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WIRE ROPE TERMINATIONS  
TRAINING AND INSPECTION MANUAL FOR THE  
ASSEMBLY OF WIRE ROPE TERMINATIONS

VOLUME III

UNITED STATES DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES

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16. Abstract (Limit 200 words) The assembly procedures for nine wire rope terminations used in the mining industry are presented in a format and manner to facilitate training and to provide points where inspection of the termination should be performed. The manual was prepared to be used primarily for field mining operations or training where high-capacity machinery is limited. It is not the intent of this manual to suggest that the procedures presented are those to be used by manufacturers or other commerical enterprizes. A different set of procedures may be more appropriate where ideal space and equipment resources are available. The assembly procedures were derived from standard industrial practice, manufacturers' recommendations, and open literature on the subject. These same procedures were used to prepare test specimens for an extensive series of pull and axial fatigue tests. The results of these tests indicate that these procedures are satisfactory in all respects. The manual is to be used as part of a complete training program. Although a brief glossary is included, there has been no attempt to make this a primer on wire rope. The selection of wire rope termination hardware, like the selection of the wire rope, is a subject not covered by this manual; there are various sources for such hardware and this selection must be done carefully.			
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## FOREWORD

This report was prepared by Engineering Services Company, Damascus, Maryland under USBM Contract number H0166079. The contract was initiated under the Metal & Non-Metal Mine Health & Safety Program. It was administered under the technical direction of the Pittsburgh Mining & Safety Research Center with Edwin Ayres acting as Technical Project Officer. Frank Naughton was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September 1976 to August 1978. This report was submitted by the authors on August 10, 1978.

The review of this training manual by Mr. Charles Layton and his recommendations are greatly appreciated. The informal participation of several wire rope manufacturers and manufacturers of wire rope terminations is also acknowledged.



## INTRODUCTION

This manual has been prepared to be used primarily for field type mining operations or training where high capacity machinery is quite limited. It is not the intent of this manual to suggest that the procedures presented are those to be used by manufacturers or other commercial enterprizes. A different set of procedures may be more appropriate where ideal space and equipment resources are available.

The procedures presented in this training manual are for assembling wire rope terminations most commonly used in the mining industry. They have been derived from standard industrial practice, manufacturer's recommendations, and the open literature on the subject. These same procedures were used to prepare test specimens for an extensive series of pull and axial fatigue tests. The results of these tests indicate these procedures satisfactory in all respects. Since inspection is an integral part of the assembly of a Wire Rope Termination (WRT) in the field or in the small shop, inspection points are identified in the assembly procedures.

This manual is to be used as part of a complete training program where the trainee develops skills and is tested. The manual should not simply be handed to inexperienced personnel who are then expected to prepare a safe WRT. Although a brief glossary is included, there has been no attempt to make this a primer on wire rope. Excellent wire rope handbooks and catalogs are available from major wire rope manufacturers.

The selection of WRT hardware, like the selection of the wire rope, is a subject not covered by this manual. The reader is cautioned that there are various sources for WRT hardware. In the absence of consumer information this selection must be done carefully. If in doubt request specifications and test information.

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CHAPTER 1

WIRE ROPE TERMINATIONS

1.0 The assembly and inspection procedures presented in this manual pertain only to the terminations shown in Figure 1-1. The same termination is often called by many different names. Figure 1-1 depicts the termination along with the name that will be used for that termination throughout this manual.

The assembly procedures vary from one wire rope manufacturer to another and between termination

fabricators in the industry. Such procedures may or may not give the same performance as the procedures presented in this manual.

The procedures presented in this manual are considered the most satisfactory for field or small shop operations.

Some terminology on wire rope and wire rope terminations (WRT) are defined in the Glossary at the end of this manual.

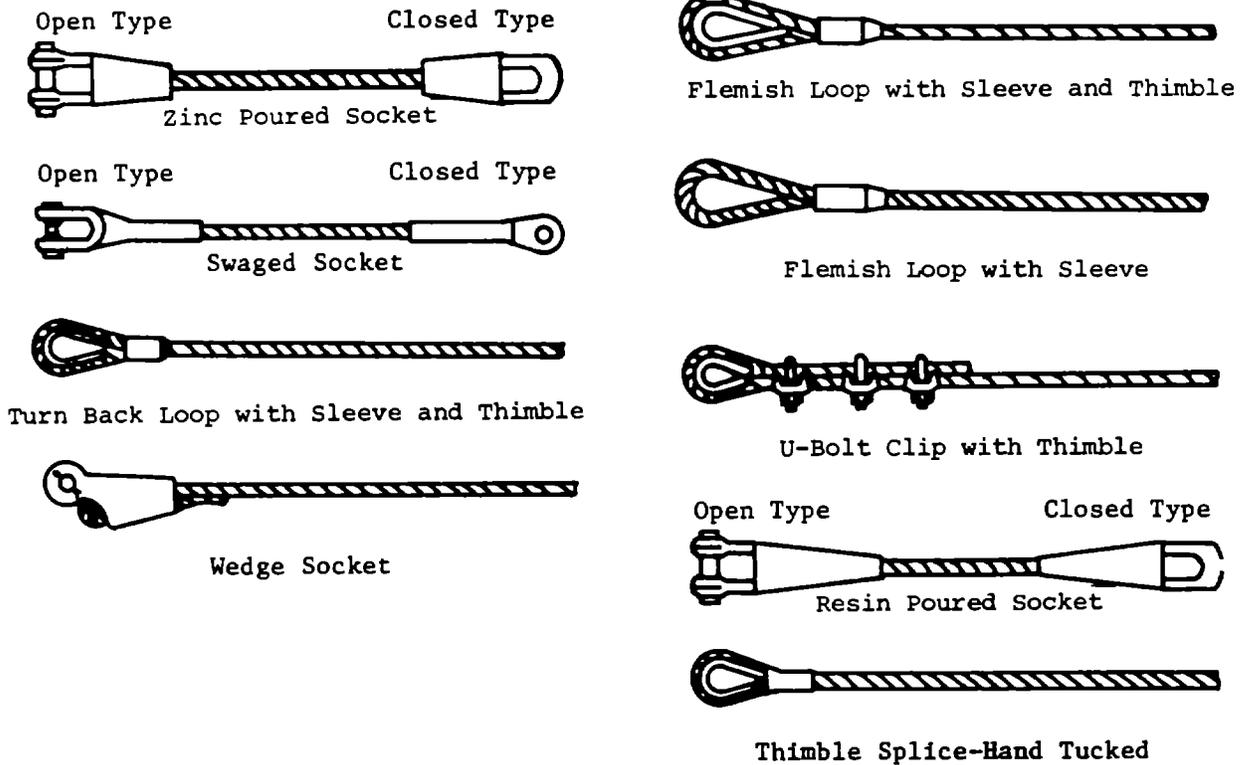


Figure 1-1. Wire Rope Terminations (WRT)



## CHAPTER 2

### SAFETY

2.0 General: Safety precautions must always be observed by all persons entering an industrial area. The persons who routinely work in industrial areas should develop the safety habit in their daily work. Outsiders should not be allowed in an industrial area except under supervision and with all safety precautions observed.

2.1 Individual Responsibility: Each individual is personally responsible for his own use of safety devices. All personnel are responsible for observing safety precautions and conducting themselves in a safe and businesslike manner when working in an industrial area.

2.2 Management Responsibility: Management is responsible for providing safety devices, enforcing their use, identifying hazardous areas, and posting safety precautions. Management is also responsible for safe and proper installation and operation of all machinery and power tools used in the shop.

2.3 Safety Devices: Eye protection is the most important single safety requirement when working with wire rope. Each person should wear their safety glasses at all times while working in an industrial area. Other devices such as hard hats, safety shoes, and gloves are used depending on personal preference and shop regulations.

2.4 Special Precautions When Working With Wire Rope:

2.4.1 It is assumed that eye protection is worn at all times.

2.4.2 Care should be exercised when handling cut ends of wire rope. Individual wires are often very sharp and will cut or pierce the skin easily, even through good quality leather gloves.

2.4.3 Wire rope is very strong and stiff, and some operations require a great deal of force to perform. This means that the work procedures must be carefully thought out so that this force cannot possibly injure the operator.

2.4.4 When bent, wire rope becomes a reservoir of stored energy. When released, intentionally or accidentally, this energy is returned with potentially damaging effects.

2.4.5 The power tools used in conjunction with WRT work are hazardous. All precautions must be observed when using these tools.

2.5 Adequate ventilation should be used when working with cleaning solvents and other chemicals.

2.6 Special Precautions: In the text of this manual potentially unsafe or dangerous operations will be identified. A warning note will be added to point out special safety requirements. This does not apply to eye protection which must be worn at all times.



## CHAPTER 3

### ASSEMBLY PROCEDURES

3.0 General: The assembly procedures presented in this chapter are to be used primarily for field type operations or training where high capacity machinery is quite limited. Procedures used by wire rope manufacturers may deviate from these procedures. They are based on the most recent available laboratory data and recommendations of the wire rope industry. Deviations from these procedures may result in an unsafe termination.

3.1 SEIZING AND CUTTING WIRE ROPE. The proper method of seizing a wire rope is illustrated in Figure 3-1.

3.1.1 Prior to cutting a wire rope, seize the rope on each side of the cut mark. Use the correct diameter annealed seizing wire (see Table 1-1). Two seizings should be placed on each side of the cut mark. They are approximately

three rope diameters apart for nonpreformed ropes and Lang lay wire rope with Independent Wire Rope Core (IWRC).

3.1.2 One seizing on each side of the cut mark is sufficient for preformed wire rope.

3.1.3 In order to get adequate tension two inch diameter and larger wire rope must be seized with a serving bar (Figure 3-2). For these larger diameter ropes seizing may be done with wire strand.

3.1.4 An abrasive cutoff wheel (Figure 3-3) is recommended for cutting wire. This makes a clean cut, does not bend or cause welding of individual wires as happens when a cutting torch is used.

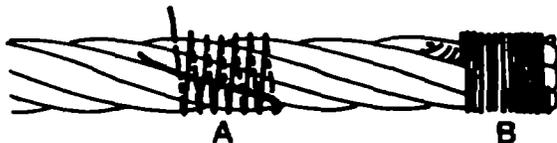


Figure 3-1. Method of Seizing a Wire Rope. At A the Turns of the Seizing Wire are Spread Apart to Illustrate the Method. At B the Completed Seizing is Shown.

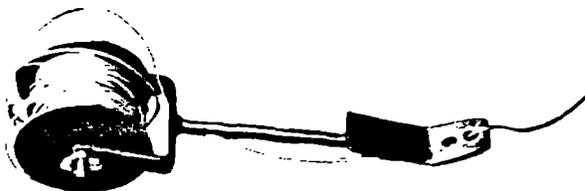


Figure 3-2. Serving Bar for Seizing Large Diameter Wire Ropes.

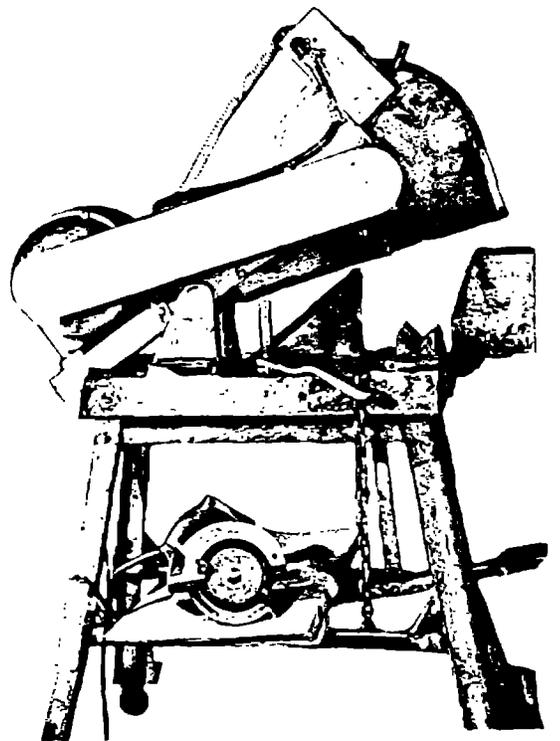
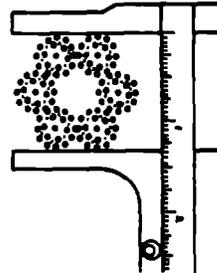
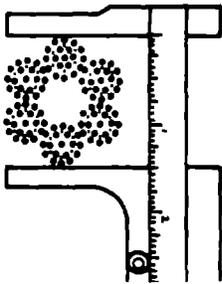


Figure 3-3. Abrasive Cut-Off Wheels.

TABLE 1 SEIZING LENGTHS AND WIRE DIAMETER

Rope Diameter		Seizing Wire Diameter		Seizing Length	
in.	(mm)	in.	(mm)	in.	(cm)
1/8 to 5/16	( 3.2 7.9)	.032	(0.8)	1/4	( .64)
3/8 to 9/16	( 9.5 14.3)	.048	(1.2)	1/2	(1.27)
5/8 to 15/16	(15.9 23.8)	.063	(1.6)	3/4	(1.91)
1 to 1- 5/16	(25.4 33.3)	.080	(2.0)	1-1/4	(3.18)
1-3/8 to 1-11/16	(34.9 42.9)	.104	(2.6)	1-3/4	(4.45)
1-3/4 to 2-1/2	(44.4 63.5)	.124	(3.2)	2-1/2	(6.35)
2-9/16 to 3-1/2	(65.1 88.9)	.124	(3.2)	3-1/2	(8.89)
3-5/8 to 4	(92.1 102)	.124	(3.2)	4	(10.2)
4-1/8 to 4-1/2	(105 114)	.124	(3.2)	4-1/2	(11.4)



However, rope diameters are limited with this method. Either hydraulic shears or a cutting torch must be used for large diameter rope.

3.1.5 Other methods for cutting wire rope are: mechanical shears, electric-resistance cutter, and flame cutting.

### 3.2 PREPARATION OF ZINC POURED SOCKET

3.2.1 Start heating zinc to 524° centigrade (975° Fahrenheit) in a melting pot (Figure 3-4). Use only high grade zinc per A.S.T.M. Specification B-6-58. Do not use babbitt or other antifriction metal.

3.2.2 Securely seize the wire rope with soft iron wire ties or strands on both sides of the cutting point. Also seize

at distances from the end of the rope equal to one length of the socket basket (first seizing) and at two lengths of the socket basket (second seizing).

3.2.3 Cut the rope at the cutting point, then slide the socket over the end of the rope. If the rope is heavily lubricated, wipe off the lubricant to a distance of six feet below the first seizing. Wrap tape over the rope which has been wiped clean. Place the rope in a vise and remove the end seizing. Open up the rope by unlaying each strand back to the first seizing. A core of fiber or synthetic material and any other nonmetal material must be cut off as close to the first seizing as possible. Do not cut off the independent wire rope core (IWRC) or wire strand core (WSC). Untwist all wires from each strand and the metallic core.

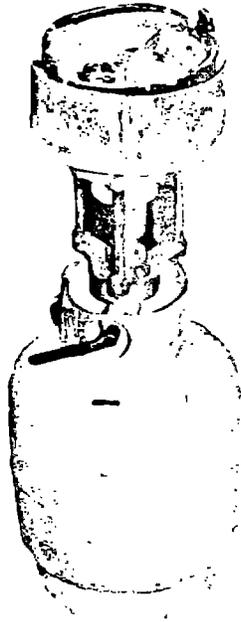


Figure 3-4. Zinc Melting Pot.

Spreading them out to form a broom (Figure 3-5). A wire straightening tool, a 12 inch length of 3/8 inch iron pipe, may be needed for large diameter wire ropes.

INSPECTION POINT: The broom should be inspected to make certain it has been prepared in accordance with 3.2.3.

**WARNING**

Before starting to clean the wire rope end make sure there is adequate ventilation. The Threshold Limit Values (TLV) must not be exceeded for the various chemicals.

3.2.4 Hold the broom end of the rope in a horizontal position. Clean all wires to the first seizing with trichlorethene. A brush may be needed to remove dirt and lubricant from between wires (Figure 3-6). Shake off excess solvent and air dry. If ultrasonic cleaning is to be used, see supplemental instructions (Steps 3.2.15-3.2.18).

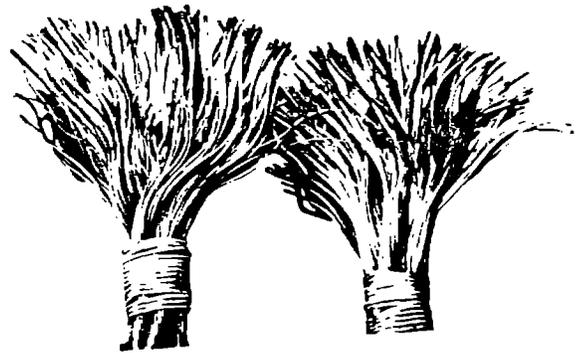


Figure 3-5. Wire Rope Broom.



Figure 3-6. Cleaning Wire Rope Broom.

INSPECTION POINT: Check broom for cleanliness and supervise Steps 3.2.5 and 3.2.6.

**WARNING**

In the following procedure be certain to add the acid to the water. Careful handling is required to prevent acid burn to the skin.

3.2.5 Dip the wire broom for three quarters of its length into a bath composed of one-half commercial muriatic acid and one-half water. Remove the wire broom from the acid bath after 30 seconds to one minute. The wires will turn a dull, steel gray color. The acid

bath must be kept clean by skimming off lubricant from previous dipping. Keep the wire broom pointing down until excess acid has been shaken off. This will prevent acid from running down into the wire rope. Next dip the wire broom into a bath of boiling water to which has been added a small amount of soda. This neutralizes any remaining acid. Remove the wire broom and shake dry.

3.2.6 If required, the wire broom can now be immersed completely for 30 seconds in hot 94° C (200° F) flux solution (one pound zinc ammonium chloride per gallon of water). After removal, let the broom dry in the air. The flux solution must be kept clean by skimming off lubricant film and changing it when it becomes rust colored.

3.2.7 Slide the socket to the end of the rope until it is above the first seizing. Clamp the rope in a vise, socket basket pointing up.

3.2.8 Check that the ends of the broom wires are even with the top of the socket basket. If they are not, slide the socket down the rope and shorten or lengthen the wire broom by adding or removing wire to the first seizing. Slide the socket back up around the wire broom. The wire broom should fill the socket basket (Figure 3-7).

3.2.9 Align the socket with the axis of the wire rope. Remove any tape which was wrapped on the rope. Place fire clay, putty, or asbestos wicking around the bottom of the socket. Work this sealer thoroughly into the space between the strand valleys and the inside surface of the socket basket.

INSPECTION POINT: Check alignment and supervise Steps 3.2.10 and 3.2.11.

