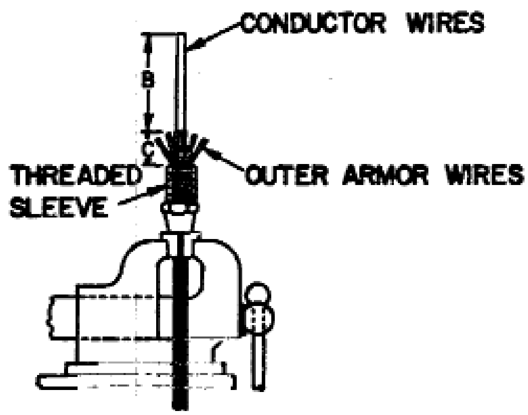


FIGURE 5-12

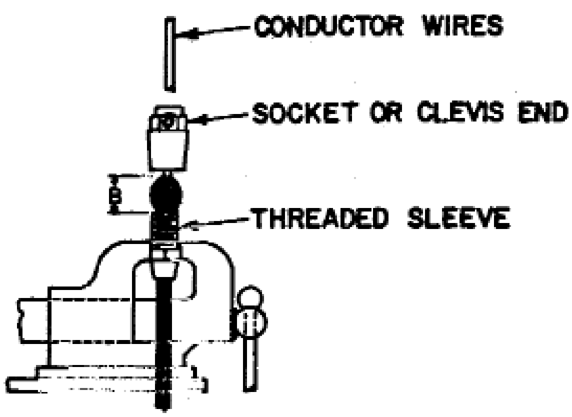


FIGURE 5-13

Once this step is completed twist the socket or clevis end portion of the fitting over the ends of the wires and feed the conductor wires through the hole provided. Engage the threads of the sleeve and tighten securely. When tightening the socket or clevis it is advisable to remember the procedure discussed in section 3.7(12).

4. Once the socket or clevis has been securely tightened on the sleeve the ends of the armor wires or tubing will be visible in the inspection hole. If the installation has been properly accomplished (Figure 5-14), several threads will be exposed on the sleeve. Should the armor wires or tubing not be visible in the inspection hole the termination should not be used, but should instead be removed and the cable re-terminated.

5. It is advisable after the termination has been successfully installed to perform a pull test at a load equal to at least two times the anticipated instrument load to assure the safety of the equipment.

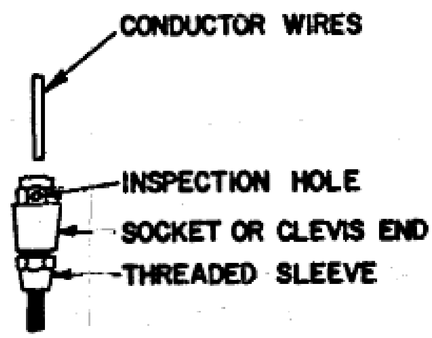


FIGURE 5-14

4.3 Combination Mechanical/Epoxy Termination

The particular fitting, which will be discussed here, is the DYNA-GRIP termination for electro-mechanical cables. The basic termination design consists of an oval-shaped hollow insert which slips over the cable, a set of helically-formed rods which wrap (by hand) over the cable and insert, a housing with internal contour to match the rods and insert and a threaded retainer (Figure 5-15). Holding strength of the termination is developed by the preformed principle of the helically formed rods and gripping by the matching insert and housing (Figure 5-16). There is no reliance upon special tools or user proficiency. Every installation is uniform and repeatable in holding ability and appearance. There is no crushing or deformation of the cable elements, and yet, the termination will hold the full-rated strength of the cable for which it is designed.

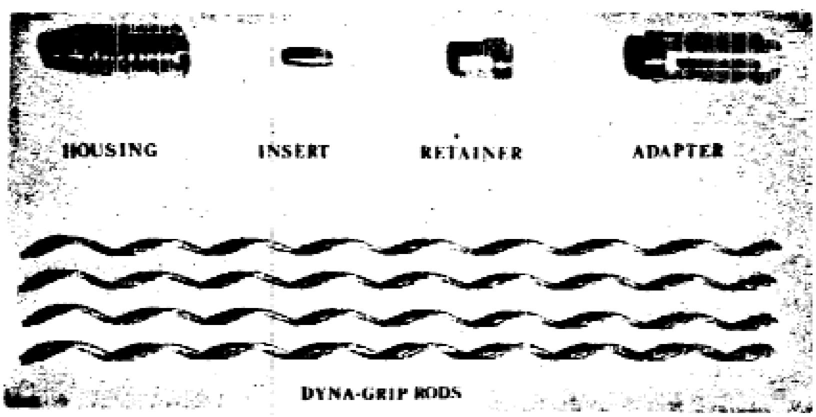


FIGURE 5-15

1. Cable Preparation: If the armor is to be terminated at the fitting, care should be taken to allow for a sufficient length of armor to extend beyond that of the Rods. The outer armor wires should be cut about 1/4” shorter than the inner wires and then taped. After application of the Dyna-Rods, the inner armor should be bent away from the cable to prevent chaffing of the insulation.

2. For proper positioning of the helical rods (Figure 5-17), match the center mark on the insert to the color mark on the rods. For proper and easy installation of the rods, the following are important:

   a. Begin application with a two-rod subset and end application with a two-rod subset.

   b. Wrap the rods one subset at a time about the cable and ‘over the insert starting at the trimmed end of the cable.

   c. Align the ends of the rods closely with each other.

   d. Do not allow gaps between subsets or accumulation of gaps between subsets or accumulation of gaps could interfere with application of subsequent subsets.

   e. Do not allow any of the helical rods to cross each other.

3. After complete set of rods is wrapped on (Figure 5-18), slide housing over rod and insert assembly until it seats over insert.

4. Insert retainer and screw tightly into housing. Use the clevis, with hex keys, as a spanner wrench (Figure 5-19). When the retainer is properly in place, there will be no looseness, in the entire assembly.

5. Place the housing in a nose down position. The epoxy filler is then prepared.

Preparation of epoxy:

Thoroughly mix the contents of each can before combining them. Each part tends to separate into layers. Each component must be thoroughly mixed until it is homogeneous. This is critical to proper cure of the material. Combine the contents of the two cans. Mix the combination thoroughly for five to ten minutes. The epoxy is then ready to pour.

6. Dam the leading edge (nose) of the housing. A mastic-modeling clay or similar material can be used. Pour the epoxy material into the housing. It is important that the epoxy penetrates into the interstices between individual armoring rods. Breaking away the dam and visually checking to see if the adhesive is seeping through the fitting may check adhesive penetration.

7. Screw in mounting adaptor and lock thread with groove-pin (or set screws) before the epoxy filler hardens (Figure 5-20).

