In-Service Inspection of Mooring Hardware for Floating Drilling Units

API RECOMMENDED PRACTICE 2I
SECOND EDITION, NOVEMBER 1996

EFFECTIVE DATE: FEBRUARY 1, 1997

American
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CONTENTS

CONTENTS

In-Service Inspection of Mooring Hardware for Floating Drilling Units

1 SCOPE

This document provides comprehensive guidelines for inspecting catenary mooring components of floating drilling units. It was developed in response to the need for an industry standard for such inspections. Some discard criteria for used chain and wire rope have been established and used by some manufacturers, regulatory bodies, operators, and drilling contractors. However, these criteria vary, widely and most of them cannot be applied directly to the mooring of floating drilling units. To ensure good mooring inspection quality and to form an industry agreement on discard criteria, this recommended practice was developed.

The need for rigorous, effective inspection of mooring hardware is apparent because most of the mooring failures involved faulty mooring components including corroded or physically damaged wire-rope or chain, defective connecting links, or mooring hardware of inferior quality.

This document should be useful to engineers and operating personnel concerned with the following:

a. Planning a mooring inspection.
b. Conducting or supervising a mooring inspection.
c. Deciding whether to reject, repair, or replace mooring hardware.
d. Communicating with others concerning acceptable mooring hardware.

This document compiles factors that are best understood and can be quantified at this time. The information in this document will be updated after further experience and knowledge are gained. Accordingly, we encourage comments and suggestions toward broadening and refining these guidelines.

Although this recommended practice was developed for moorings of floating drilling units, some of the guidelines may be applicable to moorings of other floating vessels such as floating production platforms, pipe-laying barges, and construction barges. The applicability of this document to other floating vessels is left to the discretion of the user.

2 REFERENCES

The most recent editions or revisions of the following standards are referenced in this publication:

AISI[1] *Wire Rope User's Manual*

ASTM[2]
B6-87 *Specification for Zinc*
E709 *Practice for Magnetic Particle Examination*

ISO[3]
Std 4309 *Cranes—Wire Ropes—Code of Practice for Examination and Discard*

[1] American Iron and Steel Institute, 1101 17th Street, N.W., 13th Floor, Washington, D.C. 20036-4700.
[2] American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.

3 GUIDELINES FOR IN-SERVICE INSPECTION OF MOORING CHAIN AND ANCHOR JEWELRY

3.1 Common Problems with Used Chain

The rough treatment to which mooring chain is exposed can lead to various chain problems. Eight such common problems for which inspectors should be alert are described in 3.1.1 to 3.1.8.

3.1.1 Missing studs. A chain link without a stud may significantly increase the possibility of link failure; high bending stresses and low fatigue life in links are predictable consequences of missing studs.

3.1.2 Bent links. A bent link is the result of chain-handling abuse. The link may have been excessively torqued when traversing a sharp, curved surface; or the chain may have jumped over the wildcat, making point contacts between the link and the wildcat. Jumping of chain over the wildcat is usually caused by a worn wildcat, by chain dimensions out of tolerance, or by too abrupt braking of fast moving chain.

3.1.3 Corrosion. Excessive corrosion increases the possibility of chain failure from corrosion fatigue or overloading due to reduced cross-sectional area.

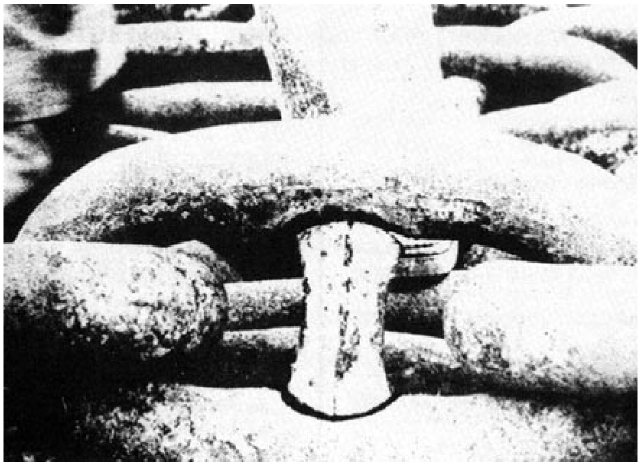
3.1.4 Sharp gouges. Physical damage to the chain surface (such as cuts and gouges) raises stress and promotes fatigue failure.

3.1.5 Loose studs. Loose studs caused by abusive handling or by excessive corrosion between the link and the stud allow excessive stretching of chain, causing higher bending stresses in the chain. A typical loose stud is shown in Figure 1, Part a.

3.1.6 Cracks. Surface cracks, flash-weld cracks, and stud-weld cracks may propagate under cyclic loading, resulting in premature chain failure. A typical stud-weld crack is shown in Figure 1, Part b.

3.1.7 Wear. Wear between links in the grip area and between links and the wildcat (see Figure 2, Part b) reduces the chain diameter. The diameter reduction decreases the load-carrying capacity of the chain and invites failure.