3.2.10 Preheat the socket basket area to about 94° C (200° F) by holding the flame of a portable torch to the socket or heat the socket basket in an oven (Figure 3-8). If a torch is used, make sure the

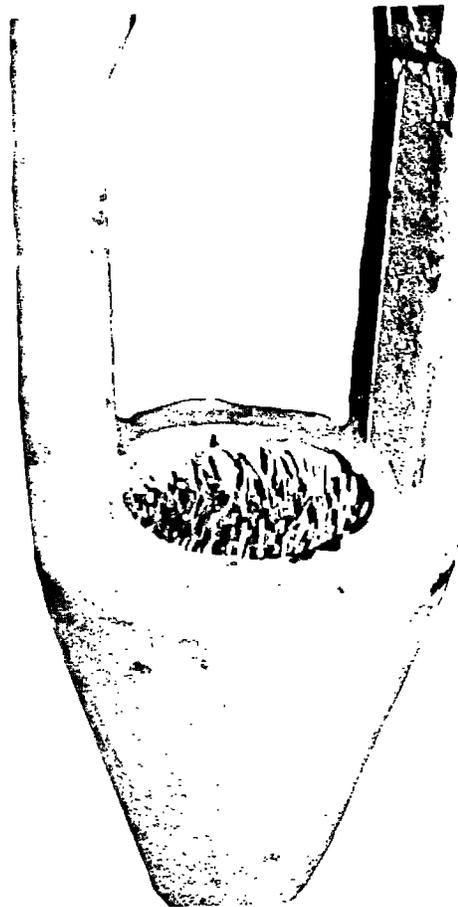


Figure 3-7. Broom Seated in Socket.

heat is evenly distributed and does not exceed suggested temperatures. Check temperatures with a temp-stick.

**WARNING**

Molten zinc will cause severe skin burns. Wear gloves and ankle high boots when pouring. Care should be exercised when pouring the molten zinc so that none is spilled or dangerous splatter will result.

3.2.11 Skim off any dross which may have accumulated on the surface of the molten zinc bath. Check the temperature of the molten zinc with a thermometer (Figure 3-9). Pour the molten zinc at 524° C

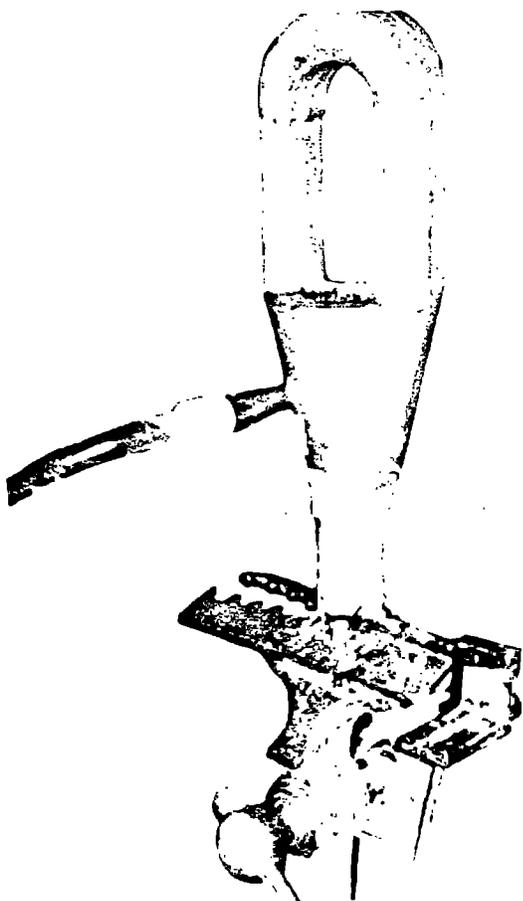


Figure 3-8. Socket Being Heated Before Pouring.



Figure 3-9. Checking Temperature of Molten Zinc.

(975° F) into the socket basket until the basket is full (Figure 3-10). Tap the socket gently while pouring to release air or gas pockets to ensure full zinc penetration.

3.2.12 After the zinc has hardened with a depression in the top of the zinc, let the socket cool in air.

**WARNING**

Care should be exercised when handling socket or burns could result.

3.2.13 Remove the sealer at the base of the socket, as well as the first and second seizing. Apply some wire rope lubricant to the rope where it joins the socket.

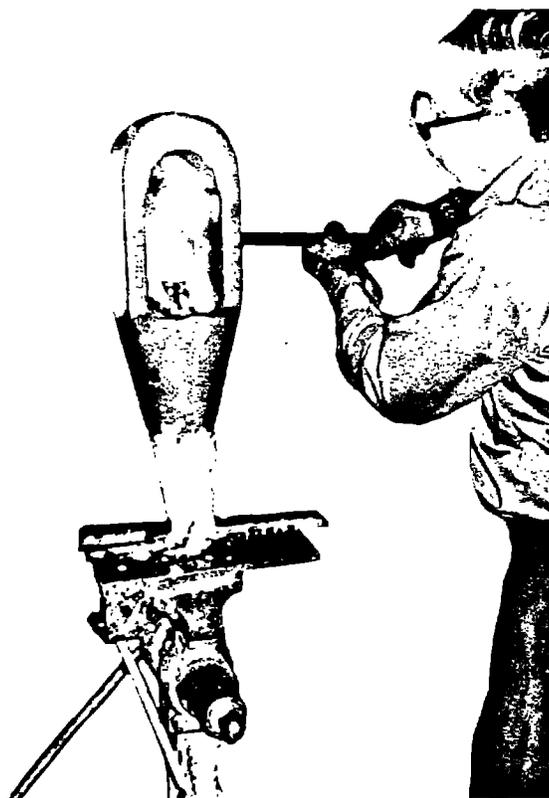


Figure 3-10. Pouring Zinc Into Socket Basket.

3.2.14 The poured socket termination is now ready for proof testing, if required, or to be put into service (Figure 3-11).

INSPECTION POINT: Check for depression in center of zinc pool and for lubricant at base of socket.

#### SUPPLEMENTARY INSTRUCTION FOR USE OF ULTRASONIC CLEANER

3.2.15 Fill the ultrasonic cleaner tank with enough solvent so the wire broom will be covered up to the first seizing (Figure 3-12). With the wire broom immersed in the solvent turn on the cleaner. After cleaning action starts, set timer from two to five minutes. The time can be determined by experience and depends on how much lubricant and dirt must be removed.

3.2.16 After the first cleaning period, inspect the wire broom for cleanliness. Places between wires may hold large accumulations of lubricant, and these should be removed with a clean brush.

3.2.17 Repeat cleaning process until wire broom is uniformly clean in appearance. Two to four cleanings will be required.

3.2.18 Proceed with Steps 3.2.5 and 3.2.6 of basic procedure.

### 3.3 PREPARATION OF SWAGED SOCKET

#### CAUTION

In the following procedures be certain that when cutting the rope with a torch that the burning does not anneal the rope end extensively.

3.3.1 Seize and cut the rope to the desired length. Using an acetylene torch, burn the end of the rope to weld all of the wires and strands together. If the rope is preformed, that is if it does not tend to unlay when cut, this step may not

be necessary. Dress down the end of the rope with an abrasive disk, belt, or wheel, so that it will slip easily into the cavity in the swaged socket. Measure the depth of the swage socket cavity and chalk mark this distance from the end of the rope. Insert the rope all the way

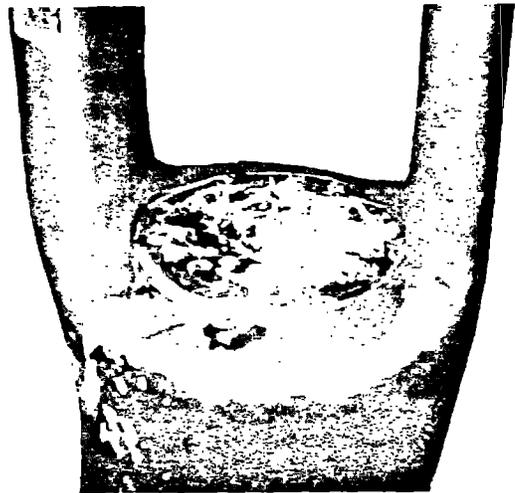


Figure 3-11. A Completed Socket with Depression in Center of Zinc Pool.

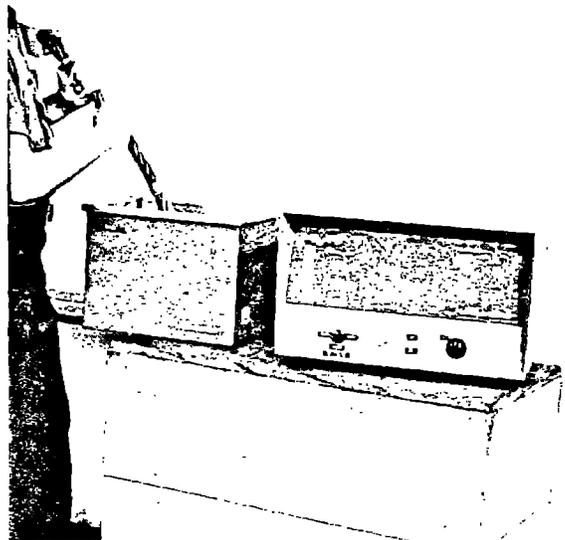


Figure 3-12. Broom Immersed to First Seizing in Ultrasonic Cleaning Tank.

into the cavity and check that the mark on the rope is at the end of the swage socket fitting.

INSPECTION POINT: Check that wire rope is inserted to the bottom of the termination cavity.

3.3.2 Apply lubricant; commercial anti-seize compound or hydraulic oil, to both die blocks to facilitate cold flow of socket metal. Although this WRT is known as the Swaged Socket, it is assembled by a pressing operation of several gradual closing of dies. Swaging involves repeated hammering blows to cold form metal.

**WARNING**

Keep hands clear of dies when machine is operating or injury to personnel may result.

3.3.3 The socket should be pressed full length if the capacity of the hydraulic press (Figure 3-13) and the size of the socket permits. This is determined by shop experience. If not, the socket should be pressed in one-third or one-half sections of its length, starting at the end next to the rope. Press the socket in the hydraulic press using the correct size die blocks, close the die blocks approximately one-half of the distance between first contact and fully closed. Turn the socket and rope 45° (one-eighth turn) after each pressing. (One-quarter turn to one-third turn for large sockets greater than one-half inch diameter ropes.) The completed Swaged Socket is depicted in Figure 3-14. Continue pressing and rotating the socket until the die blocks close and the Go Gage will pass over all the pressed area.

INSPECTION POINT: Check Swaged Socket with Go Gage (Figure 3-15). Inspect for presence of cracks or metal flashing caused by insufficient turns during pressing.

3.3.4 For larger diameter terminations, two or more pairs of die blocks may be required. If this is the case, change die blocks and proceed as in Steps 3.3.2 and 3.3.3 above.

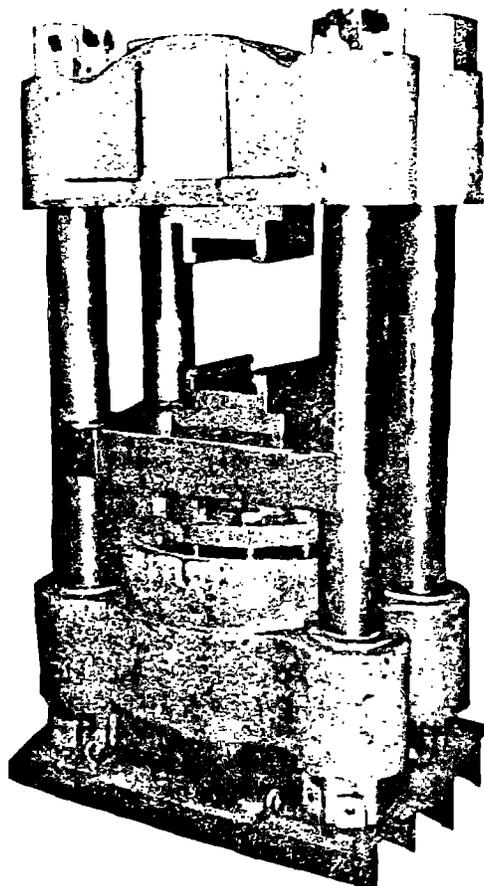


Figure 3-13. Hydraulic Press Machine.



Figure 3-14. Completed Swaged Socket with Smooth Tapered Section.

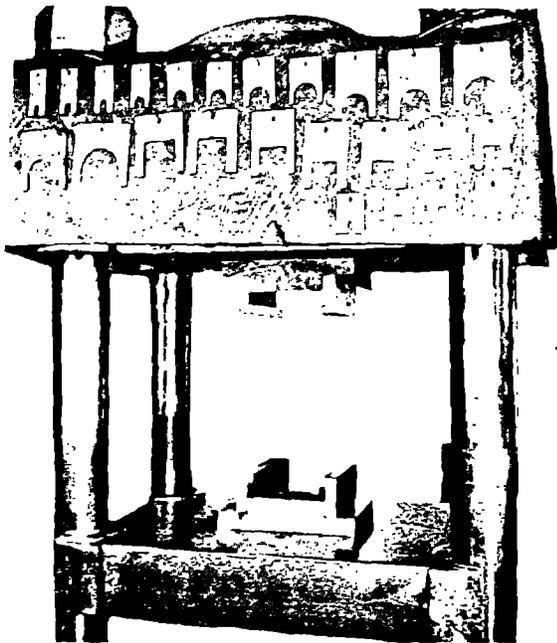


Figure 3-15. Assortment of Go Gages.

NOTE

The die blocks must not be applied out of sequence. Normally the swaged socket will not fit in the smaller die until it has been pressed by the larger die, however, this is possible and should be guarded against.

3.4 PREPARATION OF TURN BACK LOOP WITH SLEEVE AND THIMBLE

3.4.1 Mark the rope with chalk where the center of the thimble is to be located. Measure the turn back length of rope required from the first mark, and mark again. The turn back length of rope is the distance half way around the thimble, plus the length of the sleeve, plus three rope diameters.

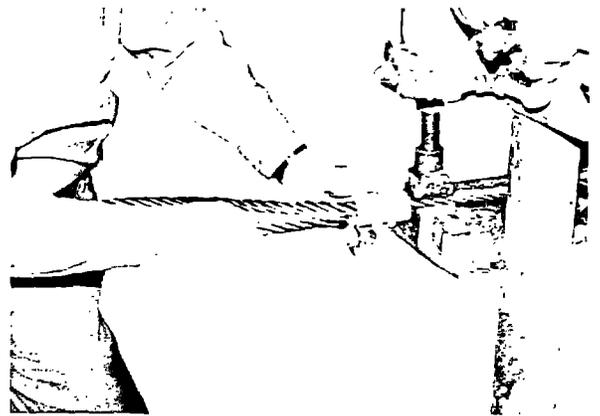


Figure 3-16. Sliding the Dead End of the Rope into the Sleeve.

CAUTION

In the following procedure be certain that when cutting the rope with a torch that the burning does not anneal the rope extensively.

3.4.2 Burn the end of the wire rope with an acetylene torch so that wires and strands are welded together. If the wire rope is preformed, that is if it does not tend to unlay after cutting, this step may not be necessary. Remove any seizing and clean up the end of the rope with an abrasive disk, belt, or wheel. Slip the sleeve over the end of the rope and slide past the location of the loop.

3.4.3 Clamp rope in a vice and bend the wire rope around to form an easy to handle loop. Slide the dead end of the rope into the sleeve (Figures 3-16 and 3-17).

3.4.4 Insert the thimble in the loop, then slide the sleeve and the dead end of the rope toward the thimble. Pull the live part of the rope over the thimble. Pull the sleeve up snug to form a tight loop around the thimble.

INSPECTION POINT: Check that loop fits tightly around thimble (Figures 3-18 and 3-19).

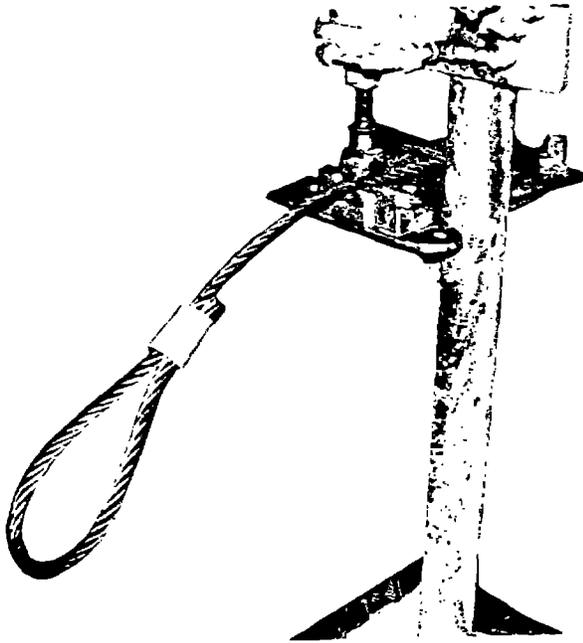


Figure 3-17. Completed Loop Without Thimble.



Figure 3-19. Thimble and Pressed Sleeve WRT Before Pressing Sleeve.

**WARNING**

Keep hands clear of dies when machine is running or injury to personnel could result.

3.4.5 Remove the wire rope, thimble, and sleeve assembly from the splicer's vise and press the sleeve in a hydraulic press. Use the correct size die blocks for the diameter rope in use. Lubricate the dies with a commercial antiseize compound or hydraulic oil.

Place the sleeve in the press with the wide dimension in the vertical plane. Close the dies, forcing excess sleeve metal into two flashing strips if using aluminum. Remove the termination from the press and knock off any aluminum flashing. Return the termination to the press. Rotate the sleeve 90° (one-quarter turn) from the first pressing. Close the dies a second time. Check again and close the dies once again (Figure 3-20).

**WARNING**

Ensure the fitting is positioned so that all wire ends are covered in the finished state to prevent injury to personnel handling the completed fitting.

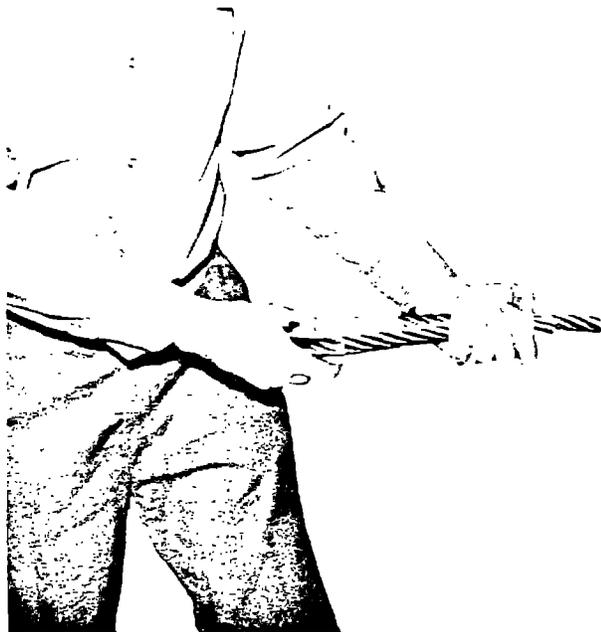


Figure 3-18. Sliding the Sleeve Up Snug to Form a Tight Loop.