8. Completed assembly (Figure 5-21).

9. The following techniques should be observed in order to terminate:

    a. Do not terminate the armor wires of electro-mechanical cable inside the housing or apply the epoxy filler in a manner that would cause a bond of the cable armor to the electrical core.

    b. Allow the epoxy filler material to cure for 24 hours (normal temperatures) before using.

    c. Reuse of the preformed helical rods is not generally recommended after load has been applied.

    d. Caution should be used when overboard sheave has a groove diameter less than 40 times the diameter over the helical portion of the assembly.

FIGURE 5-16

FIGURE 5-17

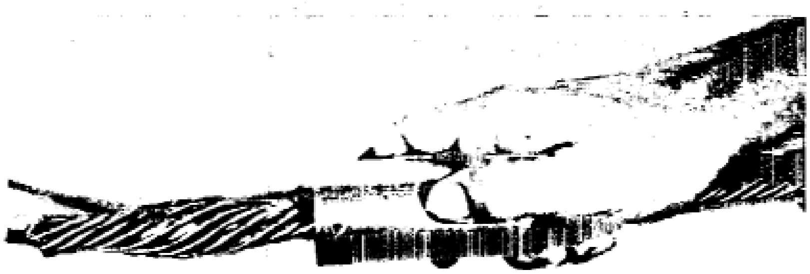


FIGURE 5-18

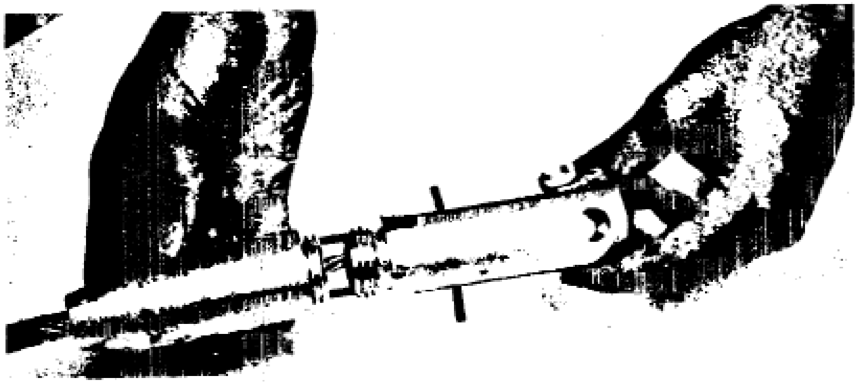


FIGURE 5-19

FIGURE 5-20

FIGURE 5-21

4.4 Helically Wound Terminations

This particular style of termination is designed for electro-mechanical cables larger than I inch diameter (Figure 5-22). Certain limitations are present in the use of this termination and are expressed below.

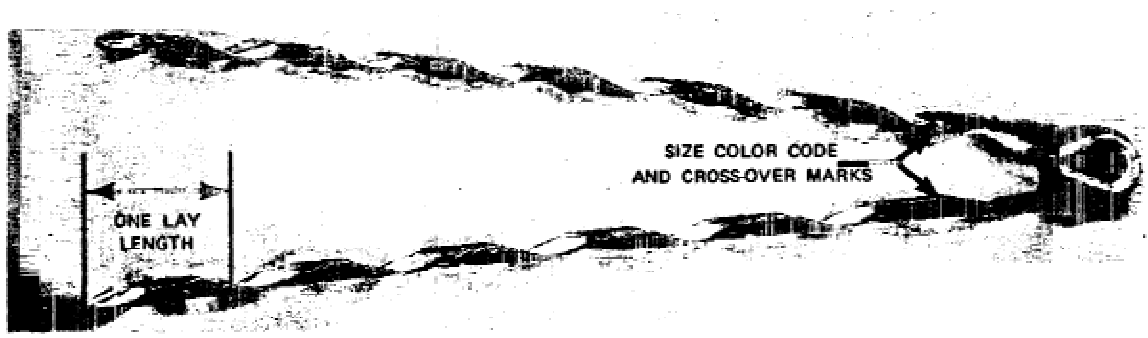


FIGURE 5-22

1. The preformed Cable Stopper must have lay direction as the cable. CAUTION: preformed Cable Stopper with an opposite lay cable.

2. In the application of preformed Cable Stoppers, marlinspikes or screwdrivers should be used only as an aid in splitting the legs and snapping the ends in place.

3. Wire rope thimbles or equivalent fittings of the same size as the Cable Stopper should be used.

   Successful application of this termination can be achieved by following the procedure detailed below.

1. Start application by wrapping on two lay lengths of first leg, starting at crossover marks (Figure 5-23).

2. At this point of the application, install a heavy-duty wire rope thimble (if required) (Figure 5-24). If the eye is intended to be attached by a shackle, it should then be placed on a pin or shackled to a pad eye to keep it from turning. Match the crossover marks and apply the second leg the same lay length as the first. Application is made easier if the leg of section being applied is pulled out and around the cable in one continuous motion.

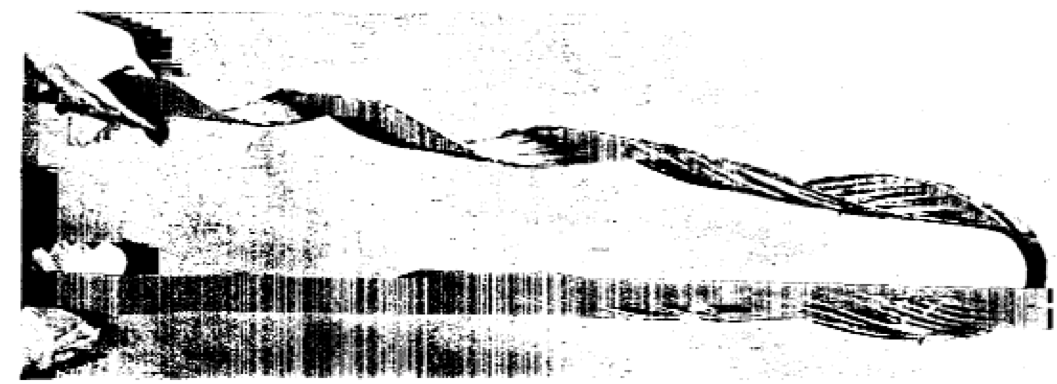


FIGURE 5-23

3. Use a marlinspike or screwdriver and split the legs into sections for the one pitch length as shown in Figure 5-25.

4. Split both legs back to the applied portion of the Cable Stopper as shown in Figure 5-26. The section closest to the cable (#1, above) should be applied and followed consecutively by the sections closest.

5. At this point the first section should be applied to completion, followed consecutively by each of the other legs (Figure 5-27).

6. As shown in Figure 5-28, a marlinspike or screwdriver can be used to snap the ends into place.

7. Completed application of the preformed Cable Stopper (Figure 5-29). Make sure all rods are in contact with the cable. Should there be one rod under another, remove to that point and re-apply.