[3] International Organization for Standardization. ISO publications are available from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.



A LOOSE STUD IN 3-INCH ORQ CHAIN

B. CRACKED STUD WELD IN 3-INCH ORQ CHAIN

Figure 1—Typical Chain Stud Problems

3.1.8 Elongation. Excessive permanent elongation may cause the chain to function improperly in the wildcat, resulting in bending and wear of the links. Wear in the grip area of the chain and working loads in excess of the original proof load will result in a permanent elongation of the chain.

3.2 Recommended Inspection Method

3.2.1 GENERAL

Chain installed on mobile offshore drilling units can be inspected by the two methods in 3.2.2 and 3.2.3.

3.2.2 DOCKSIDE INSPECTION

As shown in Figure 3, the drilling vessel is taken into a dock, and the chain is laid out on a dry surface for inspection. Normally such chain inspection is carried out in con-

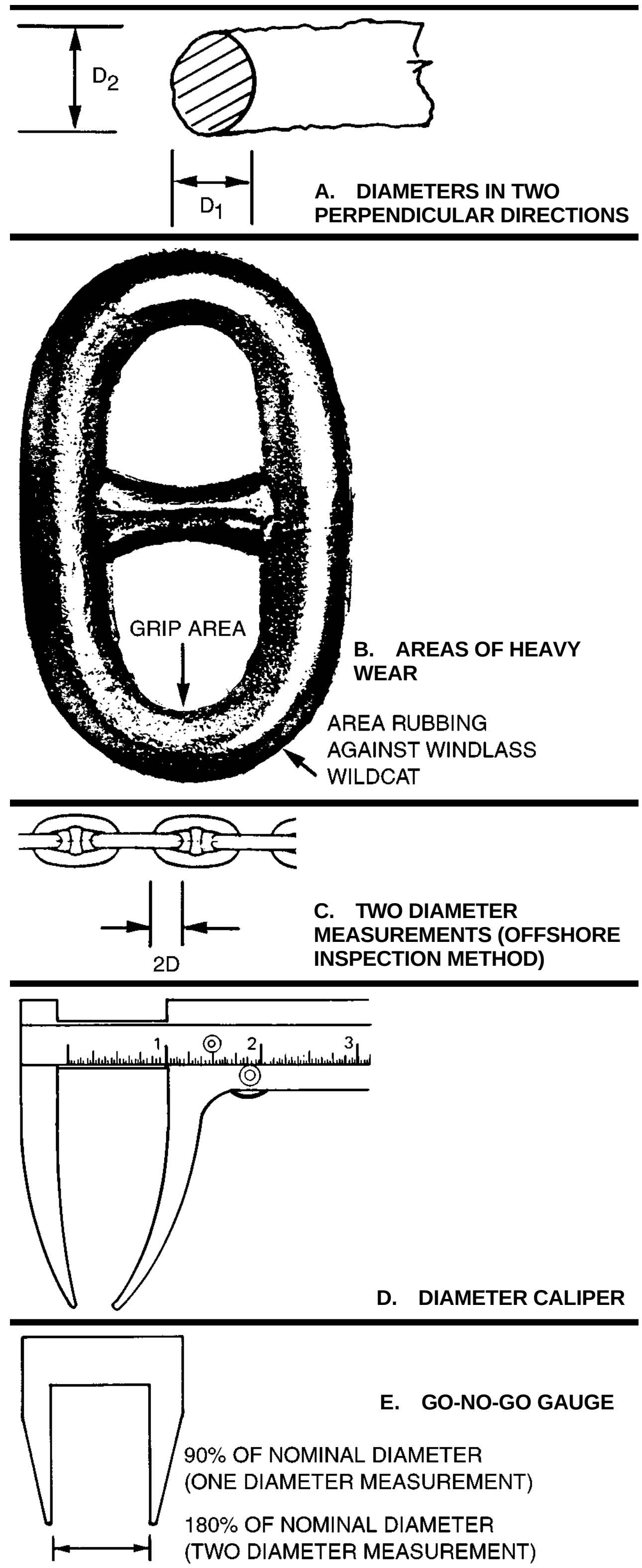


Figure 2—Chain Diameter Measurement

junction with other work such as major structural repair or special survey.

In this manner the entire chain can be thoroughly cleaned and carefully inspected, and the connecting links and anchor shackles can be examined by magnetic particle inspection (MPI). Since the chain is not under tension, the chain diameter in the grip area can be readily measured. However, the measurement of a length of five links, which should be accomplished under tension, would be inaccurate.

3.2.3 OFFSHORE INSPECTION

As shown in Figure 4, the drilling vessel stays offshore, and the chain is inspected with the assistance of a workboat. The chain in the chain locker should be paid out fully and then examined by an inspector standing close to the windlass while the chain is slowly taken back into the chain locker. At the same time, the workboat picks up the anchor and moves slowly toward the vessel.