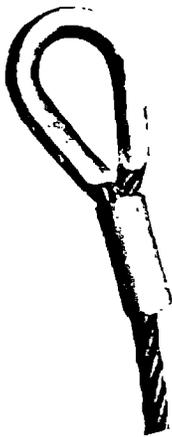


Figure 3-20. Turn Back Loop with Sleeve and Thimble WRT After Pressing Sleeve.

INSPECTION POINT: Check pressed sleeve with Go Gage. Inspect for presence of cracks, metal flashing, or protruding wires.

### 3.5 PREPARATION OF WEDGE SOCKET

3.5.1 The following procedure applies to small diameter wire ropes. Applications of larger wedge sockets such as used on big shovels and draglines may differ. The basic idea in the use of the wedge is the same, but assembly would depend on local conditions.

3.5.2 Seize the wire rope and cut to desired length.

3.5.3 Insert and seat the wedge in the socket. Mark a line with chalk on the side of the wedge next to the top of the socket (Figure 3-21). Check socket for sharp edges or flashing that might cut or damage the wire rope.

3.5.4 Lock the socket in an upright position or grip the rope in a vise, if available. Reeve the rope through the socket and turn back away from the ears (lugs) in a large, easy to handle loop (Figure 3-22).

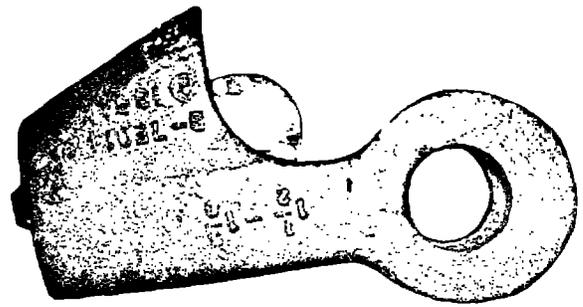


Figure 3-21. Marking the Wedge for Final Seating.

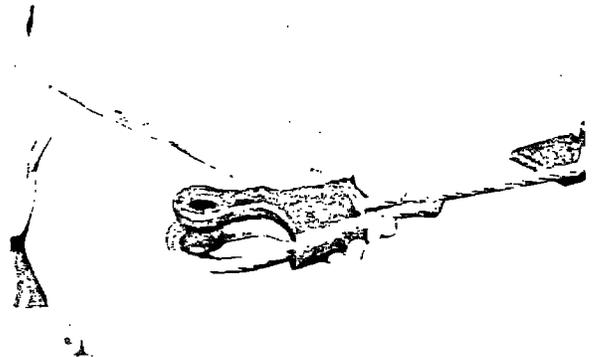


Figure 3-22. Rope Passed Through Socket to Form Loop.

3.5.5 Reeve the dead end of the rope back through the socket so that it extends a distance of one rope lay past the end of the socket. Attach a wire rope clip to the dead end of the rope to prevent the dead end from slipping out of the socket. Insert the wedge in the socket between the live and dead parts of the rope (Figure 3-23).

3.5.6 Take a strain on the live end of the rope or the socket. Pull the wedge and rope loop into position tightly enough to hold the wedge in place during handling (Figure 3-24).

INSPECTION POINT: Check that the rope was reeved properly.

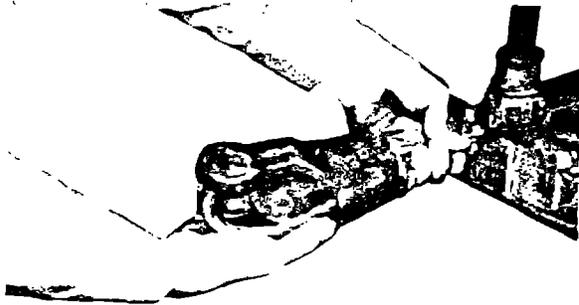


Figure 3-23. Placing Wedge Inside Loop and Socket.

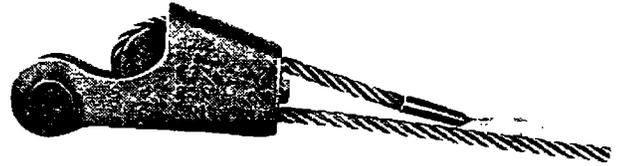


Figure 3-25. Completed Termination with Fully Seated Wedge and Load Pin Inserted Through Ears.

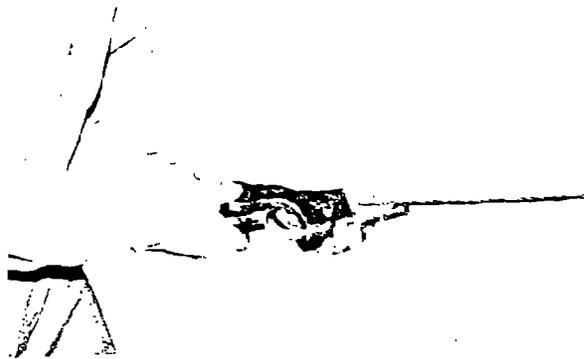


Figure 3-24. Pulling Wedge Into Socket Before Applying Safe Working Load.

3.5.7 Attach the socket to a load sufficient to develop 20% of the rope's catalog breaking load. Apply the load gradually until the chalk line on the wedge is next to the top of the socket (Figure 3-25).

INSPECTION POINT: Check that wedge is in the fully seated position.

### 3.6 PREPARATION OF FLEMISH LOOP WITH SLEEVE TERMINATION

#### NOTE

Also known as "Flemish Eye", "Molly Hogan", "Rolled In Eye Splice", or "Farmers Splice".

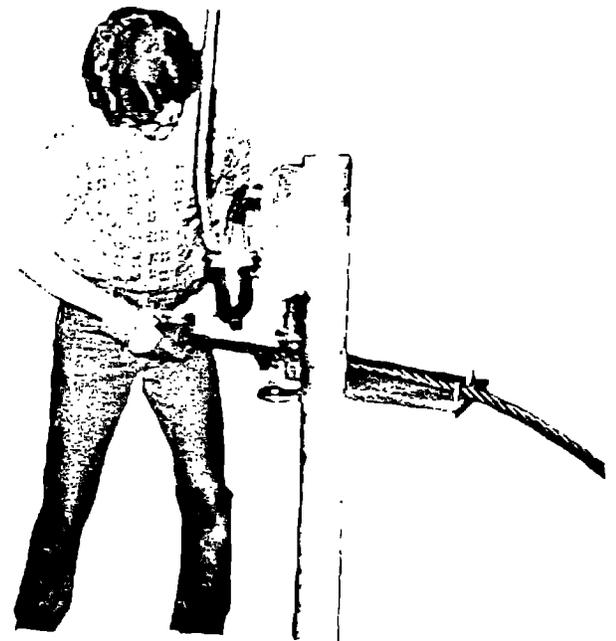
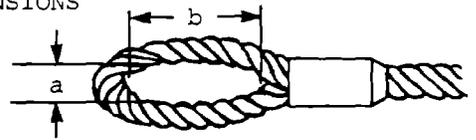


Figure 3-26. Sliding Sleeve Onto Rope Before Opening Into Two Parts.

3.6.1 Slide the sleeve to be pressed later onto the rope (Figure 3-26). Seize the rope at a distance from the end equal to the length of the loop desired plus ten rope diameters. Preformed wire rope does not require seizing. Table 2 gives the length of rope required for the loop for rope sizes 1/4 in. to 2 in. diameter.

TABLE 2 FLEMISH LOOP DIMENSIONS

Rope Diameter	Loop Dimensions: in. (cm)		Rope Length for Loop: ft. (m)	No. of Rope Lays Opened	No. of Rope Lays Laid In
	Short Axis	Long Axis			
1/4	( 6)	2 x 4 ( 5.08 x 10.16)	1'6" ( .46)	8	7
3/8	(10)	3 x 6 ( 7.62 x 15.24)	2'2" ( .61)	8	7
1/2	(13)	4 x 8 (10.16 x 20.32)	2'10" ( .86)	8	7
5/8	(16)	4-1/2 x 9 (11.43 x 22.86)	3'3" ( .99)	7	6
3/4	(19)	6 x 12 (15.24 x 30.48)	4' (1.22)	7	6
7/8	(22)	8 x 14 (20.32 x 35.56)	5'2" (1.56)	8	7
1	(25)	8 x 16 (20.32 x 40.64)	5'8" (1.73)	8	7
1-1/8	(29)	9 x 18 (22.86 x 45.72)	6'8" (2.03)	8	7
1-1/4	(32)	10 x 20 (25.40 x 50.80)	7'4" (2.23)	8	7
1-1/2	(38)	12 x 24 (30.48 x 60.96)	8'5" (2.56)	8	7
1-3/4	(44)	16 x 30 (40.64 x 76.20)	11' (3.35)	8	7
2	(51)	16 x 32 (40.64 x 81.28)	12' (3.66)	8	7



3.6.2 Separate the rope into two equal parts with one part containing the core. See Table 2 for number of rope lays to open. For a six strand wire rope there would be three strands in one part and three strands and the core in the other part (Figure 3-27).

3.6.3 Bend the two rope parts toward each other and pass one part under the other in an over hand knot (Figure 3-28). Begin to lay rope back into itself.

3.6.4 Pull the two rope parts tight. Lay the two parts back into each other until the two parts project past the bottom or throat of the loop (Figure 3-29). See Table 2 for number of rope lays to lay in. Figure 3-30 depicts a completed loop.

3.6.5 Cut the projecting rope parts to the length of the large diameter section of the sleeve. If fiber core, cut core at this point. If IWRC, spread strands to lay in voids of the main strand.

3.6.6 To complete the loop, roll the two parts into the main rope, each strand in the valley between two other strands. Remove seizing (Figure 3-31).



Figure 3-27. Rope Opened Into Two Parts; Three Strands in One Part, Three Strands and Core in Other Part.



Figure 3-28. Bend Two Rope Parts Toward Each Other and Pass One Part Under the Other in an Overhand Knot.



Figure 3-29. Lay in Two Rope Parts to Form Loop.

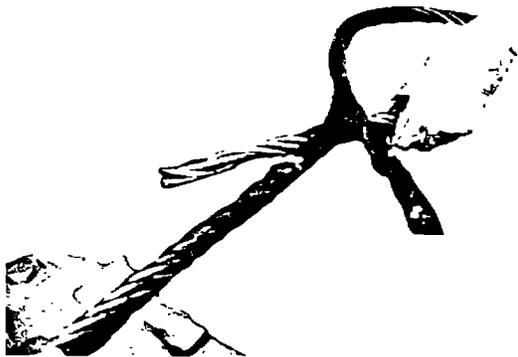


Figure 3-30. Loop Completed.

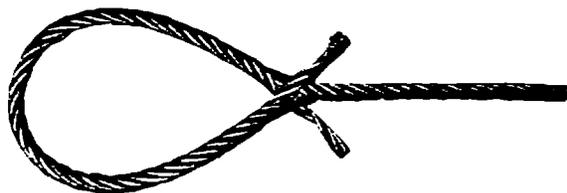


Figure 3-31. Loop Completed and Ready to Form Rolled-In Splice.

3.6.7 If the thimble is to be used the loop is twisted to open it enough to force the thimble into place.

INSPECTION POINT: Check correctness of loop.

3.6.8 Slide the sleeve up to the bottom of the loop. It must contain all of the ends of the strands and the live part of the rope as well.

**WARNING**

Keep hands clear of dies when machine is operating or injury to personnel could result.

3.6.9 Press the sleeve between the correct size dies following the procedure for Swaged Sockets (Figures 3-32, 3-33, and 3-34).

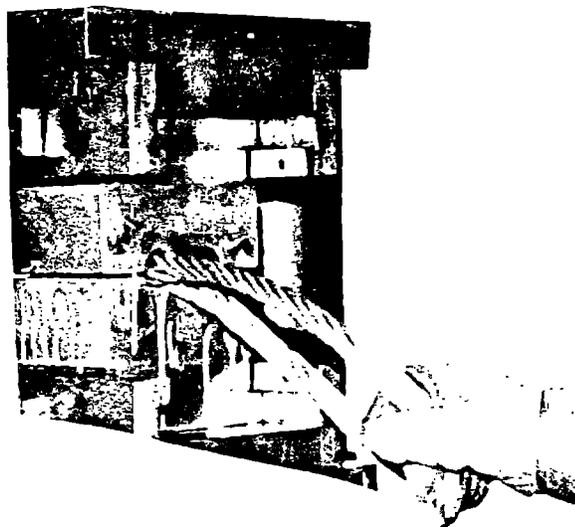


Figure 3-32. Pressing Sleeve Onto Rolled-In Splice Part of Termination.

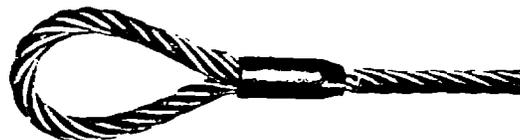


Figure 3-33. Completed Flemish Loop Without Thimble.

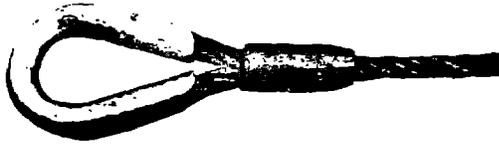


Figure 3-34. Completed Flemish Loop With Thimble.

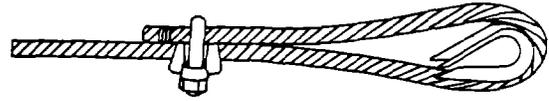


Figure 3-35. Apply First U-Bolt Clip One Base Width from the Dead End of the Wire Rope.

INSPECTION POINT: Check pressed sleeve with Go Gage. Check for presence of cracks or metal flashing.

### 3.7 PREPARATION OF U-BOLT CLIP WITH THIMBLE TERMINATION

3.7.1 Seize the end of the wire rope and slide a loosely assembled U-bolt clip onto the rope.

3.7.2 Measure and chalk mark the specified turn back length given in Table 3. This length is measured from the bottom of the loop or thimble.

3.7.3 Turn back the wire rope, bending it around the thimble. Slide it into the end of the U-bolt clip.

3.7.4 Position the live (long) part of the rope in the saddle (base) of the clip and the dead (short) part of the rope in the U-bolt part of the clip. The chalk mark is positioned at the bottom of the loop or thimble.

3.7.5 Tighten the nuts on the U-bolt and position the rope end about one saddle width from the clip (Figure 3-35). Continue tightening evenly and torque to values in Table 3 for the size wire rope in use. The first clip is now the clip farthest from the loop or thimble.

3.7.6 Position the next U-bolt clip at the bottom of the loop and as close to the thimble as possible. Tighten nuts, but do not torque them (Figure 3-36).

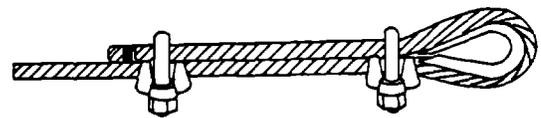


Figure 3-36. Apply Next Clip As Close to the Loop Base as Possible.

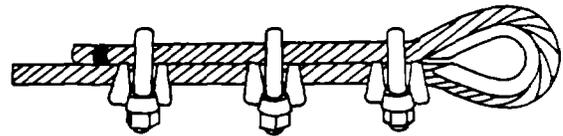


Figure 3-37. Apply Additional Clips at Points Equally Spaced Between the First Two.

3.7.7 Position additional clips, as given in Table 3, at locations equally spaced between the first two clips. Tighten all nuts, but do not torque them (Figure 3-37).

3.7.8 To remove any slack and equalize tension in both parts of the rope, pull the long part of the rope while restraining the loop.

INSPECTION POINT: Check position of saddles on live part and verify presence of torque wrench.

3.7.9 Tighten all nuts evenly on all clips to the torque values given in Table 3.

TABLE 3 U-BOLT CLIP TERMINATIONS

Rope Diameter		Minimum No. of Clips	Rope Turnback		Required Torque	
in.	(mm)		in.	(cm)	Foot Pounds	(Joules)
1/4	( 6)	2	4-3/4	(12.06)	15	(20.34)
5/16	( 8)	2	5-1/4	(13.34)	30	(40.67)
3/8	(10)	2	6-1/2	(16.51)	45	(61.01)
7/16	(11)	2	7	(17.78)	65	(88.13)
1/2	(13)	3	11-1/2	(29.21)	65	(88.13)
9/16	(14)	3	12	(30.48)	95	(128.80)
5/8	(16)	3	12	(30.48)	95	(128.80)
3/4	(19)	4	18	(45.72)	130	(176.26)
7/8	(22)	4	19	(48.26)	225	(305.06)
1	(25)	5	26	(66.04)	225	(305.06)
1-1/8	(29)	6	34	(86.36)	225	(305.06)
1-1/4	(32)	7	37	(93.98)	360	(489.00)
1-3/8	(35)	7	44	(111.76)	360	(489.00)
1-1/2	(38)	8	48	(121.92)	360	(489.00)
1-5/8	(41)	7	51	(129.54)	430	(583.00)
1-3/4	(44)	7	53	(134.62)	590	(799.93)
2	(51)	8	71	(180.34)	750	(1016.87)
2-1/4	(57)	8	73	(185.42)	750	(1016.87)
2-1/2	(64)	9	84	(213.36)	750	(1016.87)
2-3/4	(70)	10	100	(254.00)	750	(1016.87)
3	(76)	10	106	(269.24)	1200	(1629.99)

3.7.10 In the field, retorque all nuts after applying initial load and at regular intervals during rope use.

3.7.11 The number of clips shown in Table 3 is based upon using right regular or lang lay wire rope, 6x19 class or 6x37 class, fiber core or independent wire rope core, improved plow steel or extra improved plow steel. The number of clips shown also applies to right regular lay wire rope, 8x19 class, fiber core improved plow steel, sizes 1-1/2 inch and smaller; and, right regular lay wire rope, 18x7 class, fiber core, improved plow steel, or extra improved plow steel, sizes 1-3/4 and smaller.

For other classes of wire rope not mentioned above, it may be necessary to add additional clips to the number shown. If a greater number of clips are used than shown in the table, the amount of rope turn back should be increased proportionately.

### 3.8 PREPARATION OF RESIN POURED SOCKET

3.8.1 Resin Poured Sockets are prepared in a manner similar to Zinc Poured Sockets. There are several important differences which require a separate section in this manual. Furthermore, the procedures may vary from one resin manufacturer to another. It is necessary that the manufacturers instructions also be used in preparing a Resin Poured Socket. At the time of publishing this manual two resin kits were commercially available for wire rope use, an epoxy resin and a polyester resin. The polyester resin can be used in any conical shaped baskets such as used for Zinc Poured Sockets. The epoxy resin, however, is to be used only with sockets that have a longer tapered basket. Consult the manufacturer to confirm this.