8. The following should also be considered when this type of termination is selected:

   a. The preformed Cable-stopper dead-end was developed as a Strain-relief fitting for data cables. These can be applied to either bare armor or jacketed cables and are normally designed to hold 50% of the rated breaking strength.

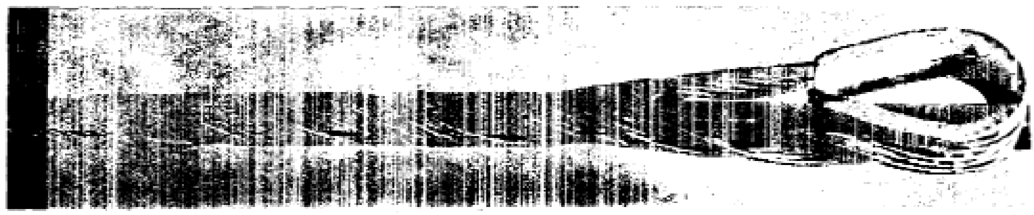


FIGURE 5-24

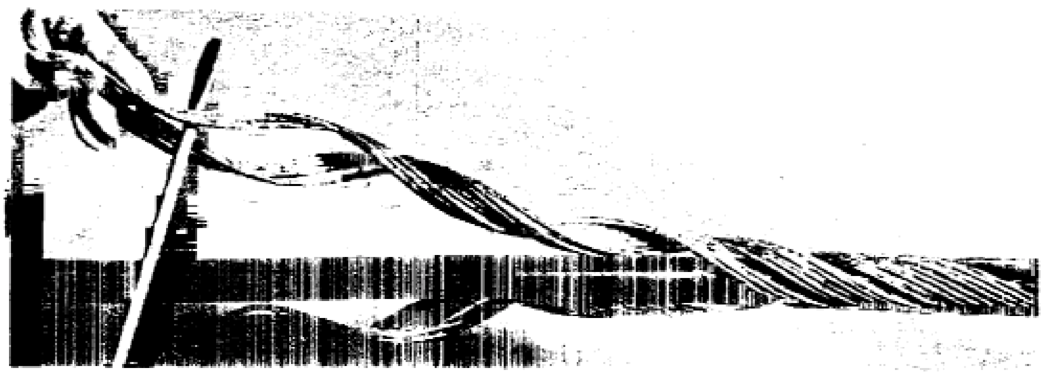


FIGURE 5-25

FIGURE 5-26

FIGURE 5-27

FIGURE 5-28

FIGURE 5-29

b. The eye of the grip is made with sufficient length to allow the cable to proceed on through and beyond the termination point. This provides complete continuity of the cable to an over-boarding application with a strain-relief member of proven performance.

c. The preformed helical concept is the only method of termination or holding of a cable that will not crush the cable or create a high-stress potential failure point.

5.0 KEVLAR ROPE CONSTRUCTIONS

The construction of KEVLAR® ropes may be similar to that of wire rope or to synthetic braided ropes. The best construction depends on the particular application. This decision should be left to the experts such as the rope manufacturers. To date there are no MLL-R or MIL-W specifications for KEVLAR® ropes as there are for wire ropes. The state-of-the-art is expanding so rapidly that whatever is written for this text may be obsolete by the time it is printed. There are certain generic types of KEVLAR® ropes. Without going into great detail on the internal constructions, we will attempt to explain their basic designs.

5.1 Working Ropes and Cables

Aramid working ropes are a high strength, low stretch flexible rope for the same applications as nylons and polyesters synthetic braided ropes. Aramid has the advantages of a higher strength to weight ratio in addition to greater personnel safety. Due to low stretch, the snap-back safety hazard at failure is virtually non-existent. Working ropes are used for:

Boat davits & gripes
canopy stays
constant-tension mooring lines
safety ropes
lashing ropes
pendant lines
pusher cables
tow lines
trawling lines

Working ropes are supplied with a braided polyester jacket although other jacket materials are available.

5.2 Static Ropes

Aramid static ropes are a high strength to weight replacement for wire ropes in static applications. They are designed for cyclic-loading but has a low fatigue life when used on winches or over sheaves. For long-term applications, an extruded jacket is recommended (as flexibility is not required) to exclude dirt, water and ultra-violet light. Aramid static ropes are effective where low weight and non-conductivity are required. Typical applications for static ropes are:

naval lifelines
antenna guys
canopy stays
barrier ropes

The selection of the best jacket material is dependent on the requirements for:

abrasion resistance
flexibility
insulation resistance
aeolian vibration dampening
protection from light
resistance to chemicals
protection from heat
ice shedding
cold flow
water permeability
cut thru resistance

See Table 6.

5.3 Winch Ropes

Aramid winch ropes are a replacement for wire rope where long lengths are required. Oceanographic winch wire ropes have corrosion problems and their length is limited by their own weight. An aramid rope of the same size as wire rope has a greater operating load capacity due to the low weight of the rope. The internal construction or lay of the aramid yarn is a function of torque, strength, internal abrasion, flexibility, operating load, winch cycle life, etc. As with wire rope, each different construction has its own unique advantages and disadvantages.

The life of a winch rope may be improved by (1) adding an extruded jacket, (2) separating the extruded jacket from the aramid core with a braided jacket or Mylar tape, and by (3) pre-stressing the aramid core prior to extruding the jacket. The two primary reasons for the extruded jacket are (1) abrasion resistance for use with a sheave or winch, and (2) the jacket will maintain the original shape of the aramid core when the rope passes over a sheave. If the rope is allowed to flatten, internal abrasion of the aramid fibers will shorten its life.

The purpose of the intermediate braid or tape is to reduce the abrasion at the aramid/jacket interface in bending. Pre-stressing or tensioning the rope prior to extruding the jacket is used to remove the constructional stretch of the aramid rope. If this is not accomplished, the rope will shrink under load and pull away from the jacket. This, in turn, will allow the rope to deform when passing over a winch or sheave and the subsequent internal abrasion will shorten the operating life of the system. Pre-stressing is an additional expense and the user must decide if the increase in rope life is justified.

5.4 Dynamic Cycling Ropes

These ropes are designed to survive constant cyclic loading and working over sheaves. An example would be Riser Tensioner ropes for the risers of oil drilling rigs. Ropes of this type may range from 7/8" diameter to as large as 6" diameter. Normally they were constructed of multiple small "working" ropes in a typical wire rope lay, such as 1 x 6 x l2, etc. Each of the individual small ropes or strands will be jacketed with a braid or braid and extruded jacket or only a thin extruded jacket. An outer jacket is normal over the finished construction to maintain the shape of the rope. The outer jacket may be braided or extruded as determined by the need for abrasion protection and flexibility.