The advantage of this method is that it requires no dock facilities. The inspection can be performed whenever a work boat is available or in conjunction with anchor retrieval. However, this method has the following disadvantages:

a. Inspecting the last approximate 200 feet of chain is difficult. However, if the chain can be reached by a crane, and deck space on the drilling vessel is available, the anchor and the last portion of chain can be picked up by the crane and laid on the deck for inspection. Otherwise, the anchor and the last portion of chain can be brought on board the work boat and inspected there.

b. Inspection of connecting links by MPI is suggested in 3.3. However, MPI is difficult and time consuming with the offshore inspection method; it could substantially increase workboat waiting time and delay the rig moving schedule. This problem can be alleviated by exchanging the connecting links in the chain with spare connecting links that have been examined by MPI prior to chain inspection.

3.3 Recommended Inspection Procedure

3.3.1 PERSONNEL

3.3.1.1 Dockside Inspection Method

The following list describes personnel and duties for the dockside inspection method:

a. The chief inspector coordinates the work among inspection personnel, performs visual inspection, performs measurements, and rejects or accepts damaged links.

b. The assistant keeps inspection records and assists with measurements.

c. The MPI inspector performs MPI on connecting links and anchor jewelry.

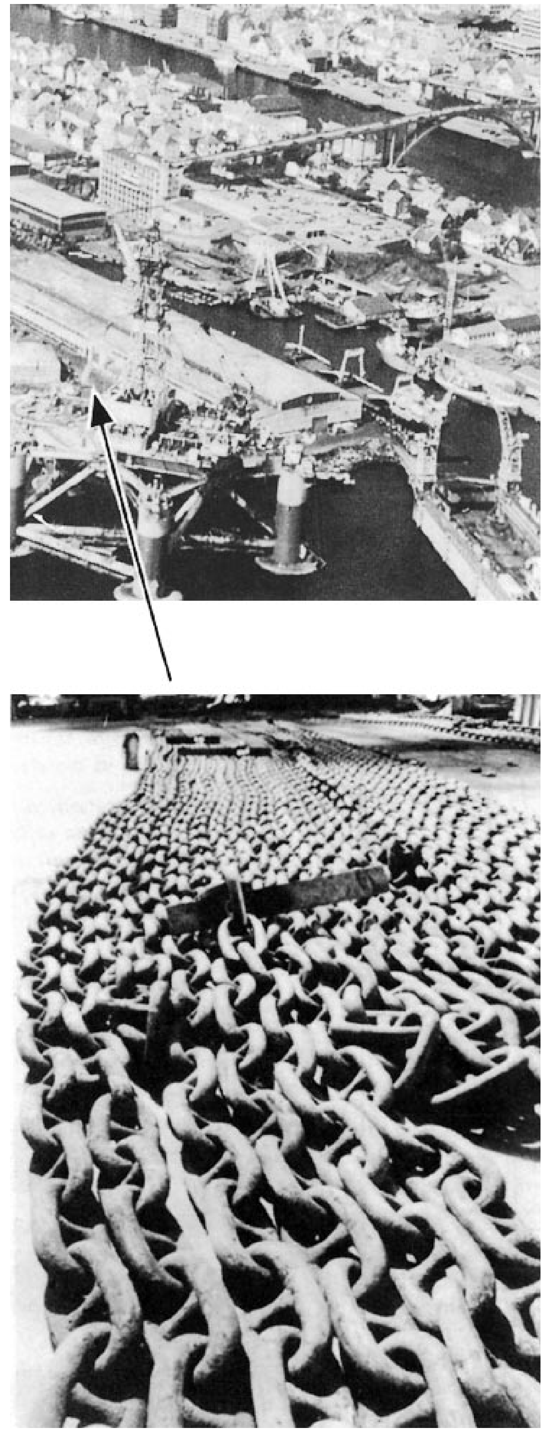


Figure 3—Dockside Inspection Method

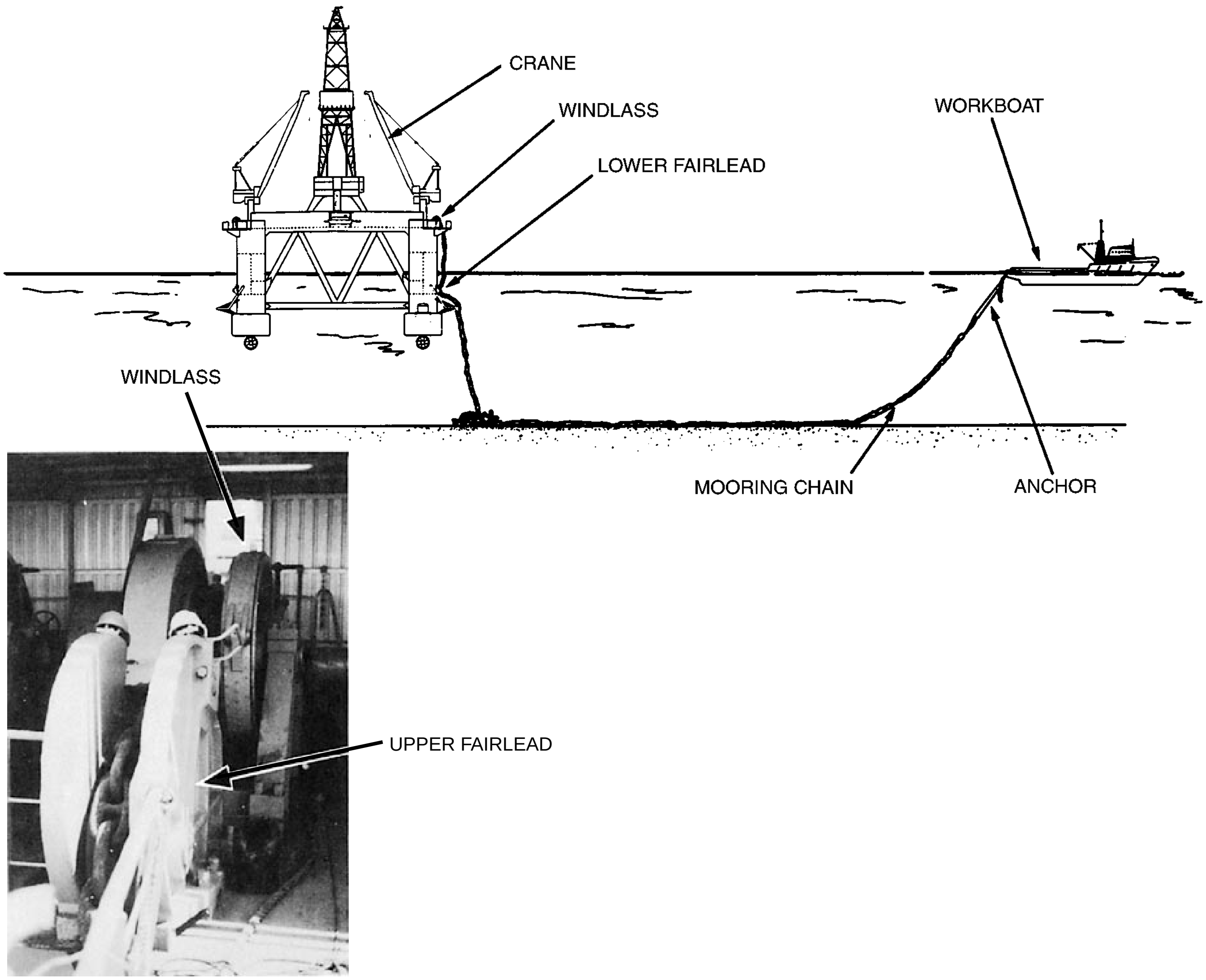


Figure 4—Offshore Inspection Method

d. Roughnecks clean chain, grind out surface defects, dismantle/assemble connecting links, and assist in inspection of anchor jewelry.

3.3.1.2 Offshore Inspection Method

The following list describes personnel and duties for the offshore inspection methods:

a. The windlass operator runs and stops chain on the order of the chief inspector, stopping chain after every 100 feet of chain movement.

b. The chief inspector coordinates the work among the inspection personnel, gives orders to the windlass operator, rejects or accepts damaged links, and performs visual inspection and measurements.

c. The assistant inspector keeps inspection records, performs visual inspection, and assists with measurements.

d. The MPI inspector performs MPI on anchor jewelry and spare connecting links prior to inspection.

e. Roughnecks clean chain, grind out surface defects, change connecting links, and assist with inspection of anchor jewelry.

3.3.2 EQUIPMENT

The following equipment is often needed for chain inspection. Its need and availability should be checked before the inspection is started.

a. Workboat (offshore inspection method).

b. Dockside crane or other suitable equipment to lay out chain (dockside inspection method).

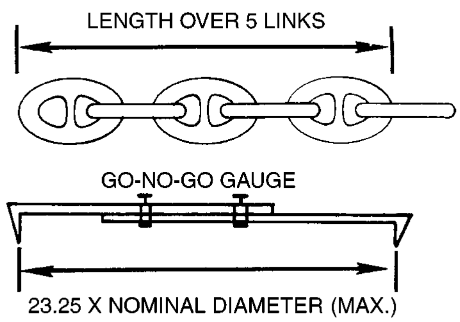
c. High-pressure fire hose.

d. Sandblasting equipment.