3.8.2 Check the storage temperature of the resin kit, and if necessary, place the kit in a warm area to raise its temperature to about 22° C (72° F). Also check the shelf life of the kit by referring to the manufacturer's instructions.

3.8.3 A rope to be placed in a standard length socket with a polyester resin can be seized, cut and broomed out as described in paragraph 3.2.2 and 3.2.3 for Zinc Poured Sockets.

3.8.4 A rope to be placed in a longer length socket with an epoxy resin, then the end of the rope should be prepared in the manner described in paragraphs 3.8.5, 3.8.6, and 3.8.7 or in accordance with manufacturer's instructions.

3.8.5 Chalk mark the rope at a distance from the end equal to the length of the socket basket plus one rope diameter. Slide the socket onto the rope. The inside of the socket should first be cleaned with trichloroethene.

3.8.6 Seize the rope just below the chalk mark. Mount the rope in a vise, gripping it just below the seizing (Figure 3-38). Separate the strands down to the seizing and cut out any fiber core down to the seizing.

3.8.7 Separate the strands of an IWRC core for 1/3 of the length from the seizing. Unlay the rope strands to just over 1/3 of the length from the seizing (Figure 3-39). This procedure results in a Coke Bottle shape and is different from the broom shape of polyester resin or zinc poured terminations (Figure 3-40).

INSPECTION POINT: The Coke Bottle should be inspected to make certain it has been prepared correctly.

**CAUTION**

Petroleum distillate type solvents containing an oil fraction should never be used for cleaning of the rope end or socket. The

solvent should not come in contact with the resin mixture or improper curing may result.

3.8.8 The rope end should be briskly stirred in Varsol or some other grease solvent to remove most of the lubricant, using a brush to help in cleaning (Figure 3-41). Rinse the rope end in trichloroethene and let dry.

**NOTE**

An acid wash and a flux rinse is not required for resin poured sockets and may result in improper curing.

**CAUTION**

When sliding the socket onto the unlaidd end care must be taken not to redeposit lubricant in the socket or onto the cleaned wires.

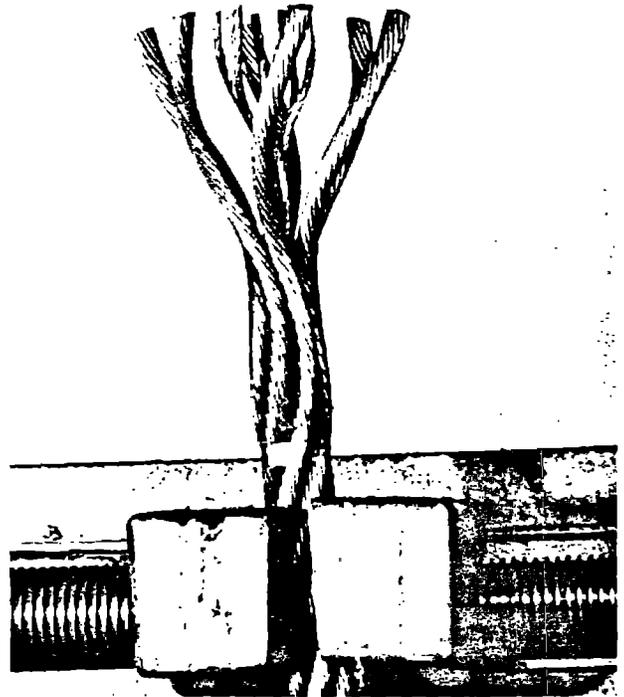


Figure 3-38. The "Coke Bottle" Shape of the Opened Wire Rope End.



Figure 3-39. The Core is Opened Up Before the Strands.

3.8.9 Slide the socket up to the seizing and grip rope in a vise at a point below the socket. Remove the seizing. Pull the socket onto the rope end, twisting the socket in the lay direction. When properly seated the wire ends should be flush with the inside top edge of the basket.

3.8.10 Suspend the socket vertically at a comfortable working height. Secure rope to prevent movement in relation to socket. Place the duct seal putty at the joint of the socket base and rope and below for a length of twice the rope diameter. Press the putty firmly into the strand valleys and against the base of the socket. Then using cloth or paper, squeeze the putty tight around the rope (Figure 3-42).

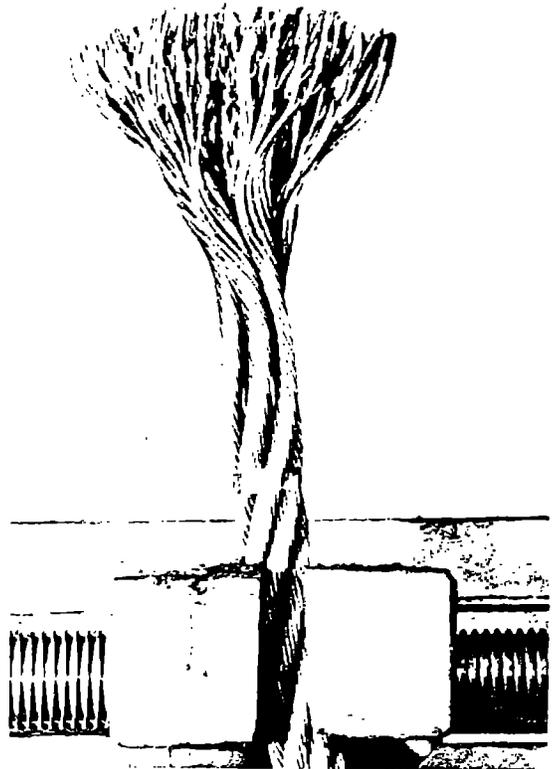


Figure 3-40. The Completed "Coke Bottle" Configuration.



Figure 3-41. Cleaning the Rope End with a Solvent.



Figure 3-42. Pressing the Seal Putty Firmly into the Strand Valleys to Prevent Leaking of Resin.



Figure 3-43. Heating the Socket Before Pouring the Resin.

3.8.11 Apply heat to socket to warm it and remove any moisture (Figure 3-43). If the working room or area temperature is below 22° C (72° F) heat the socket until it is hot to the touch. If the socket becomes too hot to even touch then let it cool down before pouring the resin mixture.

**WARNING**

Observe manufacturer's precautions concerning skin contact with resin.

3.8.12 Prepare the resin mixture in accordance with the manufacturer's instructions. The resin kits contain two parts which must be thoroughly mixed to ensure proper curing (Figure 3-44). The epoxy resin kits require adding a hardener part to the base

part. The polyester resin kits require adding a catalyst to the resin.

INSPECTION POINT: Check the temperature of the socket and reheat if necessary. Observe that resin is poured slowly into basket.

3.8.13 Pour the resin mixture in accordance with the manufacturer's instructions. In particular note the pot life, or length of time between mixing and when mixture has cured too much to be used. The resin mixture should be poured slowly down one side of the basket. This will avoid trapping air in the socket (Figure 3-45).

The resin mixture may be transferred from the manufacturer's container to a clean



Figure 3-44. Adding the Hardener to the Base.



Figure 3-45. Slowly Pouring the Resin into the Basket.



Figure 3-46. Completely Filled Basket with Only Small Pin Size Holes Showing in Surface.

paper cup to facilitate pouring. Do not use a styrofoam cup which may contaminate resin.

3.8.14 Completely fill the basket with resin, covering the ends of the wires. Only pin head size air bubbles should appear on the surface. Larger bubbles may be burst as they rise to the surface with a small piece of clean wire (Figure 3-46).

**INSPECTION POINT:** Examine the surface of the resin for air bubbles and make sure the basket is filled. Note the time and announce or mark the time when the termination can be moved.

3.8.15 Allow the termination to remain in the suspended position for at least one half hour. Consult the manufacturer's instructions for cure times and the use of heat to speed up the curing process. A heat assisted cure can develop the full breaking load of a Resin Poured Socket within one hour of pouring the mixture.

3.8.16 After the resin has cured remove the seal putty and lubricate the rope if necessary.

### 3.9 PREPARATION OF THIMBLE SPLICE WITH FOUR HAND TUCKS

#### NOTE

The four hand tuck splice described in the following is one of several which can be made.

3.9.1 Bend the wire rope around a matching size heavy duty thimble at the location desired. Hold in a splicer's vise. The splicer's vise may be oriented horizontally or vertically (Figure 3-47). Current preference is for vertical orientation with loop pointing down and the long rope and short rope point upward, long rope to the right. The long rope should be secured in some manner to the ceiling, and splicing will be facilitated if the long rope is untwisted a little before it is secured to the ceiling. All

instructions here apply to righthand lay rope. For lefthand lay rope, use the same steps but reverse the procedure. If a regular vise is used, securely bind the rope to the thimble with seizing wire.

3.9.2 The turn back length of the dead end of the wire rope, not including wire required to pass around the thimble, should be as given in Table 4.

3.9.3 Seize and cut the wire rope to the proper length. Remove seizing from short rope (dead end) and untwist the strands all the way to the thimble (Figure 3-48). The end of each strand is burned with an acetylene torch to weld the wires together, or seized. Preformed wire rope strands may not need to be seized.

3.9.4 In Figures 3-49 thru 3-67 the strands of the long rope (live end) are labelled A through F inclusive. The strands of the short rope are numbered 1 through 6 inclusive. Strand 1 is adjacent to and directly opposite Strand C at the point of the thimble.

3.9.5 Open the long rope for the first forming tuck by passing a marline spike between Strand C and D; through the center of the rope, three strands on each side of the marline spike, Strands C, B, A below the spike, and Strands D, E, F, and the core above the spike (Figure 3-49).

TABLE 4 TURNBACK LENGTH FOR THIMBLE SPLICE

Rope Diameter		Turnback Length	
in.	(mm)	ft.	(m)
1/4, 3/8	(6,10)	1	(0.305)
1/2	(13)	1-1/2	(0.457)
5/8, 3/4	(16,19)	2	(0.610)
7/8	(22)	2-1/2	(0.762)
1, 1-1/8	(25,29)	3	(0.914)
1-1/4	(32)	3-1/2	(1.067)
1-1/2	(38)	4	(1.219)
1-3/4	(44)	4-1/2	(1.372)
1-7/8	(48)	5	(1.524)
2	(51)	5	(1.524)

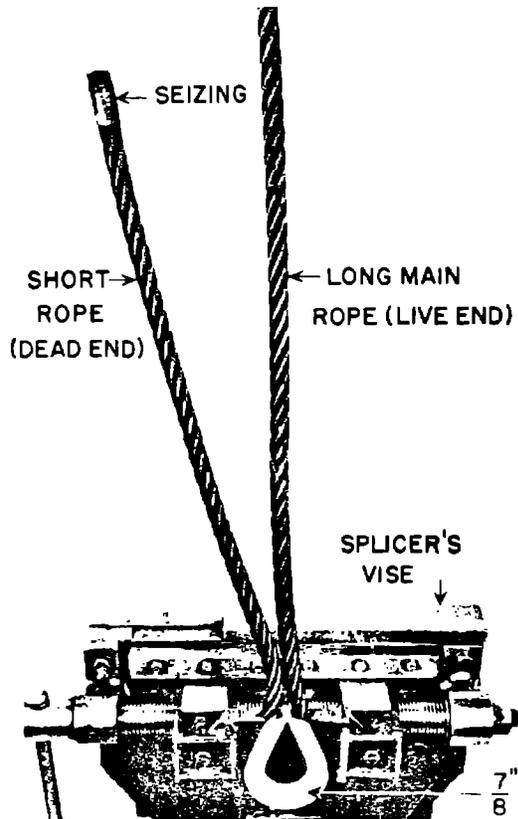


Figure 3-47. Mounting the Thimble and Rope Loop in Splicers Vice.



Figure 3-48. The Dead End is Opened Up, Exposing a Fiber Core Which Will Be Cut Off.

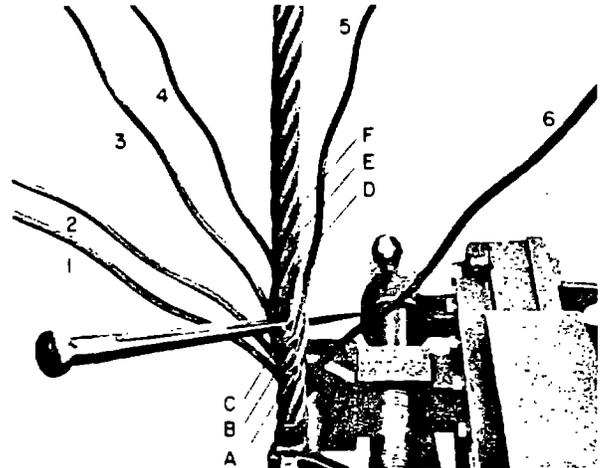


Figure 3-49. Opening the Long Part of the Rope for the First Forming Tuck.

3.9.6 Rotate the marline spike to the right so that it moves between the strands and away from the vise, and a quarter to a half turn. Make the first forming tuck by passing Strand 1 from the short rope around the long rope and through the hole created by the marline spike, between it and the vise; and in the direction that the spike is pointing (Figure 3-50). Pull Strand 1 tight, and rotate the marline spike back with the lay of the rope towards the vise (Figure 3-51). The spike carries Strand 1 with it. Seat Strand 1 as tightly as possible and remove the spike.

INSPECTION POINT: Check correctness of first tuck.

3.9.7 Insert the marline spike between Strands C and D again, and under Strands B and C of the long rope. Rotate the spike a quarter turn with the lay and wrap Strand No. 2 from the short rope around the long rope and through the opening caused by the spike on the thimble side and pull tight (Figure 3-52). Rotate the spike back with the lay towards the thimble, pulling Strand 2 tight and seat Strand 2 (Figure 3-53). Strand 2 now enters the long rope in the same location as Strand 1, but is tucked under only two strands of the long rope (B and C).

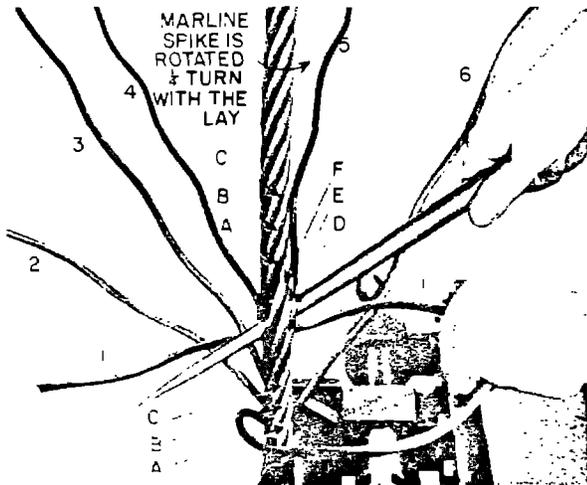


Figure 3-50. Passing Strand 1 Through the Hole Created by the Marline Spike.

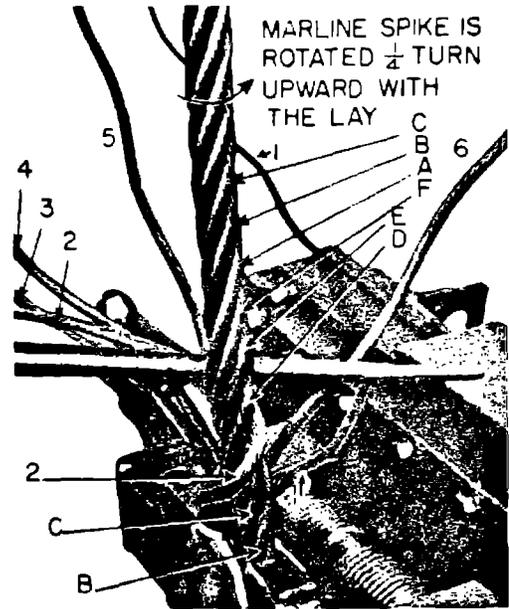


Figure 3-52. Passing Strand 2 Through the Hole Created by the Marline Spike.

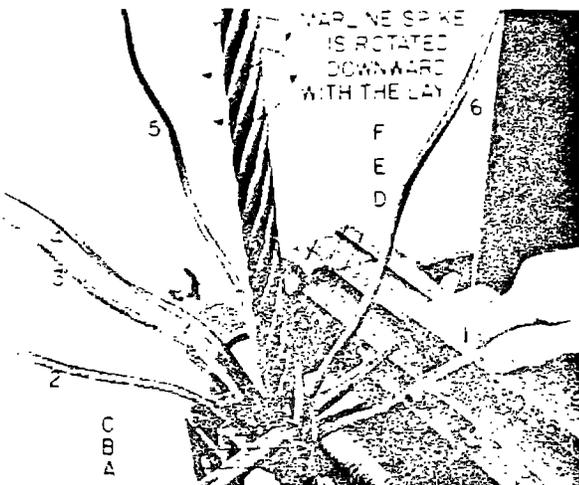


Figure 3-51. Pulling Strand 1 Tight as Marline Spike is Rotated Downward With Lay.

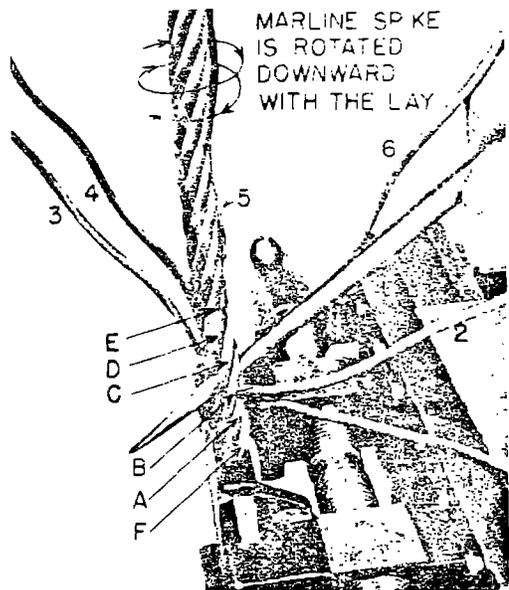


Figure 3-53. Pulling Strand 2 Tight as Marline Spike is Rotated Downward With Lay.

3.9.8 Insert the marline spike under Strand C of the long rope, rotate the spike a quarter turn with the lay and wrap Strand 3 from the short rope around the long rope and through the opening made by the spike on the thimble side of the spike (Figure 3-54). Pull Strand 3 tight and rotate spike back with the lay towards the thimble seating strand 3. This completes the forming tucks (Figure 3-55). Cut off core of short rope as short as possible.

3.9.9 Insert the marline spike under Strand D, rotate a quarter turn with the lay and tuck Strand 4 under Strand D, pull tight and seat by rotating the spike back towards the thimble. Strand 4 now rests above Strand 3, and between Strands C and D.