5.5 Electromechanical Cables

EM cables are a composite of electrical conductors, jackets, separators and a KEVLAR® strength member. These cables are of special construction to suit the user. A typical construction would be a core of multiple electrical conductors or fiber optics, around which is an extruded jacket or bedding for the KEVLAR® strength members. The KEVLAR® may be braided or applied in contra-helical layers. Finally, there is an extruded jacket for protection. When the cable must survive bending under load, the layers of KEVLAR® may be separated by a braid or tape to reduce internal fretting of the KEVLAR®. As KEVLAR® has more stretch than the electrical conductors, it should be pre-stressed or the outer jacket extruded with the KEVLAR® under some tension to reduce the constructional stretch.

6.0 JACKET MATERIALS

The selection of the best jacket material for the application is as important to the life of the rope as is the internal construction.

An explanation of the relative merits and characteristics of jacket materials may be seen in Table 6. There are various formulations for each of these materials that alter their relative attributes. Consult the rope manufacturer for their cost, availability and specific attributes.

6.1 Braided

The braided jacket will, provide the most flexible of all jacket materials but will allow the rope to be degraded by dirt and ultraviolet light. Also, the abrasion resistance is less than that of the extruded jackets. The braid is easily removed for terminations such as eye splices and potted terminals.

6.2 Extruded Polyethylene

Polyethylene is the easiest to extrude and the least expensive of the jacket materials. It has excellent dielectric and ice shedding properties. It is more flexible than some other extruded materials.

6.3 Extruded Nylon

These are perhaps the most all around jacket materials, but make for a very stiff rope.

6.4 Extruded Polyurethane

Polyurethane provides a flexible rope with good dielectric isolation properties, abrasion resistance and, is the easiest to chemically bond electrical connectors. It is ideal for underwater ropes and electromechanical cables.

6.5 Extruded Hytrel®

Hytrel® can be formulated to have dielectric, abrasion, flexibility and ice shedding properties equal to or exceeding any other material. It is recommended for antenna guys where ice and high winds cause aeolian vibrations, which can fatigue polyethylene antenna guys. Hytrel® is, however, the most expensive of the extruded jackets.

TABLE 6 JACKETING MATERIALS

JACKET MATERIAL	ABRASION RESISTANCE	FLEXIBILITY	ELECTRICAL INSULATION RESISTANCE	AEOLEAN VIBRATION DAMPING	PROTECTION FROM UV	PROTECTION FROM HEAT	ICE SHEDDING	COLD FLOW	LOW WATER PERMEABILITY	RESISTANCE TO CUT THRU
BRAIDED	1	5	NONE	NONE	1	1	NONE	N/A	NONE	1
EXTRUDED NYLON (POLYAMIOS)	4	2	4	3	5		3	5	4	5
EXTRUDED HYTREL (POLYESTER)	5	3	5	5	5		5	5	5	4
EXTRUDED POLYURETHANE	3	3	5	5	5		3	5	5	4
EXTRUDED POLYETHYLENE	3	3	5	2	5		5	2	5	2
EXTRUDED TEFLON	3	3	5	2	5	5	5	2	6	2

6.6 Extruded Teflon®

Extruded Teflon® is used where the highest resistance to external heat is required. Neither Teflon®, nor polyethylene is recommended for use with terminations, which have an external compressive action, due to their poor cold flow properties.

7.0 TERMINATIONS FOR KEVLAR® ROPES

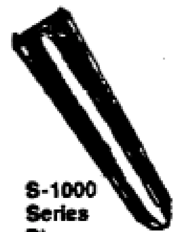
There are a multitude of considerations in the selection of the terminations for KEVLAR® ropes. The construction of the rope, in many cases, will be primary in the selection of the end fitting. These fittings are much more rope and jacket construction dependent than those of wire ropes. Wire rope terminations are usually not satisfactory for KEVLAR® ropes. KEVLAR® will withstand high tension and compression. However, the KEVLAR®, being very brittle in shear, will not tolerate the high shear forces at the tension/compression interface. Wire rope fittings depend on high compressive forces, which produce these high shear loads.

The most favorable termination for KEVLAR®, produces a low compressive load, over a much longer length, to reduce these shear forces. The relative attributes of these terminations can be seen in Table Il. The descriptions and assembly methods of these terminations are as follows.

7.1 Internal Plug or Wedge Terminals

The internal wedging terminal is easy to install in the field (Figures 5-30 and 5-31). The holding ability is somewhat dependent on the technique of the installer. It has not proven satisfactory for dynamic applications or when loads cycle thru zero. There is some damage to the KEVLAR® fibers during assembly. Installation on Naval Lifelines has shown that the KEVLAR® will creep out of the fitting after a period of time. These fittings may be acceptable for short-term applications. Lengthening the plug, as seen in the SEFAC and Linear Composite fittings, may increase the holding strength of these fittings.

Assembly Instructions



S-1000 Series Plug

ROPE SIZE	PLUG CAT. NO.	DIA. 'A'	ROPE SIZE	PLUG CAT. NO.	DIA. 'A'
1/8	SD-1012	1-3/16	5/8	SD-1062	3-3/16
3/16	SD-1018	1-1/2	3/4	SD-1075	4-1/2
1/4	SD-1025	1-9/16	7/8	SD-1087	5-1/8
5/16	SD-1031	1-7/8	1	SD-1099	5-1/2
3/8	SD-1037	1-15/16	1-1/8	SD-10112	7-5/8
7/16	SD-1043	2-3/16	1-1/4	SD-10125	9
1/2	SD-1050	2-1/2	1-3/8	SD-10137	10-1/2
9/16	SD-1056	2-13/16	1-1/2	SD-10150	11-1/2

Double Braided Construction

1. Insert the rope into the non-threaded end of the sleeve.
2. Place the sleeve into a vise.

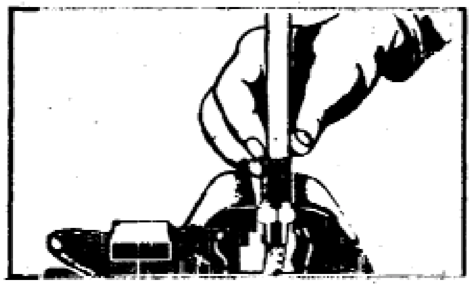
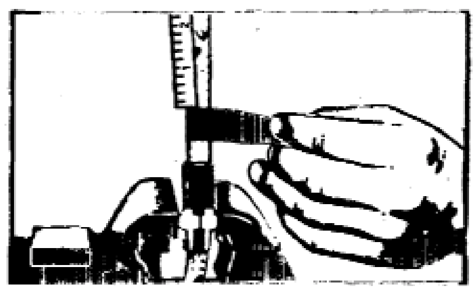
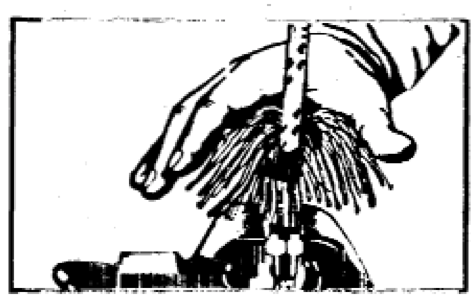