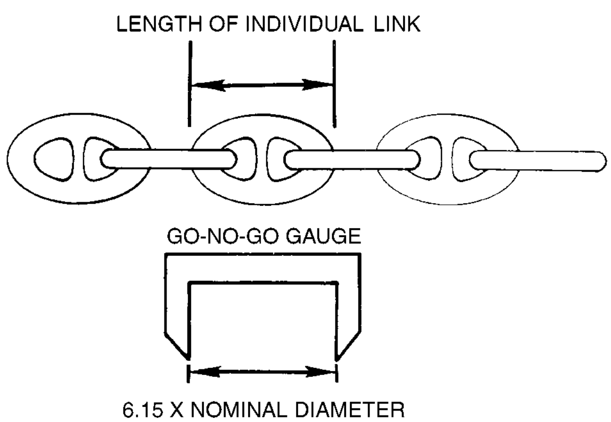
e. MPI equipment.

f. Go-no-go gauge for chain diameter measurement (Figure 2, Part e).

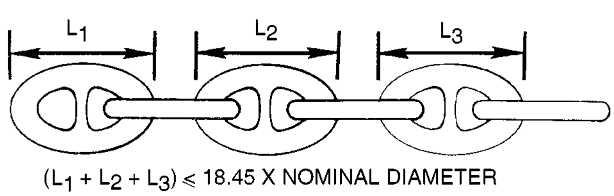
g. Go-no-go gauge for maximum allowable length over five links (see "Offshore Inspection Method," in Figure 5, Part a) or go-no-go gauge for maximum allowable length of individual link (see "Dockside Inspection Method," Figure 5, Part b).



A. OFFSHORE INSPECTION METHOD



B. DOCKSIDE INSPECTION METHOD (OPTION 1)



C. DOCKSIDE INSPECTION METHOD (OPTION 2)

Figure 5—Chain Length Measurement

h. Steel wire brush.

i. Hammer.

j. Spare connecting links that have been inspected by MPI (a sufficient number of connecting links must be prepared for replacing existing connecting links and damaged common links).

k. Grinder.

l. Diameter caliper (Figure 2, Part d).

m. Measuring tape.

n. Tape recorder.

o. Spray paint.

p. Camera.

q. Lighting equipment.

3.3.3 ARRANGEMENT

3.3.3.1 Dockside Inspection Method

For arrangement in the dockside inspection method, one should lay out the chain on a dry area in rows approximately 100 feet long. If this arrangement is impractical, one should use spray paint to mark every 100 feet of chain.

3.3.3.2 Offshore Inspection Method

The inspector should stand close to the windlass or the upper fairlead. Chain inspections have been carried out on a specially built platform near the lower fairlead of a semisubmersible, but this practice is discouraged because it can endanger the inspectors if the chain breaks at the windlass. For chain systems, inspection could be accomplished on the deck of a large anchor-handling boat that has adequate handling gear and chain lockers.

3.3.4 CLEANING

One should clean the chain with a high-pressure hose. Also marine growth and corrosion scale should be removed at every 100 feet of chain and at places close examination is needed.

3.3.5 INSPECTION STEPS

3.3.5.1 Visual Inspection

One hundred percent of the chain is visually inspected for missing studs, bent links, corrosion, sharp gouges, loose studs, cracks, and wear. When using the offshore inspection method, the line speed should be less than 30 feet per minute. When chain abnormalities are suspected, the chain movement should be stopped for close examination. The inspector should also watch the movement of the chain passing through the wildcat. Jumping of chain over the wildcat may indicate misfit between the chain and wildcat.

The inspector should tap each stud with a hammer to check for loose studs. An experienced inspector can detect loose studs by listening to the tone of the tapping.

The offshore inspection method is most effective where one inspector checks the links in a vertical plane while another inspector checks the links in a horizontal plane.

The last portion of chain should be brought on board the deck of the drilling vessel or the deck of the workboat for inspection.

3.3.5.2 Connecting-Link Inspection

To perform a connecting-link inspection, the inspector should dismantle all connecting links and inspect by MPI or replace with links that have been examined by MPI.

3.3.5.3 Measurement

3.3.5.3.1 One should measure the following parameters once at every 100 feet of chain and on both sides of each connecting link. If chain problems are found, more measurements may be needed.

For chain diameters in two perpendicular directions as shown in Figure 2, Part a, one should remove corrosion scale and marine growth before measuring diameters. The diameter measurement should be performed at the location with the worst reduction in cross-sectional area, which is normally the grip area or the area that rubs against the windlass wildcat (see Figure 2, Part b). If the grip area has the worst reduction and the offshore inspection method is used, two diameters should be measured as shown in Figure 2, Part c.

In the offshore inspection method, length over five links can be measured with a go-no-go gauge (see Figure 5, Part a). For the dockside inspection method, length over five links cannot be measured accurately since the chain is not under tension. Therefore, the length of individual links should be measured by a go-no-go gauge as shown in Figure 5, Part b. Another option of chain length measurement for dockside inspection is shown in Figure 5, Part c.