3.9.10 Insert the marline spike under Strand E, rotate one quarter turn with the lay and tuck Strand 5 under Strand E. Pull tight and seat by rotating spike back towards the thimble. Strand 5 is now located above Strand 4 and between Strands D and E.

3.9.11 Insert the marline spike under Strand F, rotate one quarter turn with the lay and tuck Strand 6 under Strand F, pull tight and seat by rotating spike back towards the thimble. Strand 6 is now above Strand 5 and between Strands E and F. This completes the first set of tucks for all strands (Figure 3-56).

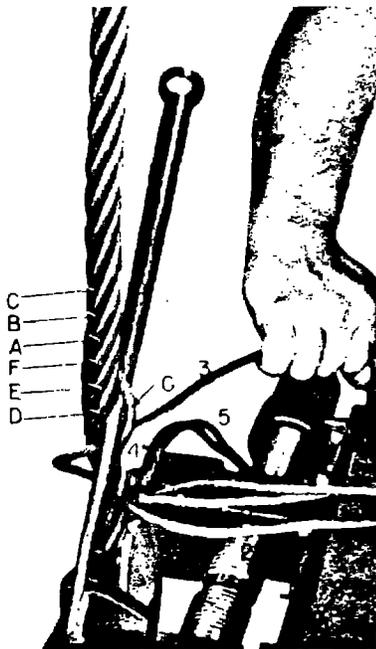


Figure 3-54. Passing Strand 3 Through the Hole Created by the Marline Spike.

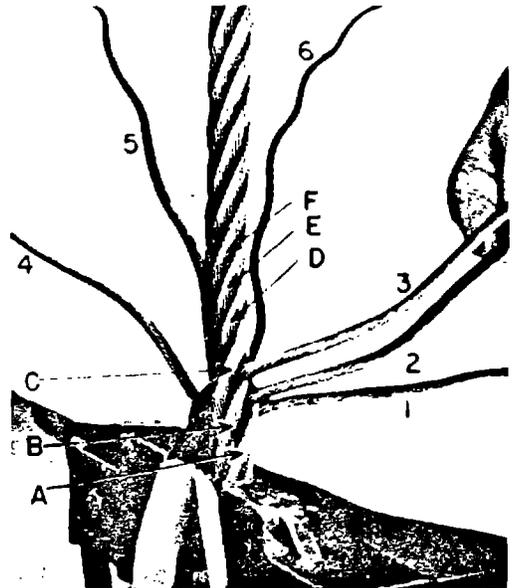


Figure 3-55. The Splice As It Appears After Completing the First Tuck for Strands 1, 2, and 3.

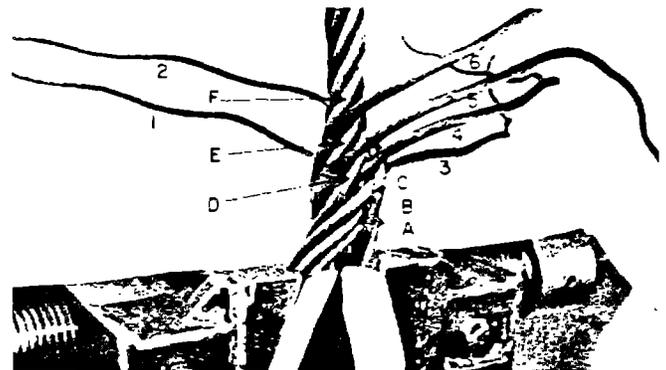


Figure 3-56. The Splice After Completing the First Tuck for All Six Strands.

3.9.12 The second set of tucks for the six strands are put into the splice in a manner similar to that of the first set of tucks, starting with Strand 1 (Figure 3-57). Insert the marline spike under Strand A, rotate a quarter turn with the lay and tuck Strand 1 under Strand A on the thimble side, pull tight and rotate marline spike back towards the thimble seating Strand 1 (Figures 3-58 and 3-59).

3.9.13 Repeat procedure of 3.9.12 above for Strand 2 tucked under Strand B, (Figures 3-60, 3-61, and 3-62) Strand 3 under Strand C, Strand 4 under Strand D, Strand 5 under Strand E, and Strand 6 under Strand F (Figures 3-63 thru 3-66). This completes the second set of tucks.

3.9.14 Repeat the procedure of 3.9.12 and 3.9.13 above, twice more in succession to form the third and fourth set of tucks (Figure 3-67).

INSPECTION POINT: Check that all tucks have been properly formed.

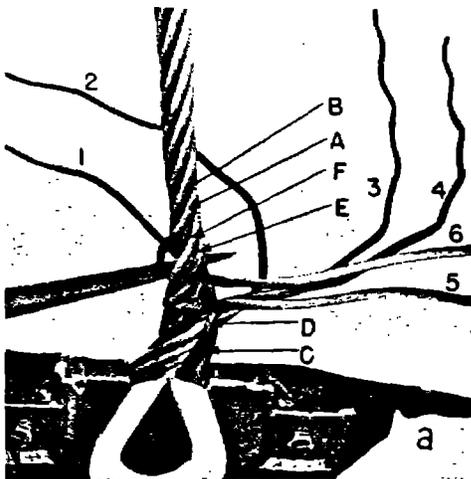


Figure 3-57. Starting Second Set of Tucks for Strand 1 by Inserting Marline Spike Under Strand A.



Figure 3-58. Passing Strand 1 Under Strand A.

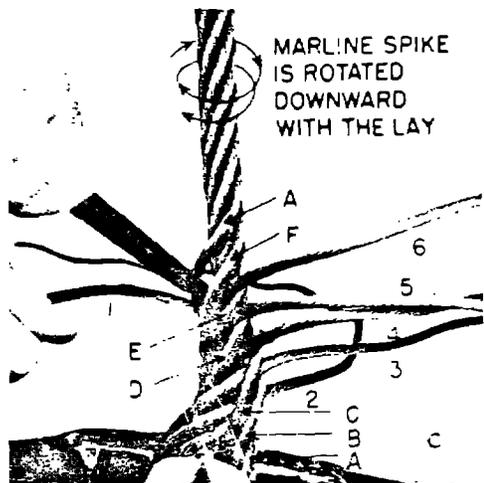


Figure 3-59. Pulling Strand 1 Tight as Marline Spike is Rotated Downward With Lay.

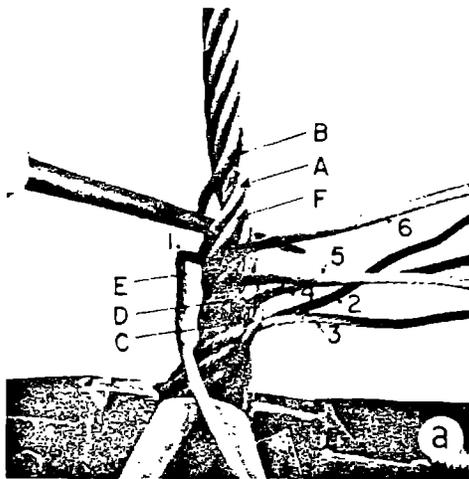


Figure 3-60. Starting Second Set of Tucks for Strand 2 by Inserting Marline Spike Under Strand B.

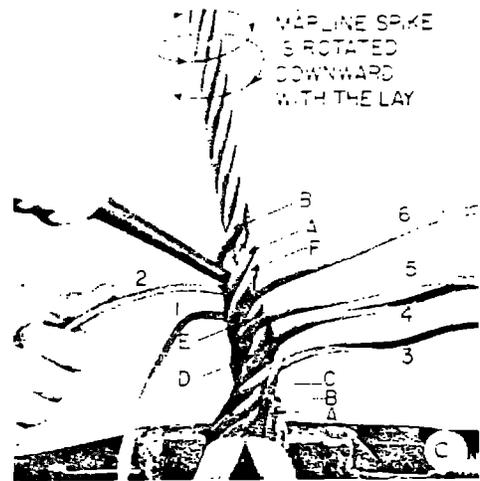


Figure 3-62. Pulling Strand 2 Tight as Marline Spike is Rotated Downward With Lay.

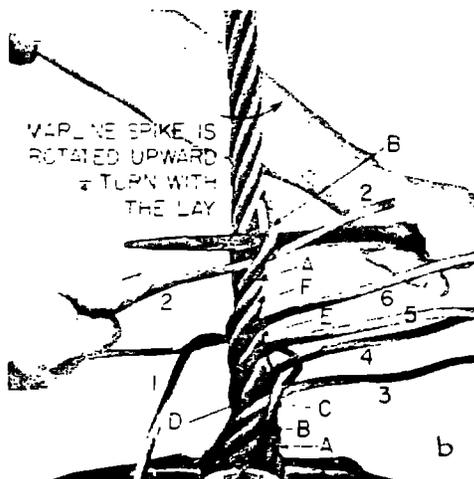


Figure 3-61. Passing Strand 2 Under Strand B.

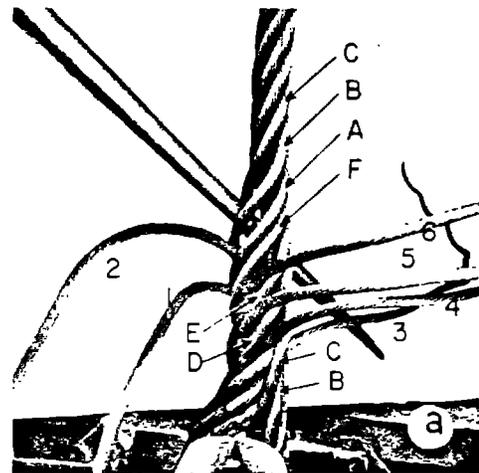


Figure 3-63. Starting Second Set of Tucks for Strand 3 by Inserting Marline Spike Under Strand C.

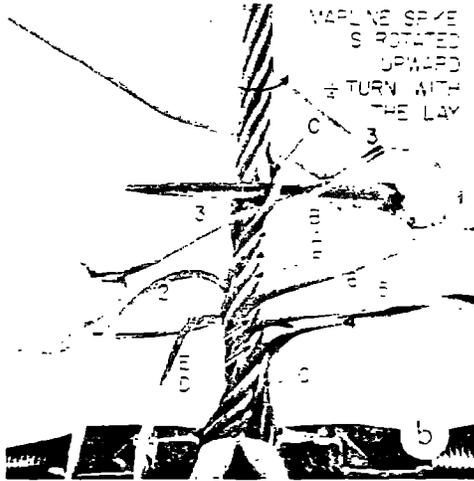


Figure 3-64. Passing Strand 3 Under Strand C.



Figure 3-66. The Splice After Completing the Second Set of Tucks for All Six Strands.

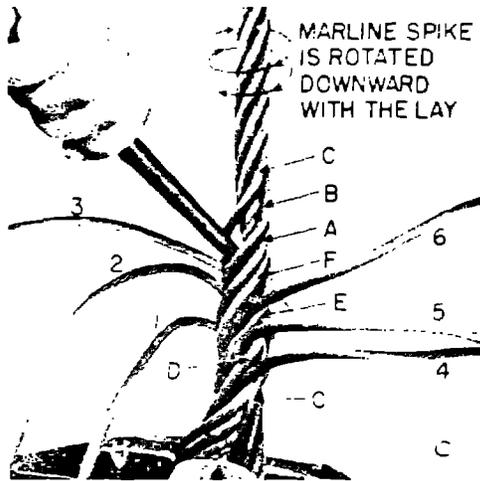


Figure 3-65. Pulling Strand 3 Tight as Marline Spike is Rotated Downward With Lay.

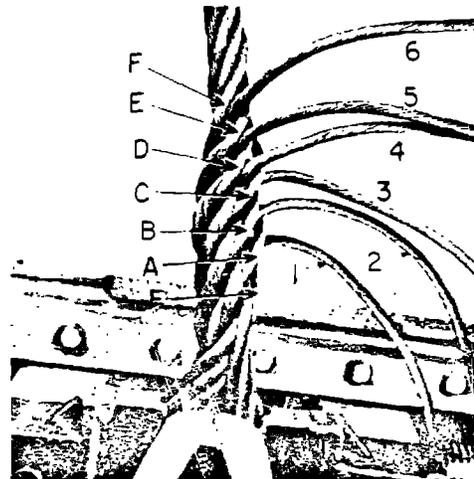


Figure 3-67. The Splice After Completing the Third Set of Tucks for All Six Strands.

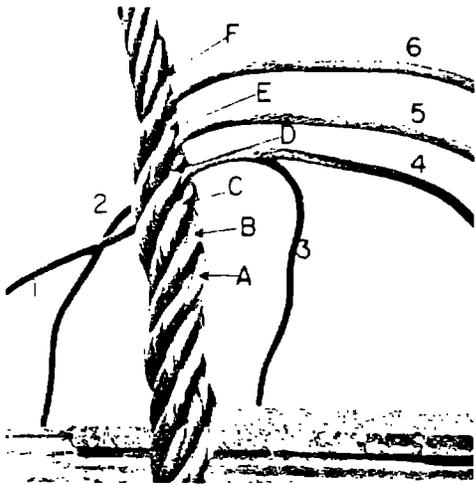


Figure 3-68. The Splice After Completing the Fourth Set of Tucks for All Six Strands.

3.9.15 Now the thimble splice is complete (Figure 3-68). Any irregularities in the shape of the splice can be smoothed out by tapping the splice with a 2-pound blacksmith's hammer against a solid flat surface.

3.9.16 Cut off the excess length of the protruding strands with large snippers (Figure 3-69).

3.9.17 The splice may be seized with wire, the size of the seizing wire determined by the diameter of the wire rope in use (Figure 3-70). Pass the marline spike under two strands of the long rope approximately one rope diameter away from the end of the seizing wire through the rope and curve or spiral it between strands to the thimble. Pull the seizing wire tight and with a seizing tool or the marline spike, wrap against the lay tightly until the ends of the cut strands are well covered, or if desired, seize all the way to the thimble (Figure 3-71). Twist the two ends of the seizing wire together, cut the seizing wire off short and tuck the twisted end between two strands.

3.9.18 If seizing is not desired, cut the strands off about a half-inch long and burn the ends with an acetylene torch to

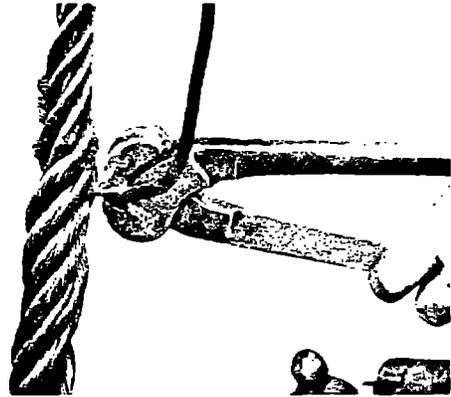


Figure 3-69. Large Nippers are Used to Cut Off Any Excess Lengths of the Protruding Strands.



Figure 3-70. Starting a Seizing on the Completed Splice.



Figure 3-71. Applying a Smooth and Tight Seizing to Prevent Hand Injuries from Wire Ends in Splice.

weld the wires together and to remove the sharp edges from the cut ends of the strand wires (Figure 3-72).

**INSPECTION POINT:** Inspector must be intimately familiar with the splice to detect errors in workmanship visually.

3.9.19 The loop splice without a thimble is made exactly the same as the thimble splice with the following exception:

Cut the rope to the proper length allowing for the length of the loop and the length of the short rope as given in Table 2.



Figure 3-72. The Completed Thimble Splice.

Measure back from the dead end the short rope length and starting at this point make a long (two rope diameter) seizing with the correct diameter seizing wire.

3.9.20 Bend the rope into a loop and place in a splicer's vise with the short rope to the left of the long rope.

3.9.21 Construct the loop splice exactly the same as the thimble splice, as outlined in paragraphs 3.9.3 through 3.9.18. The seizing described in paragraph 3.9.2 above may be removed.

## CHAPTER 4

### INSPECTION

4.0 Scope: Inspection as described in this chapter includes inspection during the fabrication process and inspection of the finished WRT, whether assembled in the shop or in the field, and ready for installation. Inservice inspection is not covered by this chapter.

4.1 Safety: WRT inspection is extremely important because many of the uses of wire rope such as elevators, cranes, drag lines and safety lines, are such that failure of a termination in service would cause a serious accident. Wire rope is manufactured under highly controlled processes and thus is uniform in quality. The rated breaking load, or Catalog Breaking Load, published by wire rope manufacturers is used as the basis for determining design loads. The working load is usually based on a design factor of 5, that is the working load is 1/5, or 20%, of the Catalog Breaking Load. Although this is normally considered adequate there are applications where the design factor is higher so that the working load may be less than 20% of the Catalog Breaking Load. Thus, there is a large factor designed into each wire rope application, but the weak link may be the termination unless assembly is followed by careful inspection.

4.2 Inspector: The inspector may be a well-experienced mechanic, a supervisor, or an individual who is separated from fabrication responsibility and is specially trained and experienced in inspection.

4.3 Inspector Qualifications: The qualifications of an inspector must include but are not limited to:

4.3.1 He must have an intimate knowledge of the fabrication or assembly process.

4.3.2 He must have experience in observing the quality of the finished product.

4.3.3 He must be able to enter the fabrication process at any point and check the operator's performance.

4.3.4 He must be able to measure some aspects of the finished with measurement devices.

4.3.5 He must have some understanding of statistical methods; random sampling, etc.

4.4 Inspection points: Chapter 3 of this manual details all of the fabrication and assembly procedures for the various WRTs considered. At selected points in the procedures, "INSPECTION POINT" identifies an inspection step to be performed while a step or a series of steps are in progress or at the completion of a particular step. This might be a mechanic checking himself or a mechanic checking a helper, or a supervisor or inspector making a routine or spot check.

4.5 Final Inspection: Upon completion of a termination and prior to shipment to the field, or if already in the field prior to installation, the WRT should be inspected. This may be a visual inspection, a measurement, or it may go as far as a proof test depending on end use, local practice, or regulations.

4.6 Visual Inspection: Human error can often be detected visually.

4.6.1 Hand splices should be correctly assembled, neat and uniform, and have the correct number of tucks.

4.6.2 The wedge socket shall be of the proper size for the wire rope and correctly assembled. The wedge shall be seated deep enough to permit unobstructed assembly with a mating part, and to avoid accidentally slipping out of the socket.

4.6.3 Pressed sockets and sleeves should be smooth, uniform in diameter, free from visual cracks. Die impressions are acceptable if there is no tearing of the metal.

4.6.4 Wire rope clips should be correctly installed, not too close to the end of the short rope, and torqued to specifications.

4.6.5 Thimbles where used should be of correct size for the wire rope in use, securely enclosed so that they will not fall out, and not distorted by handling or proof test.

4.6.6 Zinc Poured Sockets should have the seizings removed, the wires below the socket lubricated, and the top of the poured zinc should show a distinct depression.