FIGURE 5-30

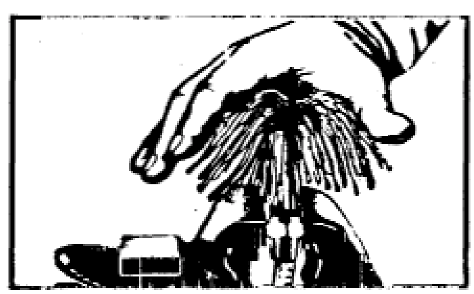
3. Use tape to seize the rope so that a section of rope that is equal to the 'A' dimension protrudes. (See chart for 'A' dimension of each plug.)



4. Unlay both the inner braids.



5. . . . and the outer braids.



NOTE: Before inserting plug into center of fibers pull a section of unlayed rope, equal to twice the diameter of the rope, into the sleeve.

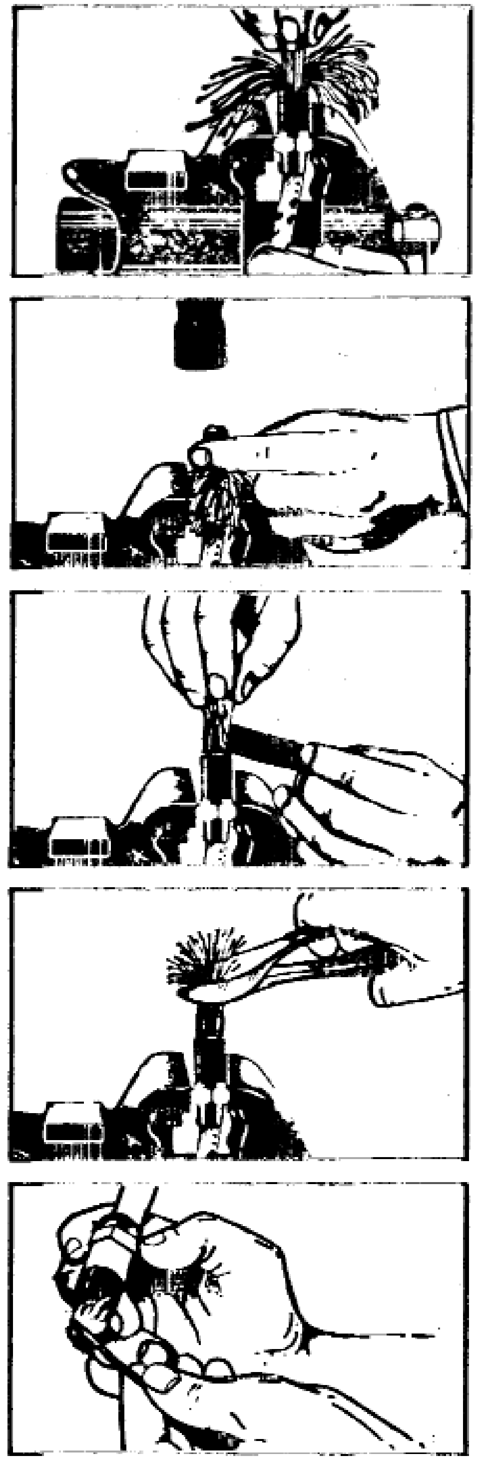


FIGURE 5-31

6. Insert the plug into the center* of the fibers, then pull the rope, with the plug inside, into the sleeve. *Plug must be exactly centered in order to achieve the best possible termination.

7. Make certain that all the fibers are uniformly distributed around the plug. Then use a hammer to tap the plug to a solid seat.

8. Make certain that all the fibers are uniformly distributed around the plug. Use tape to tightly seize all the fibers against the body of the protruding plug.

9. Trim excess fibers to within one-half inch of the end of the plug.

10. Use a torch, match or heat gun to fuse the protruding fibers together. **(IMPORTANT: Do not melt the fibers below top of plug.)** For proper assembly, diameter of fused rope must be less than the inside diameter of the fitting.

7.2 External Plug or Wedge Terminal

Electroline Termination for Jacketed KEVLAR® Rope

The Electroline mechanical termination has been developed for Aramid ropes with extruded jackets. The efficiency is 100% when applied to ropes of the following construction: thick jacket of medium hardness and materials not susceptible to cold flow under pressure. Less than 100% efficiency is obtained on extruded jackets of polyethylene and Teflon® and on ropes with a braided jacket between the aramid and the extruded jacket. This termination is also efficient on jacketed, aramid electro-mechanical cables. This termination is easily installed in the field and required no special tools or training. They are manufactured in aluminum, bronze and stainless and with various types of clevis, stud or eye adaptors. As shown in Figure 5-32 jacket removal is not required.