3.3.5.3.2 If grinding is performed to remove surface defects, one should measure link diameter after grinding with a diameter caliper as shown in Figure 2, Part d.

3.3.5.4 Anchor and Anchor Jewelry Inspection

3.3.5.4.1 The inspector should visually inspect all anchor jewelry such as anchor shackles, swivels, open links, and connecting links. In addition, certain areas as shown in Figure 6 should be inspected by MPI. MPI procedures are presented in Appendix A.

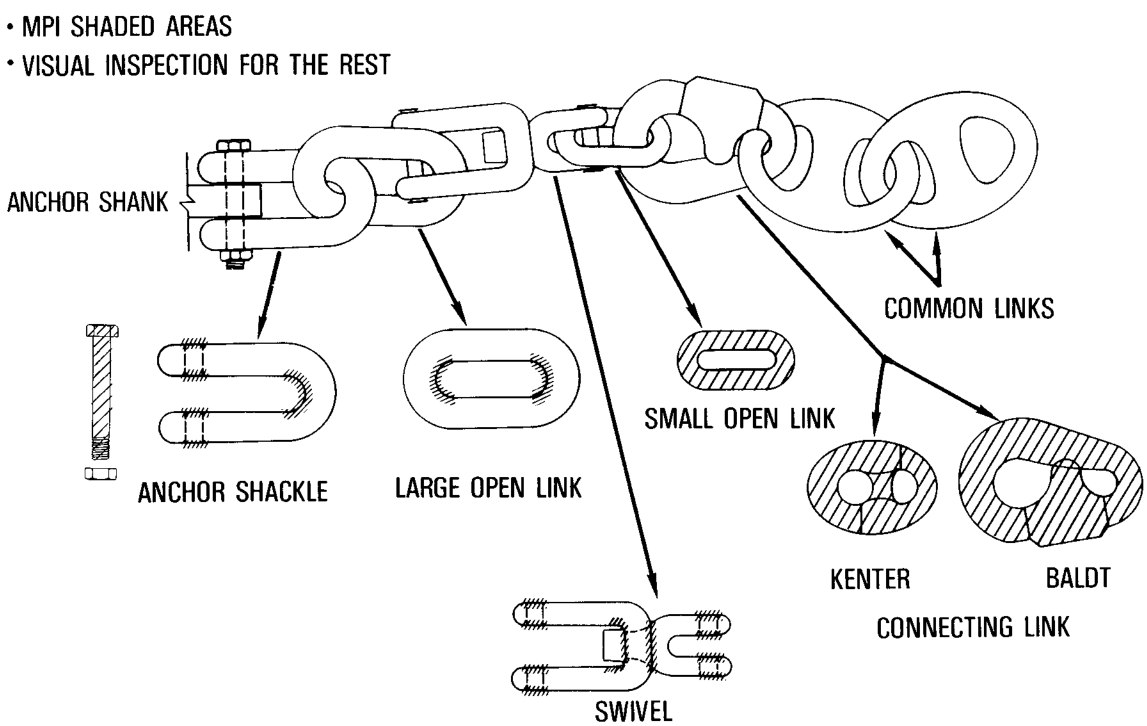


Figure 6—Inspection of Anchor Jewelry

MPI should be conducted under the supervision of an operator's representative or a representative from recognized classification societies. The areas to be examined by MPI should be clearly marked on each item. One should dismantle all connecting links and other anchor jewelry as required.

Anchors should be visually inspected. Attention should be given to welds, corners, and areas of high stress.

3.3.5.5 Winching Equipment Inspection

The working conditions of the windlasses, fairleads, chain stoppers and chain chasers, and the like, should be checked.

3.3.5.6 Inspection Record

The following information should be included on the inspection record:

a. Name of the chain manufacturer, size and grade of chain, and method of securing studs (unwelded, one side welded, or both sides welded).
b. Operation history, including the age of the chain, inspection and failure history, and previous operating locations.
c. Inspection date and names of inspectors.
d. Locations and nature of all chain abnormalities, plus the corrective measures taken.
e. Chain diameter and length over five links (or length of an individual link) and locations where measurements are taken; also the general conditions of the last section inspected.
f. Locations of connecting links.
g. MPI results.
h. Recommendations for further action to be taken.

3.4 Guidelines for Rejecting Chain Components

Links having any of the following problems should be removed:

a. A missing stud.
b. A noticeable out-of-plane bending (see Figure 7).