4.6.7 The wire rope near the termination should not be damaged.

4.7 Measurement: All pressing operations rely on plastic flow of steel to grip the rope wires. The diameter of the fitting is reduced considerably to the die blocks by the pressure of the hydraulic press. The job is considered satisfactory when the correct Go Gage passes over the pressed fitting. This may be done by the

mechanic or helper on the job or the inspector at final inspection or both. If the inspector is a separate individual in the shop organization, he should have a separate set of Go Gages which he maintains and checks to standards periodically. If shop gages are used for inspection, it is the supervisor's responsibility to see that the gages are properly maintained and checked at regular intervals. Many Swaged Sockets have inspection holes provided. These should be used to determine whether the wire rope is properly inserted to the bottom of the socket hole.

#### 4.8 Proof Test:

4.8.1 Proof tests may be required on all WRT, on a certain percentage, or on a random sampling.

4.8.2 If required a proof test should be twice the design working load of the wire rope assembly, that is 40% of manufacturer's catalog breaking load. Higher proof tests may be specified in certain instances.

4.8.3 For proof tests the load should be applied slowly in a calibrated test machine or dynamometer.

## CHAPTER 5

### SKILL LEVEL REQUIREMENTS

5.0 General: The skill level required for fabrication or assembly of wire rope terminations varies somewhat depending on the termination used and the shop facilities available. Generally speaking, a termination made in a well equipped shop can be fabricated by a lower skilled operator than a termination assembled in the field with hand tools.

5.1 Skill Levels Defined: In order to identify skill levels the four common terms Laborer, Helper, Mechanic, and Supervisor are used. To avoid confusion, these terms are defined as follows:

5.1.1 Laborer: A laborer is assumed to have some experience working in an industrial environment, is used to heavy work, and has worked in and around many different trades, but never long enough in one trade to attain helper status. He can use some hand tools, operate simple machines, and follow simple instructions.

5.1.2 Helper: The helper mechanic has considerable experience working with and under the supervision of a mechanic in a specific trade. He should be able to use hand tools with skill, operate machines, understand assembly sequences, and follow instructions exactly.

5.1.3 Mechanic: The mechanic has much industrial experience in a given trade. In addition to having qualified as a helper and mastered the skills of his trade, the mechanic can be expected to set up and operate machines, keep an assembly process moving, supervise the work of one or more helpers, and perform some inspection functions.

5.1.4 Supervisor: The shop supervisor is in charge of all operations in the shop. He plans and schedules work, supervises the work in process and is responsible for inspection of the finished product. He may have other such responsibilities as shop safety, material flow, records and time-keeping.

5.2 Psychomotor Skills: Working with wire rope is a "brute force" type of operation and as such the psychomotor skills involved are not demanding. Some of the procedures require such skills as listed below. It can be expected that all psychomotor skills will be mastered by all skill levels of helper and above. At the laborer skill level, it will be necessary to teach some of the less obvious psychomotor skills, however, none are so difficult that they cannot be easily mastered.

5.2.1 Measurements with ruler, steel tape, calipers in the English (foot, pound, second) system or Metric (meter, kilogram, second) system.

5.2.2 Temperature measurement with thermometer, temp sticks, etc., in Fahrenheit or Celcius.

5.2.3 Judging by eye the amount of closure of die blocks, one-third closed, one-half closed; and rotation one-quarter turn, one-eighth turn.

5.2.4 Numbering and lettering wire rope strands to keep track of them while making a splice.

5.2.5 Reading dials and gages such as foot-pounds on a torque wrench, air or hydraulic pressure, or pounds force on a dynamometer.

5.3 Skill Levels Required For Assembly of WRTs: Considering the termination procedures of Chapter 3 and the psychomotor

skills defined in this chapter, the skill levels required for the various terminations are tabulated in Table 5. It should be noted that the supervisor is not considered in this table. He may provide much of the assistance and training, but he will not perform these tasks on a production basis.

TABLE 5 SUGGESTED SKILL LEVELS FOR ASSEMBLY OF WIRE ROPE TERMINATIONS

SKILL LEVEL	SHOP FABRICATION ONLY			SHOP OR FIELD FABRICATION				
	SWAGED SOCKET	TURN BACK LOOP W/ SLEEVE AND THIMBLE	FLEMISH LOOP	ZINC POURED SOCKET	WEDGE SOCKET	THIMBLE SPLICE	U-BOLT CLIP	RESIN POURED SOCKET
LABORER	2	3	4	3	2	4	2	3
HELPER	1	2	3	2	1	3	1	2
MECHANIC	1	1	1	1	1	1	1	1

- KEY:
1. Can be expected to perform without assistance or instruction.
  2. Can be expected to perform with minor instruction.
  3. Can be expected to perform with instruction and assistance.
  4. Can be expected to perform with prolonged instruction and practice.

## APPENDIX A

### GLOSSARY

- BASKET (SOCKET)** The conical bore of a socket into which the opened up end of the rope is inserted and secured with zinc or some other binding material.
- BREAKING LOAD** (1) Ultimate or Actual: The load required to pull a wire, strand, or rope to destruction. (2) Aggregate: The sum of the individual breaking loads of all wires in a strand or rope. (3) Catalog: The nominal breaking load of a rope or strand guaranteed by the manufacturer.
- BRIGHT WIRE** Wire made of iron or carbon-steel and not galvanized, aluminized, or otherwise coated.
- BROOMING** The unlaying and straightening of strands and wires in the end of a wire rope, usually in preparation for socketing.
- CLIP (U-BOLT CLIP)** A strand or rope fitting comprised of a malleable iron or forged steel saddle piece (grooved to suit rope lay) and a U-bolt by which the clip is held to two parallel ropes. Primarily used to anchor the dead end of a rope to the live side to form a loop.
- CLOSED SOCKET** A socket in which the basket and the curved bail are connected.
- CONSTRUCTION** Term used to describe the design of a rope, covering the number of strands, number and arrangement of the wires in the strands, direction and type of lay, grade of wire material, and type of core.
- CORE** The axial member of a wire rope about which the strands are laid. It may consist of wire strand, wire rope, synthetic or natural fiber, or solid plastic.
- DEAD END (OR PART OF A ROPE)** Portion of an operating rope which carries no load. Often refers to the nonactive part of a rope protruding from a loop termination.
- DESIGN FACTOR** The ratio of the catalog breaking load to the maximum load during operation. Standards are often set by statutory bodies for minimum design factors. Replaces FACTOR OF SAFETY -- See SAFE WORKING LOAD (SWL).
- DROSS** Impurities that rise to the surface of molten zinc.
- EXTRA IMPROVED PLOW STEEL** Highest grade of wire rope (EIPS).
- EYE SPLICE** A loop formed in the end of a rope by tucking the strand ends under or around the strands of the live part of the rope. A thimble is often used in the loop.
- FILLER WIRES** Small auxiliary wires in a strand for spacing and positioning of other wires.
- FLEMISH EYE** A type of eye loop made by separating the rope end into two groups of strands and then relaying the strands to form a loop. Used with and without a thimble in the loop, but always with a tapered sleeve pressed around the dead and live parts of the rope.
- GALVANIZED ROPES, STRANDS, AND WIRES** Ropes, strands, and wires in which the individual wires are coated with zinc.
- GRADES: ROPE** Classification of wire rope according to wire breaking strength per unit area. In order of increasing strength the various rope grades are "iron", "traction", "improved plow steel", and "extra-improved plow steel".

IMPROVED PLOW STEEL Next to highest grade of wire rope (IPS).

INDEPENDENT WIRE-ROPE CORE (IWRC) The supporting center of a wire rope, which is itself a smaller diameter wire rope.

LANG-LAY ROPE Rope in which the direction of lay of the wires in the strands is the same as the direction of lay of the strands in the rope. Sometimes called ALBERT'S LAY.

LAY The helical shape that the strands take in the rope. Lay length is the distance required for a strand to make one turn around the rope. Lay may be right hand (the same as the threads of a right hand screw), or left hand. If the wires of the strands and the strands of the rope are both of the same lay, the construction is called Lang Lay. If the two lays are opposite, the construction is called Regular Lay.

LIVE (PORTION OF A ROPE) The portion of an operating rope which carries the load. Usually applied to a rope that is not cut at the termination, but passes through it, leaving an unloaded (dead) rope section.

LONG SPLICE A splice which joins two ropes end-to-end and which involves about twice the rope length of a short splice.

LOOP SPLICE An eye splice without a thimble.

MARLINE SPIKE A pointed metal spike, used to separate strands of rope in splicing.

MOLLY HOGAN See FLEMISH EYE.

MURIATIC ACID A liquid chemical used with water to etch the surface of steel wires when preparing a Zinc Poured Socket.

OPEN SOCKET Wire-rope fitting with two integral lugs through which a pin connection is made to the load or anchorage.

PITCH (1) Length of Lay: The distance parallel to the axis of the rope (or strand) in which a strand (or wire) makes one complete helical revolution about the core (or center). (2) The spacing of grooves on a drum.

POLYPROPYLENE FIBER CORE A plastic rope core made of many polypropylene filaments.

POT LIFE Time in minutes which a resin mixture remains in a condition to be poured. After this time the mixture will have begun to harden and must be scrapped.

POURED SOCKET See ZINC POURED SOCKET.

PREFORMED WIRE ROPE A wire rope in which the strands and wires receive a final helical shape before closing that matches the lay and set of the finished rope.

PRESSED SLEEVE AND THIMBLE See TURN BACK LOOP WITH SLEEVE AND THIMBLE.

PROOF-LOADING (Proof Testing) Preliminary loading of a rope to the maximum expected working load to test the load bearing capability of the rope and associated equipment. This proof load can sometimes be twice the Safe Working Load.

RATED CAPACITY The Safe Working Load of a rope or termination. Usually less than or equal to 1/5 the Catalog Breaking Load of the rope involved.

REEVING The threading of a wire rope through a block, sheave, or other parts of a wire-rope system.

REGULAR-LAY ROPE A rope in which the lay of the wires in the strand is opposite the lay of the strand in the rope.

RESIN SOCKET An end fitting attached to a rope by pouring a thermosetting resin (epoxy or polyester) into a cavity around the opened end of a rope, and allowing the resin to cure.

**RIGHT LAY** The direction of a strand or wire helix corresponding to that of a right-hand screw thread.

**SADDLE** That part of a U-Bolt Clip that bears against the live side of the rope. Grooved to fit the external surface of the rope, it is fastened to the U-Bolt with nuts. Also called a bridge.

**SAFE WORKING LOAD** The maximum load on the rope during operation. SWL equals the Catalog Breaking Load divided by the Design Factor.

**SEALE STRAND CONSTRUCTION** A strand with uniformly sized wires with the same number of uniformly sized but smaller wires in the inner layer(s).

**SEIZE** To bind a rope or strand securely with annealed strand or wire. Also, to secure by wire two parallel portions of rope.

**SEIZING** (1) The annealed wire or strand used to seize a rope. (2) The completed wire wrapping itself.

**SHELF LIFE** The number of months a material, such as resin, can be stored before using it. After this time the material must be scrapped.

**SHORT SPLICE** A splice used for attaching two rope ends together. See **SPLICING**.

**SLEEVE** A type of pressed fitting usually employed in the formation of a loop or eye in the end of a wire rope.

**SOCKET** A wire rope termination fitting, one end of which has a long axial cavity to receive the end of the wire rope. The socket may then be squeezed down onto the wire rope (swaged socket) or may be filled with molten metal or synthetic resin.

**SPELTER SOCKET** See **ZINC Poured Socket**.

**SPLICING** Interweaving a rope end into a rope section or another rope end to form a loop termination (**EYE SPLICE**) or a longer or circular rope (**ENDLESS SPLICING**).

**STRAND CORE** A wire strand used as the core of a rope. Sometimes called a **WIRE STRAND CORE (WSC)**.

**SWAGED SOCKET** A tubular steel or alloy fitting sized to accommodate one or more parts of rope or strand. The fitting is applied by squeezing it onto the rope, usually in a press.

**TERMINATION** Any device or process applied to the end of a wire rope.

**THIMBLE** A grooved ring (usually teardrop-shaped) used to fit in a loop of a rope as protection from chafing and to provide support for the rope in the loop.

**THIMBLE SPLICE** A termination made by forming a wire rope loop around a thimble and then splicing (4 or 5 hand tucks) the dead end into the live part of the rope.

**TRICHLOROETHENE** A liquid chemical used as a solvent to clean lubricant from wire rope.

**TUCK** In splicing, the passage of a strand from a rope into or through another section of rope.

**TURN BACK LOOP WITH SLEEVE AND THIMBLE** A termination made by forming a wire rope loop around a thimble and then pressing a metal sleeve around the live and dead parts of the rope.

**U-BOLT CLIP** A clip consisting of a U-bolt and a saddle or bridge which is fastened to the bolt with nuts.

**VALLEY** The crevice between strands or between wires in a wire rope.

WEDGE SOCKET Wire-rope fitting in which the rope is secured with a wedge inside the socket.

WIRE Single continuous length of metal drawn from a rod. May be "round" in cross section or "shaped" into ovals, triangles, helices, etc.

WIRE ROPE A number of wire strands laid helically about an axial core.

WIRE-STRAND CORE See STRAND CORE.

WORKING LOAD The load that a rope is designed to carry in a particular service. See SAFE WORKING LOAD (SWL).

ZINC AMMONIUM CHLORIDE A chemical in pellet or powder form used with water to deposit a zinc flux on the surface of steel wires when preparing a Zinc Poured Socket.

ZINC Poured SOCKET An end fitting having a conical basket into which the broomed end of a rope is seated. Molten zinc is poured into the basket and secures the rope when it solidifies.

SELECTION AND INSPECTION GUIDE FOR WIRE ROPE TERMINATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES

by

ENGINEERING SERVICES COMPANY  
10916 Middleboro Dr., Damascus, Maryland 20750

Final Report

Contract No. H0166079  
Wire Rope Terminations

2

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16. Abstract  This guide considers only nine of the many wire rope terminations used in the mining industry so use of the information presented for terminations not specifically addressed can be done, but with some risk. The nine terminations considered are: Flemish Loop with Steel Sleeve & Thimble, Flemish Loop with Steel Sleeve, Wedge Socket, Swaged Socket, Turn Back Loop with Aluminum Sleeve & Thimble, Thimble Splice with Four Tucks, U-Bolt Clip with Thimble, Zinc Poured Socket, and Epoxy Resin Poured Socket. The guide uses pull test data, axial fatigue test data, and data on sensitivity to poor workmanship, to rank the nine terminations with respect to these performance measures. A selection procedure is suggested and illustrated with an example. Failure data is used to identify the common modes of failure of each termination and so help the inspector direct his attention to the likely location for a failure and describe what he should be looking for. The data on which this guide is based is included so that as new data becomes available, the ranking order can be adjusted accordingly.					
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## FOREWORD

This report was prepared by Engineering Services Company, Damascus, Md. under USBM Contract number H0166079. The contract was initiated under the Metal & Non-Metal Mine Health & Safety Program. It was administered under the technical direction of the Pittsburgh Mining & Safety Research Center with Edwin Ayres acting as Technical Project Officer. Frank Naughton was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September 1976 to August 1978. This report was submitted by the authors on August 10, 1978.

The assistance and cooperation of the subcontractors on this project is acknowledged with gratitude. The hospitality of mining personnel during the mine site visits is hopefully repaid by information in this report that may improve the safety of mine workers. The informal participation of several wire rope manufacturers and manufacturers of wire rope terminations is also acknowledged. Finally, a word of thanks to the mining consultant on this project, Mr. Wallace Barlow, who arranged for and participated in the mine site visits.



## 1.0 WIRE ROPE TERMINATIONS CONSIDERED

This guide considers only nine of the many Wire Rope Terminations (WRTs) used in the mining industry. With some degree of risk the guide may be used for WRTs not specifically considered, but which are similar in construction and operation to one of the nine described in this guide. Use of the 51 mm (2 in.) diameter data for larger diameters also introduces some risk. Since the names and assembly procedures of WRTs are not yet standardized it will first be necessary to illustrate them, name each WRT, and briefly describe how it is formed or attached to a rope. As an aid to using the guide each WRT is assigned a number which will correspond to the order in which the WRTs are described.



1. FLEMISH LOOP WITH STEEL SLEEVE & THIMBLE



The rope strands are divided into two equal parts which are bent to form a loop and laid back into each other. A thimble is placed inside the loop and a steel sleeve is pressed around the section where the dead end is rolled into the live part of the rope.

2. FLEMISH LOOP WITH STEEL SLEEVE



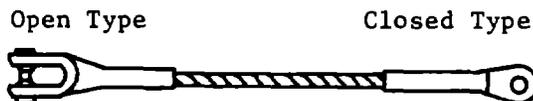
Assembled like WRT Type 1 above without the use of a thimble.

3. WEDGE SOCKET



The rope is passed through the base of the socket and turned away from the lugs to form a loop. The wedge is inserted and the loop is pulled tight.

4. SWAGED SOCKET



The rope is inserted to the bottom of the socket cavity and the socket is pressed on the rope.

5. TURN BACK LOOP WITH ALUMINUM SLEEVE & THIMBLE



The rope is formed into a loop around the thimble and an aluminum sleeve is pressed around the section where the dead and live parts of the rope are in contact.



6. THIMBLE SPLICE WITH FOUR TUCKS



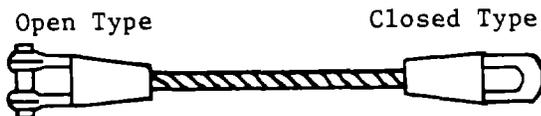
The rope is formed into a loop around the thimble then a four tuck splice is made to join the dead part of the rope to the live part.

7. U-BOLT CLIP WITH THIMBLE



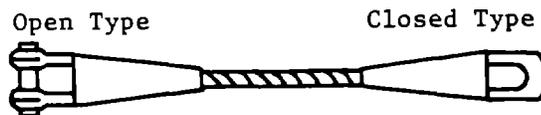
The rope is formed into a loop around the thimble and U-Bolt Clips are clamped around the live and dead parts of the rope.

8. ZINC Poured SOCKET



The rope is opened, cleaned and treated, and inserted into a RR-S-550 socket. Molten zinc is poured into the socket to hold the rope in the socket once the zinc has congealed.

9. EPOXY RESIN Poured SOCKET



The rope end is opened, cleaned, and inserted into a proprietary long tapered socket. An epoxy resin is poured into the socket and holds the rope in the socket after the resin has cured.



## 2.0 HOW TO USE THE GUIDE

This publication is not a handbook, but a guide based on information gathered from mine site visits and laboratory testing of nine different wire rope terminations (WRT). This guide is to be used to select a WRT for some application and to inspect a WRT in the field and decide whether replacement is required.

2.1 To use the guide to select a WRT one must first know the application such as one of the representative applications listed below.