7.3 Chemical Potting

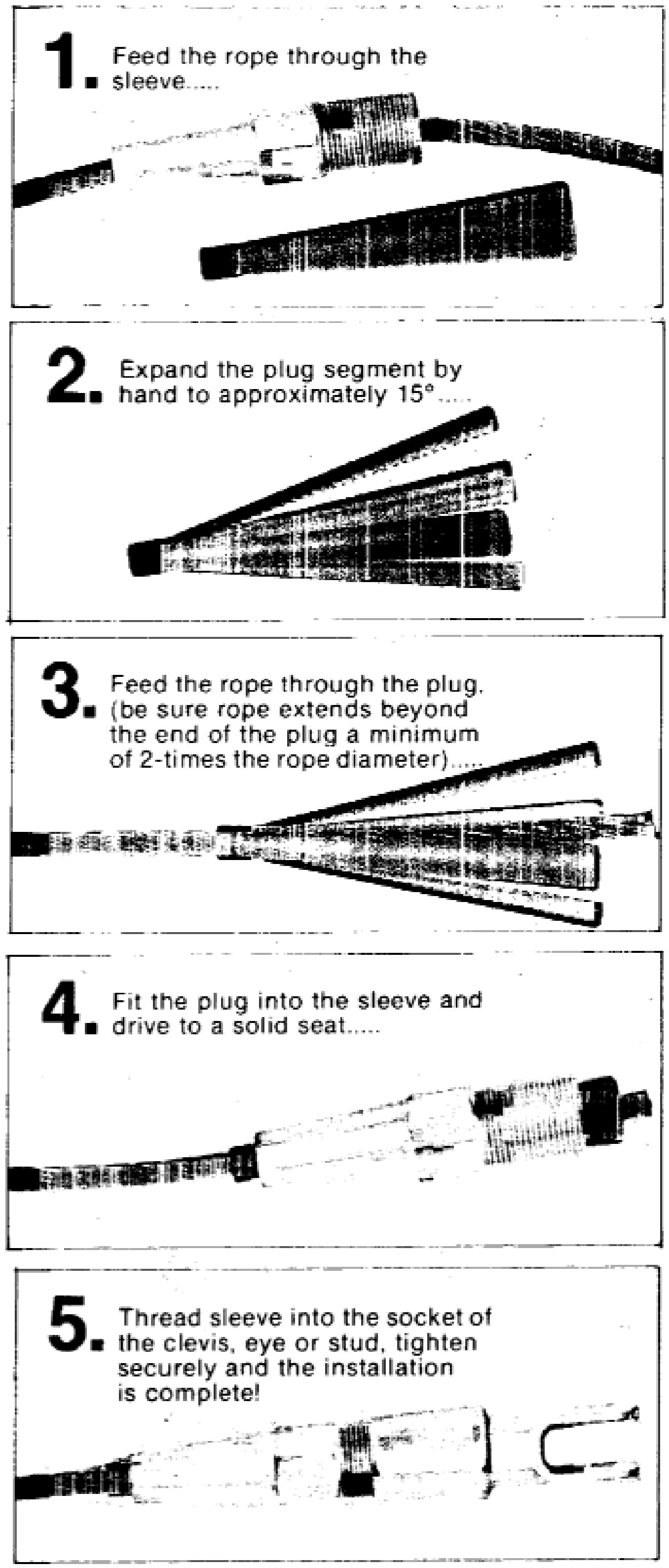
Chemical potting requires removal of the jacket. It is a high efficiency terminal but is not readily field installable. There is a possibility of fatigue failure, after long-term tension cycling, at the nose of the terminal. This is due to possible damage of the Kevlar on jacket removal and the weak transition from jacketed to unjacketed rope. For many rope constructions and applications, this is the only suitable method of terminating.

7.4 Eye Splicing

Eye splicing is making a termination from the rope itself, by looping the end of the rope and braiding the tail back onto the outside of the rope. This is a more efficient method of termination but requires some training. In many cases, it is done by the rope manufacturer or by the sling house. If done properly it will provide a full strength termination that will withstand dynamic loading.

Variations of the eye splice include: 1) the “breakout” splice where the end of the rope is looped and unbraided, then braided back into the main member of the rope; and (2) the “hollow braid” where the end of the rope is looped into an eye, run back and forth through the main member of the rope, then continued down the center of the rope.

FIGURE 5-32

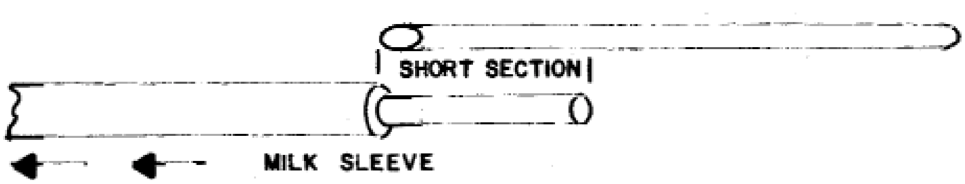

1. Feed the rope through the sleeve.....
2. Expand the plug segment by hand to approximately 15°.....
3. Feed the rope through the plug. (be sure rope extends beyond the end of the plug a minimum of 2-times the rope diameter).....
4. Fit the plug into the sleeve and drive to a solid seat.....
5. Thread sleeve into the socket of the clevis, eye or stud, tighten securely and the installation is complete!

There is a different technique for each construction of rope. Some typical methods of eye splicing are as follows:

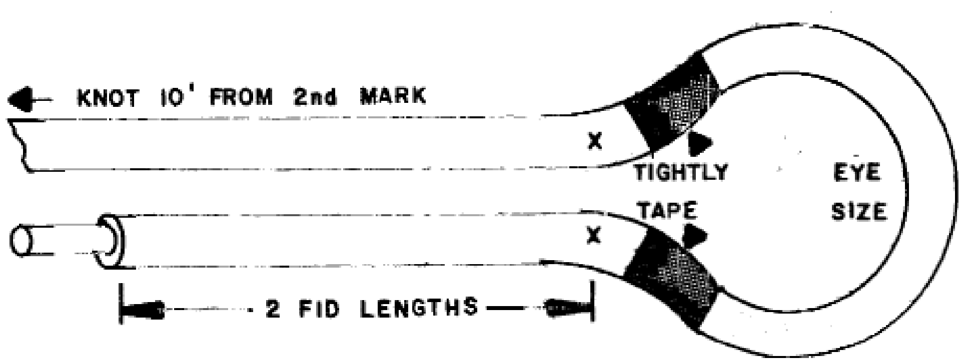
The following eye splice instructions are intended for experienced riggers familiar with conventional braid-on-braid splicing techniques. This splice method will allow the KEVLAR® core (primary strength member) of AraCom rope to pass around the eye inside the sleeve and down into the neck of the splice employing the Chinese finger grip principle. AraCom is difficult to splice. Yet the quality of the splice determines the usable strength of the rope.

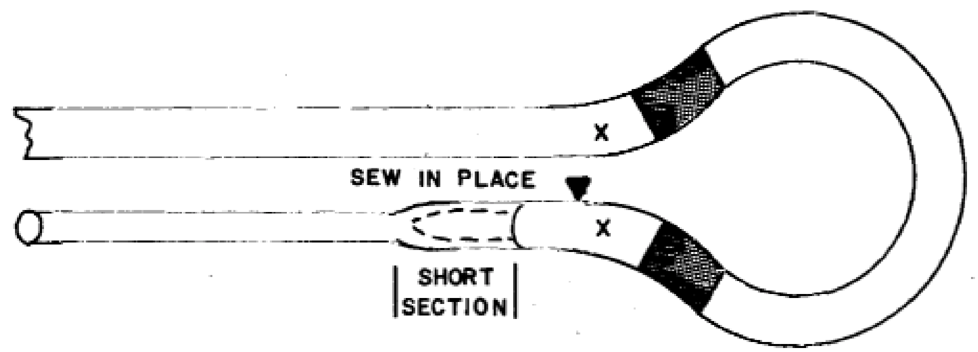
IMPORTANT: KEVLAR® is an extremely low elongation fiber demanding that close attention be paid to avoid twisting the braid or misaligning the fibers while splicing.

I. Pull core out from end of rope a distance of (1) short section. Hold end of sleeve down on core and milk excess sleeve back about five (5) feet.