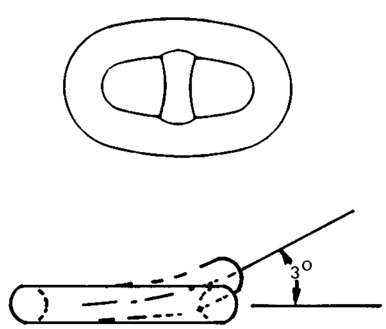


Figure 7—Discard Criterion for Bent Links

c. An average of two measured diameters less than 95 percent of the nominal diameter (about a 10 percent reduction of cross-sectional area) or a diameter in any direction less than 90 percent of the nominal diameter.
d. A crack at the toe of the stud weld extending into the base material.
e. Surface cracks or sharp gouges that cannot be eliminated by light grinding. The link should be rejected if the chain diameter is reduced to less than 90 percent of the nominal diameter after grinding.
f. Excessively loose stud. Since it is difficult to quantify excessive looseness of chain studs, the decision to reject or accept a link with a loose stud depends on the experience and judgment of the inspector. As a point of reference, if a stud can move more than ⅛ inch (3 millimeters) axially or more than 3⁄16 inch (5 millimeters) laterally in any direction (see Figure 8, Part a), rejection of the link should be considered. Similarly, if a gap of more than ⅛ inch (3 millimeters) exists between the stud end and the link in a link with a stud welded on one end, rejection of the link should also be considered (see Figure 8, Part b).

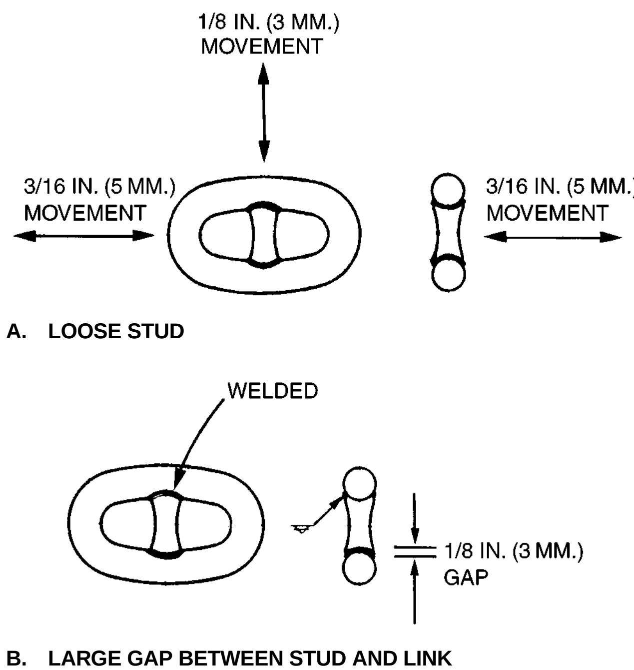


Figure 8—Examples of Severely Loose Studs

g. Cracks detected by MPI in the internal locking area of connecting links. External surface defects in connecting links are not cause for rejection if they can be eliminated by grinding to a depth of no more than 8 percent of the nominal diameter of the chain.
h. Length over five links exceeding 23.25 times the nominal chain diameter (offshore inspection method) or the length of an individual link exceeding 6.15 times the nominal chain

diameter (dockside inspection method). The upper limit values of length over five links and length of the individual link for different sizes of used chain can be found in Table 1.

i. Excessive wear or a deep surface crack on anchor shackles, open links, or swivels. Moderate wear and surface cracks that can be eliminated by light grinding are acceptable for the anchor jewelry. They should be rejected, however, under either of the following conditions:

1. Reduction in cross-section area due to wear and grinding is more than l0 percent. This is equivalent to a 5 percent reduction in the average diameter for distributed wear or grinding.
2. Reduction in diameter or critical thickness in any direction is more than l0 percent.

Table 1—Upper Limit of Length Over Five Links And Length of Individual Link for Used Chain

Nominal Diameter (inches)	Length Over 5 Links (23.25D, inches)	Length of Individual Link (6.15D, inches)
2	46.5	12.3
2⅛	49.4	13.1
2¼	52.3	13.8
2⅜	55.2	14.6
2½	58.2	15.4
2⅝	61.0	16.1
2¾	64.0	16.9
2⅞	66.8	17.7
3	69.8	18.5
3⅛	72.7	19.2
3¼	75.5	20.0
3⅜	78.5	20.8
3½	81.4	21.5
3⅝	84.3	22.3
3¾	87.2	23.1
3⅞	90.1	23.8
4	93.0	24.6
4⅛	95.9	25.4
4¼	98.8	26.1
4⅜	101.7	26.9
4½	104.7	27.7
4⅝	107.4	28.4
4¾	110.5	29.2
4⅞	113.3	30.0
5	116.3	30.8
5⅛	119.2	31.5
5¼	122.0	32.3
5¾	125.0	33.1
5½	127.8	33.8
5⅝	130.8	34.6
5¾	133.7	35.4
5⅞	136.6	36.1

3.5 Guidelines for Chain Repair, Removal, and Replacement

3.5.1 Individual links that meet the discard criteria should be removed and replaced with connecting links that have been examined by MPI.

3.5.2 If a substantial number of links in a chain section meet the discard criteria, the chain section should be removed, and the chain can be joined again by connecting links that have been examined by MPI.