### Surface Mining

Dragline Hoist	Driller Hoist
Dragline Rope	Shovel Boom Hoist
Boom Support	Shovel Bucket Hoist
Sled Haul Line	Shovel Hoist
Hand Rail	Shovel Crowd & Retract
Boom Hoist	Boom Suspension

### Underground Mining

Conveyor Roller Support	Haulage Ropes
Brake Car Hoist	Car Unloader
Shaft Hoist	Elevator Hoist
Balance Ropes	

### General Mining

Car Retarder	Railroad Car Haulage Rope
Slings	Aerial Tramways

2.2 The load on the WRT from the application can generally be labelled as mainly static (constant), or as dynamic (varying or changing). If the load is considered to be static then the three top ranked WRTs are selected from Table A, "Rank Order of Terminations with Respect to True Efficiency" found in section 3.0 of this guide along with two other tables used in the selection process. If the load is considered to be dynamic then the three top ranked WRTs are selected from Table B, "Rank Order to Terminations with Respect to Service Life." In entering either of the above tables use the rope diameter column closest to the diameter of the rope to be used on the application. The 51 mm (2 in.) column can also be used for rope diameters greater than those considered, recognizing that some risk is involved in such an extrapolation.



If the three WRTs were selected from Table A, then of these three retain only the two WRTs with the highest rank based on Table B. Similarly, if the initial three WRTs were selected from Table B, then retain only the two WRTs with the highest rank based on Table A. The user must next decide which of the two assembly conditions identified in Table C exists at the mine site. Then, of the two WRTs remaining in the initial selection, eliminate the WRT with the lowest rank based on Table C, "Terminations Ranked in Order of Increasing Sensitivity to Poor Workmanship." The remaining WRT is then evaluated against other operating conditions at the mine site, and a decision is made to use this WRT or to reject it. If the WRT is rejected, then return to Table A or B, ignoring the rejected WRT. The procedural steps are outlined in Section 3.0 which also contains Tables A, B, and C.

2.3 To use the guide to inspect a WRT in the field and decide whether replacement is required, Section 4.0 identifies the more common failure locations and characteristics. An inspection procedure is suggested as well as a replacement criteria which is considered safe, yet gets the most use of the WRT.



### 3.0 SELECTION OF A WRT

Using Tables A, B, and C of this section follow the steps listed below to select a WRT for your application.

1. Decide if load condition is primarily a static one or a dynamic one.
2. If the former case holds, then select under the closest rope diameter the top three WRTs as ranked with respect to TE.
3. If the latter case holds, then select under the closest rope diameter the top three WRTs as ranked with respect to SL.
4. If the top three WRTs were selected on the basis of TE, retain the two WRTs with the highest rank based on SL.
5. If the top three WRTs were selected on the basis of SL, retain the two WRTs with the highest rank based on TE.
6. Decide which of the two assembly conditions identified in Table C exist at the mine site.
7. Of the two WRTs remaining in the initial selection, eliminate the WRT with the lowest rank based on sensitivity to poor workmanship.
8. The candidate WRT should then be evaluated for compatibility with other operating conditions.
9. If the candidate WRT is acceptable it is designated the WRT to use.
10. If the candidate WRT is rejected, then return to Step 2 or 3 ignoring the initial candidate and repeat the procedure.

3.1 The following is an example of the above selection procedure for a Boom Suspension system with a 25 mm (1 in.) rope.

1. Load is primarily static.
2. Select WRT Types 9, 8, and 4.
3. N/A.



4. Retain WRT Types 4 and 9.
5. N/A
6. Skilled Workers or Inspection are available.
7. Eliminate WRT Type 9.
8. WRT Type 4, the Candidate WRT is compatible with other operating conditions.
9. WRT Type 4, Swaged Socket, is the designated one to use.

Suppose that in the above example it was found that there were no Swaged Sockets available in stock. One would then return to Step 2 in the selection procedure to find a new WRT.

2. Select WRT Types 9, 8, 1, 5, and 7.
3. N/A
4. Retain WRT Types 9 and 1.
5. N/A
6. Skilled Workers or Inspection still available.
7. Eliminate WRT Type 1.
8. WRT Type 9, the Candidate WRT is compatible with other operating conditions.
9. WRT Type 9, the Epoxy Resin Poured Socket is the designated one to use.



TABLE A

RANK ORDER OF TERMINATIONS  
WITH RESPECT TO TRUE EFFICIENCY

Rank	Rope Diameter mm (in.)				
	13 (1/2)	19 (3/4)	25 (1)	38 (1 1/2)	51 (2)
I	9	9	9	4	8
II	4	1	8	8	4
III	5,8	2,7	4	1	9
IV	2	4	1,5,7	7,9	7
V	1	5	2	2,5	5
VI	3	8	3	6	2
VII	7	6	6	3	1
VIII	6	3	-	-	6
IX	-	-	-	-	3

TABLE B

RANK ORDER OF TERMINATIONS  
WITH RESPECT TO SERVICE LIFE

Rank	Rope Diameter mm (in.)				
	13 (1/2)	19 (3/4)	25 (1)	38 (1 1/2)	51 (2)
I	4	9	4,9	4	4
II	1	4	1	7	9
III	9	1	5	5	7
IV	2	2	3	2	1
V	5	5	7	1	3
VI	6	7	6	8,9	5
VII	8	8	8	3	6
VIII	3	3	2	6	8
IX	7	6	-	-	2

TABLE C

TERMINATIONS RANKED IN ORDER OF  
INCREASING SENSITIVITY TO POOR WORKMANSHIP

Rank	Termination Method	
	With Skilled Workers or Inspection	With Unskilled Workers or No Inspection
I	7	3
II	8	4
III	4	7
IV	5	1
V	9	2
VI	6	5
VII	3	6
VIII	1	9
IX	2	8

## WIRE ROPE TERMINATIONS

- 1 Flemish Loop with Steel Sleeve & Thimble
- 2 Flemish Loop with Steel Sleeve
- 3 Wedge Socket
- 4 Swaged Socket
- 5 Turn Back Loop with Aluminum Sleeve & Thimble
- 6 Thimble Splice with Four Tucks
- 7 U-Bolt Clip with Thimble
- 8 Zinc Poured Socket
- 9 Epoxy Resin Poured Socket



#### 4.0 INSPECTION OF A WRT

4.1 The impending failure of a WRT can be anticipated and a timely replacement made if inspection is frequent enough, is directed to the common failure location, and the characteristics of the impending failure are recognized. The most common failure location and description are given in Table D "Location and Features of Common WRT Failures" for the nine WRTs considered. Typical WRT failures are illustrated in this section to familiarize new inspectors and an inspection procedure is suggested below. When the inspection finds cracks in the pressed sleeve or socket body, or ten (10) broken wires in the adjoining rope, the WRT should be replaced. The replacement criteria of ten (10) broken wires in the adjoining rope is a conservative rule based on the twenty (20) broken wires used for the axial fatigue tests on which this guide is based. Except for the U-Bolt Clip with Thimble WRT, these ten broken wires will be found in the first rope lay measured from the base of the WRT. These wires will have broken under axial fatigue loading. The above criteria is not the same as that specified by the Code of Federal Regulations, Title 29, Part 1910.184(f)(5)(i). This criteria requires that a wire rope sling be removed from service when it has ten (10) broken wires distributed randomly in one rope lay, or five (5) broken wires in one strand in one rope lay. These wire breaks may be due to reversed bending in the gage area of the sling and do not necessarily reflect on the condition of the WRT.

#### 4.2 Suggested Inspection Procedure

##### FLEMISH LOOP WITH STEEL SLEEVE & THIMBLE

Examine the thimble for cracks or severe deformation. Either of these conditions require inspection of the wires in the crown of the loop. Also examine the wires at the base of the steel sleeve by bending the rope from side to side and twisting the rope open.

##### FLEMISH LOOP WITH STEEL SLEEVE

Examine the wires in the crown of the loop, and at the base of the steel sleeve by bending the rope from side to side and twisting the rope open.



## WEDGE SOCKET

Examine the socket for cracks and notice whether the position of the wedge is deep enough in the socket to retain the rope. Examine the wires at the base of the socket by bending the rope from side to side and twisting it open.

## SWAGED SOCKET

Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.

## TURN BACK LOOP WITH ALUMINUM SLEEVE & THIMBLE

Examine the sleeve for cracks and the thimble for cracks or severe deformation. If the thimble is damaged examine the wires in the crown of the loop. Examine the wires at the base of the sleeve by bending the rope from side to side and twisting the rope open.

## THIMBLE SPLICE WITH FOUR TUCKS

Examine the thimble for cracks or severe deformation and if either exists, examine the wires in the crown of the loop. Examine the wires in the splice area from the base of the thimble to the end of the splice. Use a marline spike or a splicer's dagger to separate the strands. Do not pull on the strands or otherwise shift them from their seated position.

## U-BOLT CLIP & THIMBLE

Examine the thimble for cracks or severe deformation and if either exists, examine the wires in the crown of the loop. Examine the wires at the clip furthest from the thimble by removing the clip and then remounting it. Verify that the torque on the nuts agrees with those values given here or those values used by the assembler.

<u>Dia. mm (in.)</u>	<u>Torque joules (ft. lbs.)</u>
13 ( $\frac{1}{2}$ )	88 (65)
14 ( $\frac{9}{16}$ )	129 (95)
16 ( $\frac{5}{8}$ )	129 (95)
19 ( $\frac{3}{4}$ )	177 (130)
22 ( $\frac{7}{8}$ )	306 (225)
25 (1)	306 (225)
28 (1- $\frac{1}{8}$ )	306 (225)
32 (1 $\frac{1}{4}$ )	490 (360)
35 (1- $\frac{3}{8}$ )	490 (360)
38 (1 $\frac{1}{2}$ )	490 (360)
41 (1- $\frac{5}{8}$ )	585 (430)
44 (1- $\frac{3}{4}$ )	802 (590)
51 (2)	1020 (750)



ZINC Poured SOCKET

Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.

EPOXY RESIN Poured SOCKET

Examine the socket for cracks, removing any galvanizing film if necessary. Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.



TABLE D

LOCATION AND FEATURES OF  
COMMON WRT FAILURES

Termination Type	Failure Location	Characteristic Features
Flemish Loop with Steel Sleeve & Thimble	Base of Steel Sleeve	Broken wires
Flemish Loop with Steel Sleeve	Crown of Loop	Broken wires
Wedge Socket	Base of Socket	Broken wires on live rope
Swaged Socket	Base of socket & body of rope	Broken wires
Turn Back Loop with Aluminum Sleeve & Thimble	Sleeve body Base of Sleeve	Cracks Broken wires
Thimble Splice with Four Tucks	Entire length of splice	Broken wires
U-Bolt Clip with Thimble	Clip closest to main rope	Broken wires on live rope
Zinc Poured Socket	Base of socket	Broken wires
Epoxy Resin Poured Socket	Socket body Body of rope	Cracks Broken wires



Illustrations of WRT Failures



Broken strands and cracked thimble on a Flemish Loop with Steel Sleeve & Thimble.



Broken wires in crown of loop on a Flemish Loop with Steel Sleeve & Thimble where thimble became deformed.



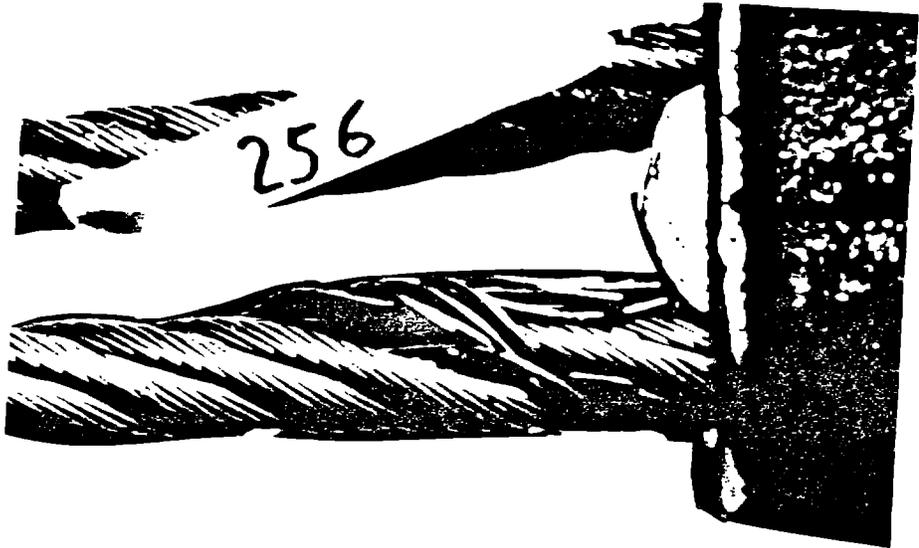
Broken wires on outside of crown of loop on a Flemish Loop with Steel Sleeve .



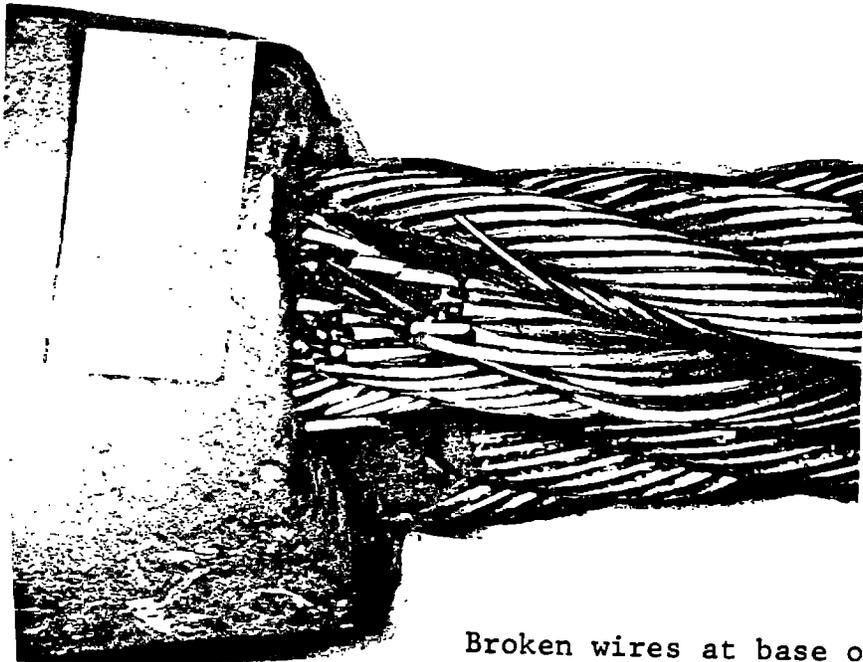
Broken wires on inside of crown of loop on a Flemish Loop with Steel Sleeve.



Broken wires on the inside of crown of loop on a Flemish Loop with Steel Sleeve.

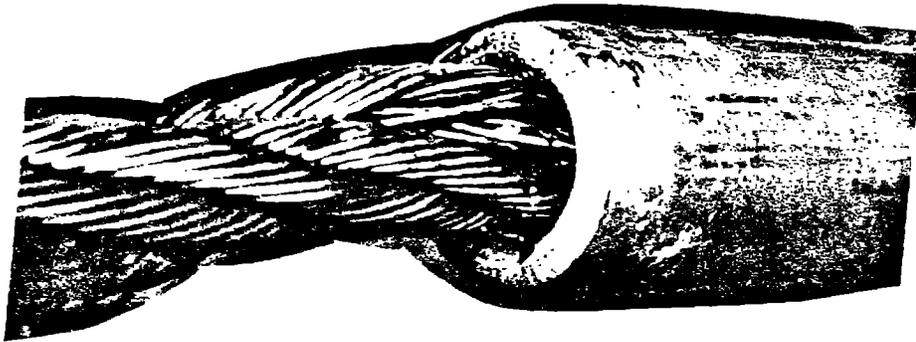


Broken wires at base of  
socket on a Wedge Socket.



Broken wires at base of  
socket on a Wedge Socket.

66<



Broken wires at base of  
socket on a Swaged Socket.



Cracked thimble and sleeve  
on a Turn Back Loop with  
Aluminum Sleeve.

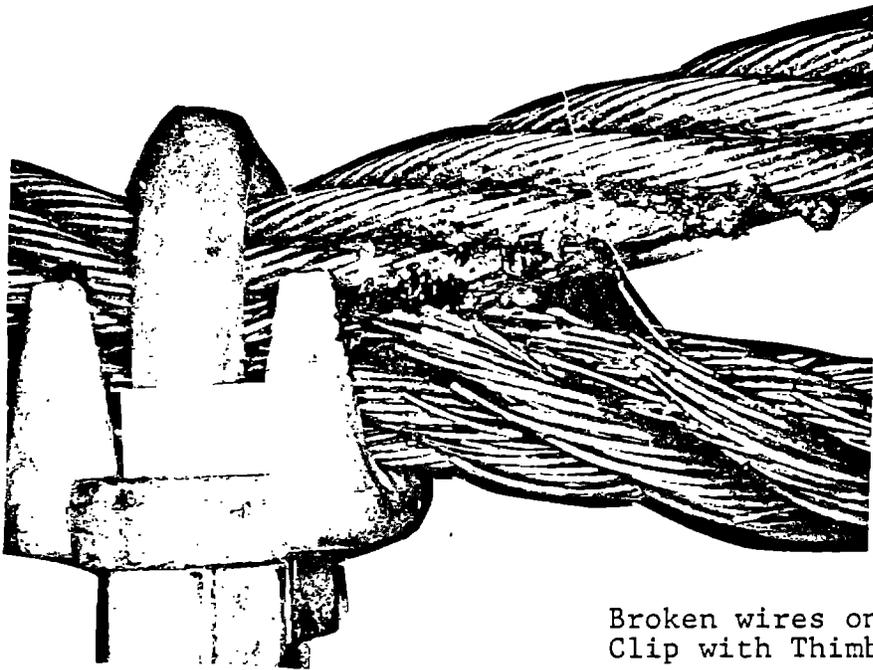
67<



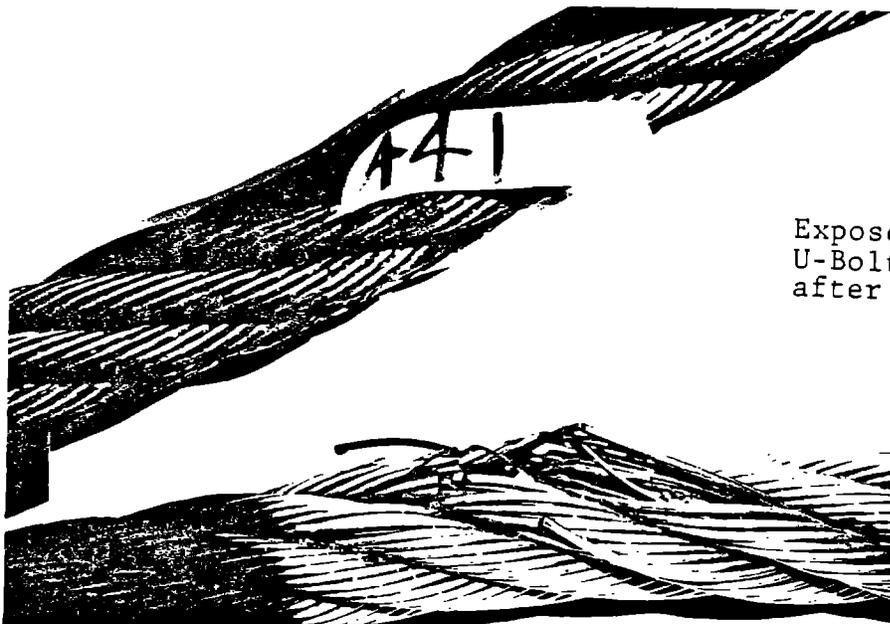
Broken wires at top of splice on a Thimble Splice with Four Tucks.