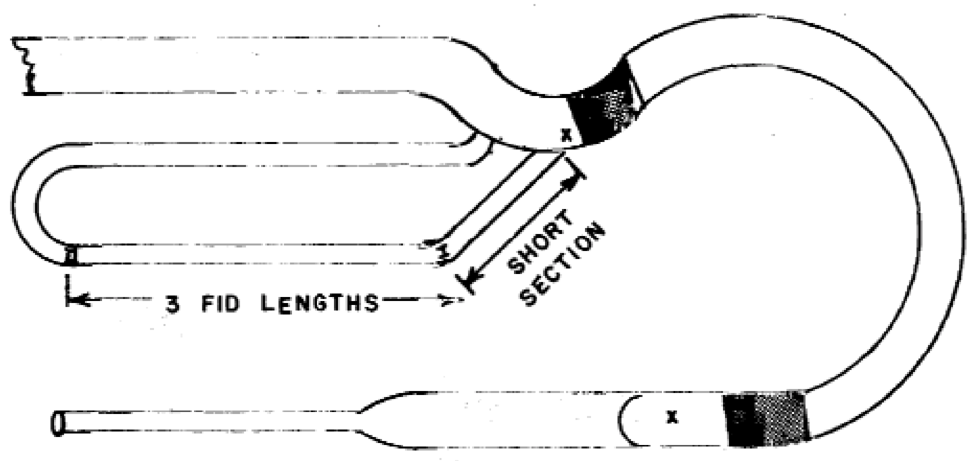


2. Measure two (2) fid lengths (approximately 40x diameter) from end of sleeve and mark sleeve. Form desired eye size and place Second Mark on sleeve opposite the First Mark. Lightly, tape sleeve on the eye side of these marks (the core and sleeve must not move in relation to each other between these marks). Tie a slipknot approximately ten (10) feet from Second Sleeve Mark.

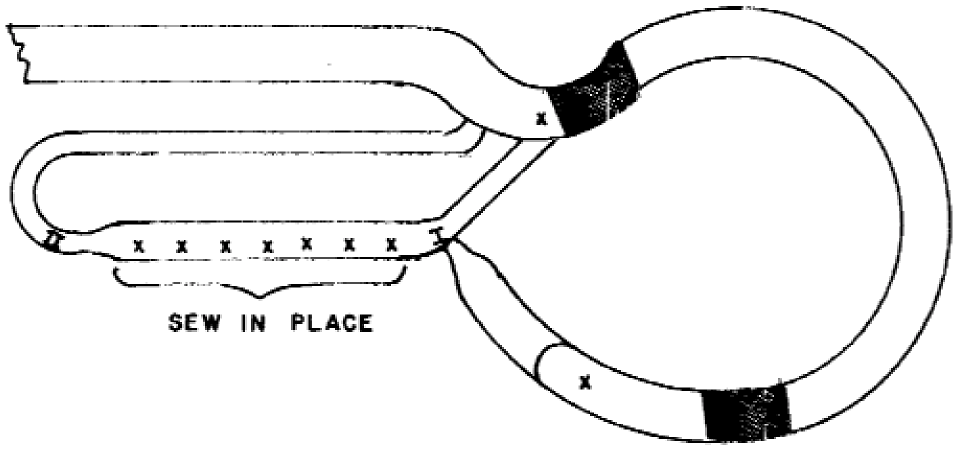




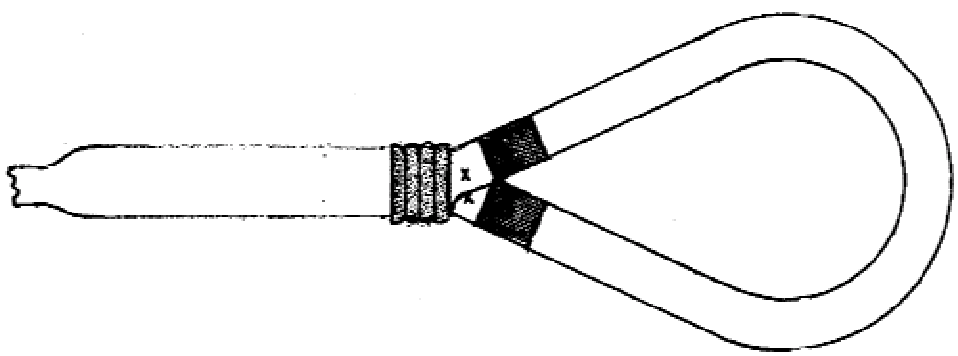
3. Extract core from sleeve at First Mark. Insert sleeve into core for a distance of one (1) short fid section from First Mark toward end of core. Sleeve end should be tapered and sewn in place.



4. Extract core from sleeve at Second Mark and pull out from direction of knot bunching sleeve toward knot. Place core Mark 1 a distance of one (1) short section from point of extraction and core Mark 2 a distance of three (3) lid lengths from core Mark 1.



5. Insert core tail into core at Mark 1 and bring out at Mark 2. Taper core tail. Align sleeve Marks I and 2. Smooth core from Mark 1 to Mark 2, allowing core tail to disappear at Mark 2. Sew from core Mark I to end of tapered core tail. DO NOT pull thread hard, distorting braid.



6. Smooth sleeve from knot toward eye allowing the core to feed back into the sleeve. DO NOT allow the core to roll or twist as it goes back into the sleeve. Repeat this process until sleeve Marks 1 and 2 are aligned and the eye is correct size.

7. Whip the throat.

7.5 Swaged Ferrules

The swaged ferrule is a quick method of terminating but will not produce an efficient terminal. The high compressive loads damage the KEVLAR®. This method is satisfactory for low static loads.

SIZE OF ROPE	NICOPRESS OVAL SLEEVES STOCK NO.	NICOPRESS HAND TOOLS STOCK NO.	- OVAL SLEEVES ~ LENGTH BEFORE COMPRESSION
1/16"	1700-C	51-C-887	3/8"
1/8"	1700-M	51-M-850	11/16"
3/16"	1582-P	51-P-850	1"
1/4"	1700-X	51-X-850	1-1/4"
NO. 635 HYDRAULIC TOOL DIES			
5/16"	1700-G3	1700-G3	1-1/8"
3/8"	1700-H5	1700-H5	1-9/16"
1/2"	1700-J8	1700-J8	2"

7.6 Line Pulling Grips

These grips are primarily for short-term applications such as line stringing. They are easy to field install and are reusable. They are not a full strength termination, but do no damage to the rope. A variety of grips exist and the majority are constructed similar to the Kellems® grip shown in Figures 5-33 and 5-34.