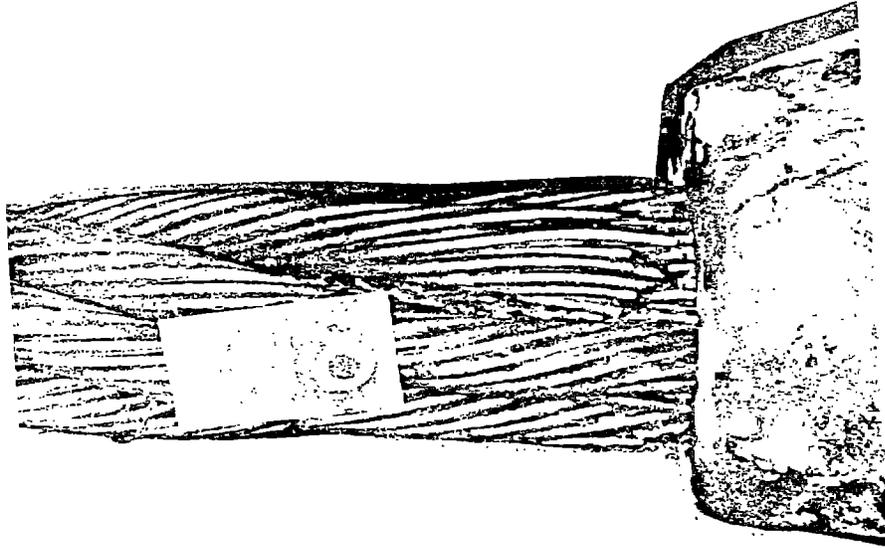
Broken wires in the first tuck on a Thimble Splice with Four Tucks.



Broken wires on a U-Bolt  
Clip with Thimble.



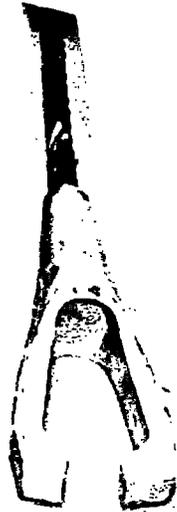
Exposed broken wires on a  
U-Bolt Clip with Thimble  
after removing clip.



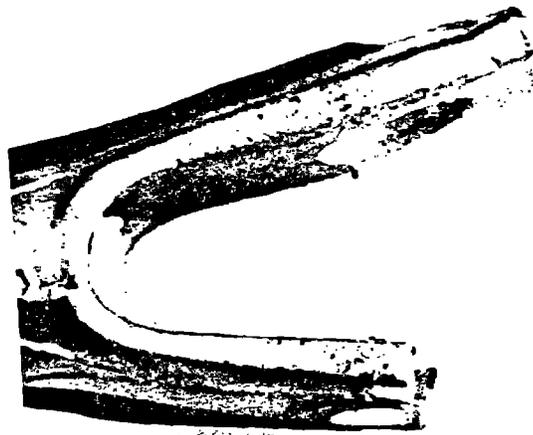
Broken wires at base of  
socket on a Zinc Poured  
Socket.



Broken strands at base of  
socket on a Zinc Poured  
Socket.



Cracked socket on an Epoxy  
Resin Poured Socket.



Cracked socket on an Epoxy  
Resin Poured Socket.

## 5.0 TEST DATA USED IN PREPARING GUIDE

The laboratory test data used to prepare Tables A, B, and C are included in the guide. Those interested can judge for themselves the rank assigned to each WRT with respect to the three factors of interest, True Efficiency (TE), Service Life (SL), and Sensitivity to Poor Workmanship. Should new or additional data become available then the selection guide tables can be updated as appropriate. The data base for Table D is also included in the guide. The test data is presented in the following six tables which are self explanatory.



TABLE E

TRUE EFFICIENCY OF  
WIRE ROPE TERMINATIONS  
AVERAGED OVER CLASS AND CONSTRUCTION<sup>(a)</sup>

Diameter	Wire Rope Construction	Termination Type <sup>(b)</sup>								
		1	2	3	4	5	6	7	8	9
13 mm (½ in.)	Lang	88	88	80	94	92	70	79	88	96
	Regular	88	90	84	95	92	76	81	95	96
	Mean	88	89	82	94	92	73	80	92	96
19 mm (¾ in.)	Lang	84	82	80	84	82	76	90	78	92
	Regular	96	93	74	89	86	81	85	86	98
	Mean	90	88	77	86	84	78	88	82	95
25 mm (1 in.)	Lang	86	79	81	90	88	68	88	92	93
	Regular	94	88	76	96	92	80	91	96	98
	Mean	90	84	78	93	90	74	90	94	96
38 mm (1½ in.)	Lang	89	81	68	91	82	67	86	94	87
	Regular	90	91	73	98	90	82	91	92	90
	Mean	90	86	70	94	86	74	89	93	89
51 mm (2 in.)	Lang	84	86	71	90	86	68	90	98	88
	Regular	81	82	61	98	88	80	91	99	98
	Mean	82	84	66	94	87	74	90	98	93

(a) True Efficiency is defined as the termination's breaking load divided by the rope's True Breaking Load.

(b) Wire Rope Terminations

- 1 Flemish Loop with Steel Sleeve & Thimble
- 2 Flemish Loop with Steel Sleeve
- 3 Wedge Socket
- 4 Swaged Socket
- 5 Turn Back Loop with Aluminum Sleeve & Thimble
- 6 Thimble Splice with Four Tucks
- 7 U-Bolt Clip with Thimble
- 8 Zinc Poured Socket
- 9 Epoxy Resin Poured Socket

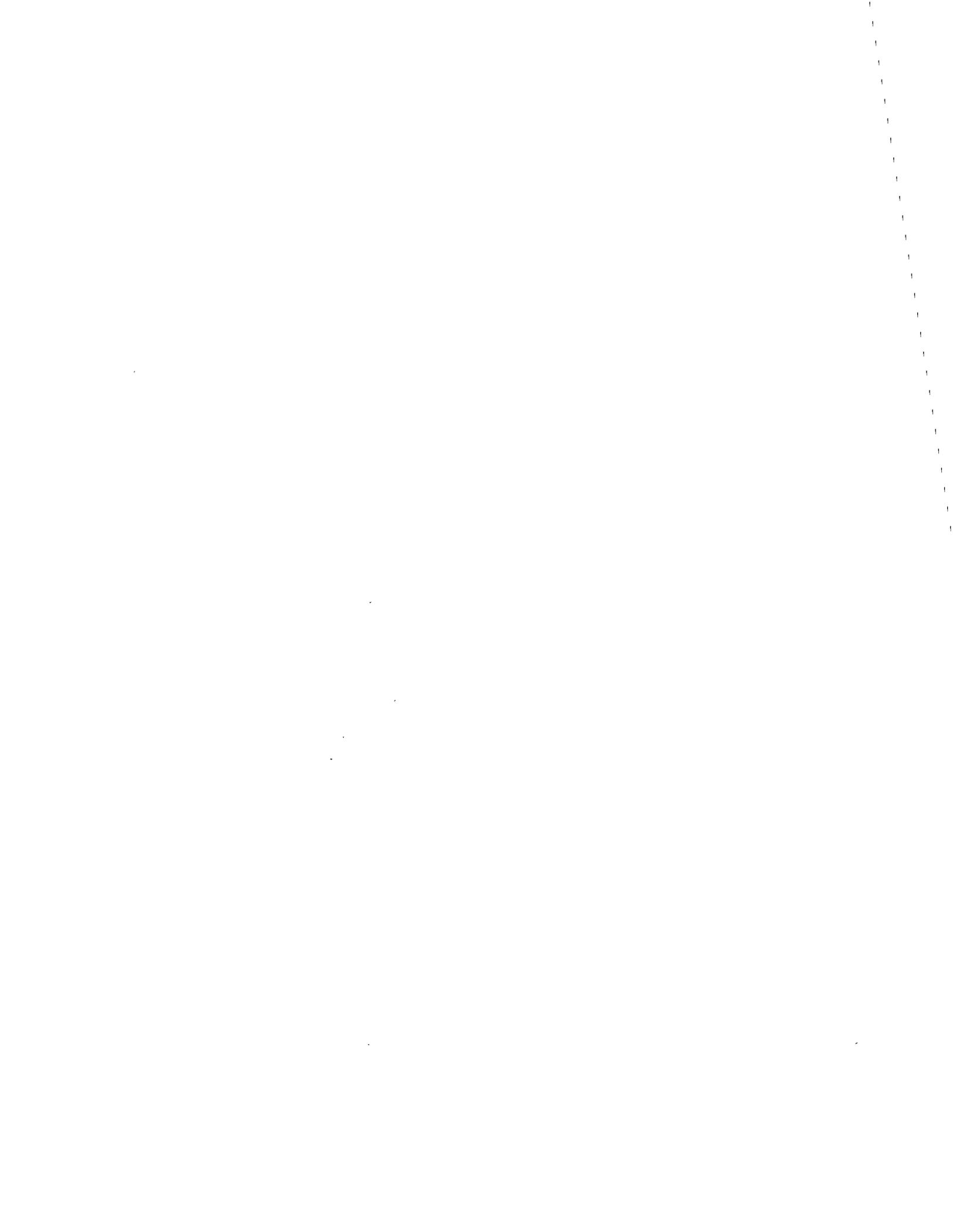


TABLE F SERVICE LIFE OF WIRE ROPE TERMINATIONS<sup>(a)</sup>

Wire Rope		Termination Type <sup>(b)</sup>								
Diameter	Construction	1	2	3	4	5	6	7	8	9
13 mm (½ in.)	Lang	676	294	128	574	292	160	203	70	653
	Regular	603	293	142	10 <sup>6</sup>	342	214	85	163	252
		817	538	189	10 <sup>6</sup>	480	337	91	183	10 <sup>6</sup>
	mean	710	416	166	10 <sup>6</sup>	411	276	88	173	625
19 mm (¾ in.)	Lang	173	168	129	277	135	105	121	54	195
	Regular	309	283	83	278	223	76	172	136	598
		358	294	99	524	230	102	241	225	10 <sup>6</sup>
	mean	334	289	91	401	226	89	206	180	799
25 mm (1 in.)	Lang	298	47	381	900	191	33	228	39	10 <sup>6</sup>
	Regular	482	42	245	900	204	40	196	42	10 <sup>6</sup>
		536	49	327	900	509	114	267	56	10 <sup>6</sup>
	mean	509	46	286	900	356	77	232	49	10 <sup>6</sup>
38 mm (1½ in.)	Lang	457	404	215	385	342	75	305	89	472
	Regular	197	241	201	460	351	65	327	177	214
		334	317	205	466	383	121	432	294	240
	mean	266	279	203	463	367	93	759	236	227
51 mm (2 in.)	Lang	272	40	226	140	87	39	146	200	133
	Regular	162	27	138	456	106	43	223	26	203
		201	29	190	549	141	46	231	52	304
	mean	182	28	164	502	124	44	227	39	254

<sup>(a)</sup> Service Life is expressed as the number of cycles to failure x 10<sup>3</sup>, except for run out values of 1 million cycles (10<sup>6</sup>).

<sup>(b)</sup> WIRE ROPE TERMINATIONS

- 1 Flemish Loop with Steel Sleeve & Thimble
- 2 Flemish Loop with Steel Sleeve
- 3 Wedge Socket
- 4 Swaged Socket
- 5 Turn Back Loop with Aluminum Sleeve & Thimble
- 6 Thimble Splice with Four Tucks
- 7 U-Bolt Clip with Thimble
- 8 Zinc Poured Socket
- 9 Epoxy Resin Poured Socket



TABLE G

TRUE EFFICIENCY OF STANDARD  
AND MODIFIED TERMINATIONS

Wire Rope Dia. mm (in.)	13 (½)				25 (1)				51 (2)			
Assembly Procedure	Std x	Mod x̄	Mod 1	Mod 2	Std x	Mod x̄	Mod 1	Mod 2	Std x	Mod x̄	Mod 1	Mod 2
Flemish Loop With Steel Sleeve & Thimble	88				94				70			
	88	89	86	82	94	94	83	84	75	75	75	16
	90				94				79			
Flemish Loop With Steel Sleeve	90				87				79			
	91	91	88	84	88	88	85	35	80	81	36	7
	93				88				85			
Wedge Socket	79				77				57			
	86	84	69	85	77	79	74	84	58	60	60	57
	88				84				64			
Swaged Socket	95				91				97			
	98	97	98	97	99	96	99	60	94	97	94	92
	98				99				97			
Turn Back Loop With Aluminum Sleeve & Thimble	91				90				78			
	93	93	87	92	92	92	92	94	90	87	76	91
	94				94				92			
Thimble Splice With Four Tucks	76				76				63			
	77	77	73	78	83	81	70	85	77	75	45	70
	79				85				84			
U-Bolt Clip With Thimble	79				93				59			
	83	82	80	80	95	95	92	97	77	76	85	77
	84				96				93			
Zinc Poured Socket	60				97				98			
	88	81	84	83	97	97	99	100	99	99	98	99
	96				98				99			
Epoxy Resin Poured Socket	84				99				80			
	98	94	0	0	99	99	57	82	99	93	26	95
	100				99				100			



TABLE H

SERVICE LIFE OF STANDARD<sup>(a)</sup>  
AND MODIFIED TERMINATIONS

Wire Rope Dia. mm (in.)	13 (½)			25 (1)			51 (2)		
	Assembly Procedure	Std	Mod 1	Mod 2	Std	Mod 1	Mod 2	Std	Mod 1
Flemish Loop With Steel Sleeve & Thimble	603	382	.70	482	611	0	162	0	0
	817			536			201		
Flemish Loop With Steel Sleeve	293	222	0	42	12	0	27	0	0
	538			49			29		
Wedge Socket	142	78	43	245	74	356	138	34	93
	189			327			190		
Swaged Socket	10 <sup>6</sup>	600	10 <sup>6</sup>	900	900	429	457	702	341
	10 <sup>6</sup>			900			549		
Turn Back Loop With Aluminum Sleeve & Thimble	342	396	346	204	112	229	106	126	28
	480			509			141		
Thimble Splice With Four Tucks	214	451	78	40	17	79	43	0	39
	337			114			46		
U-Bolt Clip With Thimble	85	109	143	196	168	251	223	163	209
	91			267			231		
Zinc Poured Socket	163	134	138	42	37	42	26	36	50
	183			56			52		
Epoxy Resin Poured Socket	252	287	149	10 <sup>6</sup>	296	110	203	0	568
	10 <sup>6</sup>			10 <sup>6</sup>			304		

(a) Service Life of Regular 6x19 specimens expressed as the number of cycles to failure x 10<sup>3</sup>, except for run out values of 1 million cycles (10<sup>6</sup>).



TABLE I

## WRT FAILURE MODES FOR PULL TESTS

<u>Termination Type/Failure Mode</u>	<u>Percent of Total</u>
Flemish Loop with Steel Sleeve & Thimble	
Multiple strand breaks inside or at base of steel sleeve	83%
Multiple strand breaks in gage area	13%
Rope pulled out of loop	4%
Flemish Loop with Steel Sleeve	
Multiple strand breaks inside or at base of steel sleeve	82%
Multiple strand breaks in gage area	8%
Multiple strand breaks in crown of loop	6%
Rope pulled out of loop	4%
Wedge Socket	
Multiple strand breaks inside or at base of socket	72%
Socket cracked	19%
Wedge pulled out of socket	9%
Swaged Socket	
Multiple strand breaks inside or at base of socket	76%
Multiple strand breaks in gage area	19%
Rope pulled out of socket	5%
Turn Back Loop with Aluminum Sleeve & Thimble	
Multiple strand breaks inside or at base of aluminum sleeve	89%
Aluminum sleeve cracked	7%
Multiple strand breaks	4%
Thimble Splice with Four Tucks	
Multiple strand breaks in splice	95%
Multiple strand breaks in gage area	5%
U-Bolt Clip with Thimble	
Multiple strand breaks at clip furthest from thimble	90%
Multiple strand breaks at clip second furthest from thimble	5%
Rope pulled out of clips	5%
Zinc Poured Socket	
Multiple strand breaks inside or at base of socket	55%
Multiple strand breaks in gage area	40%
Rope pulled out of socket	5%
Epoxy Resin Poured Socket	
Multiple strand breaks in gage area	48%
Multiple strand breaks inside or at base of socket	27%
Rope pulled out of socket	18%
Socket cracked	7%



TABLE J

## WRT FAILURE MODES FOR FATIGUE TESTS

<u>Termination Type/Failure Mode</u>	<u>Percent of Total</u>
Flemish Loop with Steel Sleeve & Thimble	
Multiple strand breaks inside or at base of steel sleeve	88%
Multiple strand breaks in gage area	6%
Thimble cracked and strands in crown of loop broke	6%
Flemish Loop with Steel Sleeve	
Multiple strand breaks in the crown of the loop	87%
Multiple strand breaks inside or at base of steel sleeve	13%
Wedge Socket	
Multiple strand breaks inside or at base of socket	94%
Socket cracked	6%
Swaged Socket	
Multiple strand breaks inside or at base of socket	46%
No strand breaks; run out	27%
Multiple strand breaks in gage area	27%
Turn Back Loop with Aluminum Sleeve	
Aluminum sleeve cracked	53%
Multiple strand breaks inside or at base of aluminum sleeve	47%
Thimble Splice with Four Tucks	
Multiple strand breaks in splice	100%
U-Bolt Clip with Thimble	
Multiple strand breaks at clip furthest from thimble	80%
Multiple strand breaks inside or at base of swaged socket	14%
Rope pulled out of swaged socket	6%
Zinc Poured Socket	
Multiple strand breaks inside or at base of socket	100%
Epoxy Resin Poured Socket	
Socket cracked	72%
No strand breaks; run out	22%
Multiple strand breaks in gage area	6%