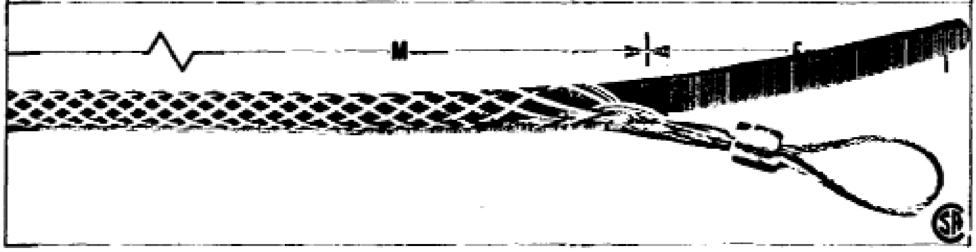
NON-CONDUCTIVE GRIP

FIGURE 5–33 KELLEMS GRIP

Catalog Number	Description	Color Code	Cable Diameter Range -Inches-	Approx. Breaking Strength -Lbs.-	E	M	A
					INCHES		
036-28-001	NCP 050	Green	.50- .62	4,000	5.5	24.0	.44
036-28-002	NCP 063	Yellow	.63- .74	5,000	5.5	26.0	.44
036-28-003	NCP 075	Red	.75- .99	6,000	6.0	31.0	.63
036-28-004	NCP 100	Blue	1.00-1.24	6,000	6.5	36.0	.63
036-28-005	NCP 125	White	1.25-1.49	6,000	6.7	41.5	.63

E – Eye length M – Mesh length at nominal diameter

SLACK GRIP — CLOSED MESH



DOUBLE WEAVE

	Catalog Number	Description	Cable Diameter Range -Inches-	Approx. Breaking Strength -Lbs.-	E	M
					Inches	
STANDARD	033-08-003	UD075-A	.75- .99	2,600	7	12
	033-08-004	UD100-A	1.00-1.24	4,000	8	15
	033-08-005	UD125-A	1.25-1.49	5,400	8	16
	033-08-006	UD150-A	1.50-1.74	6,600	9	17
	033-08-007	UD175-A	1.75-1.99	10,000	10	18
	033-08-008	UD200-A	2.00-2.49	11,000	10	19
	033-08-009	UD250-A	2.50-2.99	11,000	10	20
	033-08-010	UD300-A	3.00-3.49	14,500	12	21
	033-08-011	UD350-A	3.50-3.99	14,500	12	22
LONG	033-08-012	UD075-M	.75- .99	2,600	7	20
	033-08-013	UD100-M	1.00-1.24	5,400	8	20
	033-08-014	UD125-M	1.25-1.49	5,400	8	23
	033-08-015	UD150-M	1.50-1.99	6,600	9	25
	033-08-016	UD200-M	2.00-2.49	11,000	10	26
	033-08-017	UD250-M	2.50-2.99	11,000	10	29
	033-08-018	UD300-M	3.00-3.49	16,000	12	32
	033-08-019	UD350-M	3.50-3.99	16,000	12	35

E – Eye length M – Mesh length at nominal diameter

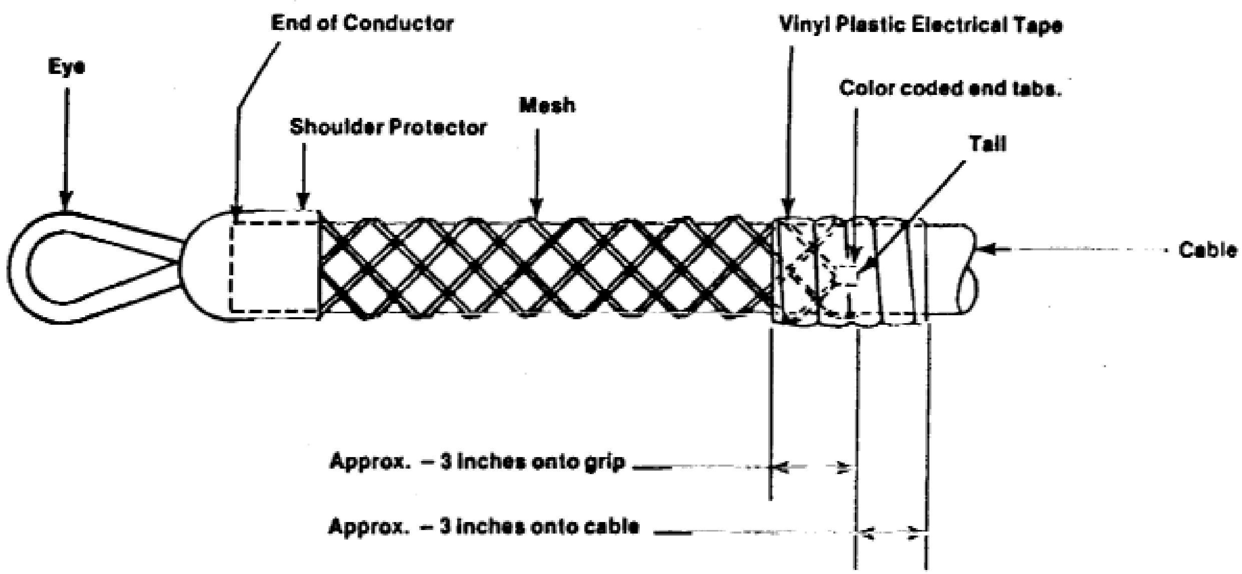
FIGURE 5-34 KELLEMS® GRIP

The following steps should be taken to assure proper assembly of Non-conductive Pulling Grips.

1. Assemble the grip so the cable is inserted into the molded shoulder protector.
2. All slack should be smoothed out of the mesh starting at the molded shoulder protector and working back toward the tail.
3. Apply vinyl plastic electrical tape starting three inches from the tail of the grip winding onto three inches of the cable. Continue back and forth, wrapping tape tightly, until two to three layers of tape have been applied. Taping is required to insure maximum reliability and guard against accidental release.

   Note: When higher loads are required, use Kellems® Multiple Strength or DUA-pull Grips.

   Note: DO NOT USE FOR PULLING ROPE. FOR PULLING ROPE, USE KELLEMS® DUA-pull GRIPS.



GRIP PART NUMBER	COLOR CODE	WORK LOAD (LBS)*	SIZE RANGE O.D. (INCHES)
036-28-001	Green	550	.50 — .62
036-28-002	Yellow	700	.63 — .74
036-28-003	Red	850	.75 — .99
036-28-004	Blue	850	1.00 — 1.24
036-28-005	White	850	1.25 — 1.49

*Rated working load is determined by using a safety factor of 5 based on approximate breaking strength.

ACKNOWLEDGMENTS

The author wishes to acknowledge the following companies who have provided material and information used in this section.

Cortland Cable Company
E. I. du Pont de Nemours and Company
Esmet Corporation (Electroline)
Hubbell Incorporated
Philadelphia Resins Corporation

Some useful links:

http://www.wireropenews.com

http://www.awrf.org

http://www.craneinstitute.com

http://www.MTSociety.org

http://www.ropecord.com