3.5.3 The number of connecting links in a mooring line should not exceed an average of one per 400 feet outboard line length. Furthermore, the total number of connecting links in a mooring line should be no more than ten, excluding the connecting links at the anchor end.

3.5.4 If a large number of links meets the discard criteria and these links are distributed in the whole length, the chain should be replaced with a new chain.

3.5.5 Rewelding of loose studs in the field is undesirable for the following reasons:

3.5.5.1 Welding in the field may produce hard heat-affected zones that are susceptible to cold cracking.

3.5.5.2 Hydrogen embrittlement may occur from absorption of moisture from the atmosphere or welding electrodes.

Weld repairs on loose studs should be delayed as long as possible. Where a few links are found with loose studs in a short section of a chain, it is recommended that this portion of the chain be cut out and a connecting link put in.

If the major portion of the chain has loose studs, the chain should be scrapped. In the case where the chain is not too old, but contains many loose studs, the chain may be reconditioned onshore at a qualified chain manufacturer where the loose studs are rewelded at one end and the chain is heat-treated again. However, this practice cannot be applied to Grade 4 chains, for which stud welding is normally prohibited.

Studs in chain links serve two purposes: (a) to avoid knots or twist problems during handling operations and (b) to support the links and prevent the sides of the links from deflecting inward during tensile loading, thus preventing high bending stresses in the chain.

It is important to keep the stud in place to accomplish the purposes just discussed. Although weld repair of loose studs should be discouraged, excessive stud movement can be prevented by careful welding using the proper electrode, preheat, interpass temperature, and rate of cooling after welding. Some regulatory bodies permit field rewelding of studs in oil rig quality chains. However, they normally require the welding contractor to submit welding specifications for their approval prior to such weld repair.

3.5.6 Any grinding to eliminate shallow surface defects should be done parallel to the longitudinal direction of the chain, and the groove should be well rounded and form a smooth transition to the surface. The ground surface should be examined by MPI.

3.5.7 It is recommended that replacements for faulty mooring jewelry such as connecting links, anchor shackles, swivels, wire rope sockets, and pelican hooks be made of forged material.

3.6 Recommended Inspection Schedule

A chain inspection schedule should be based on the age and condition of the chain and areas of operation. However, the inspection intervals should not exceed those specified in Table 2.

Table 2—Chain Inspection Intervals

Number of Years in Service	Maximum Intervals Between Major Inspections
0–3	36 months
4–10	24 months
over 10	8 months~

In addition to the major inspections, chain should be checked for visible defects frequently during anchor retrieval.

4 GUIDELINES FOR IN-SERVICE INSPECTION OF MOORING-WIRE ROPE AND ANCHOR HANDLING EQUIPMENT

4.1 Common Problems with Used Mooring-Wire Rope

Mooring-wire ropes receive rough treatment in service, which may result in various types of damage. Inspectors should be particularly attentive to the common wire rope problems described in the following paragraphs.

4.1.1 BROKEN WIRES

4.1.1.1 Broken Wires at the Termination

Broken wires at the termination, even if few in number, indicate high stresses at the termination and may be caused by incorrect fitting of the termination, fatigue, overloading, or mishandling during deployment or retrieval.

4.1.1.2 Distributed Broken Wires

The nature of the wire breaks is an important key to diagnosing wire rope problems. For example, a crown break on the top of the strand may indicate excessive tension, fatigue, wear, or corrosion. Necking down at the broken end of the wire indicates failure in tension. Broken faces perpendicular to the axis of the wire indicate fatigue. Reduced cross sections of the wire breaks may indicate corrosion and wear. An example of distributed crown breaks is given in Figure 9, and typical wire fractures are shown in Figure 10.

Valley breaks at the interface between two strands indicate tightening of strands. This is normally caused by internal corrosion reducing the area of the core or by a broken core. Valley breaks can also be caused by tight sheaves, extremely small sheave-to-rope diameter ratios, and high loads.

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Figure 9—Examples of Distributed Crown Wire Breaks

4.1.1.3 Locally Grouped Broken Wires

If broken wires are closely grouped in a single strand or adjacent strands, as shown in Figure 11, there may have been local damage at this point. When wire breakage of this type begins, it will usually worsen. Such concentrated wire breakage will upset the balance of loads carried by the strands.

4.1.2 CHANGE IN ROPE DIAMETER

The rope diameter can be reduced by external wear, interwire and interstrand wear, stretching of the rope, and corrosion. Excessive reduction in diameter can substantially reduce the strength of the rope. Therefore, the diameter should be measured and recorded periodically throughout the life of the rope. The new rope diameter should also be measured and recorded.

An increase in the rate of change in diameter may indicate accelerated corrosion or stretching of the rope due to overload. A localized decrease in diameter at any point in the rope as shown in Figure 12 may indicate a break in the core. Any increase in wire rope diameter is also a cause for concern, since it may indicate swelling of the core due to internal corrosion.

4.1.3 WEAR

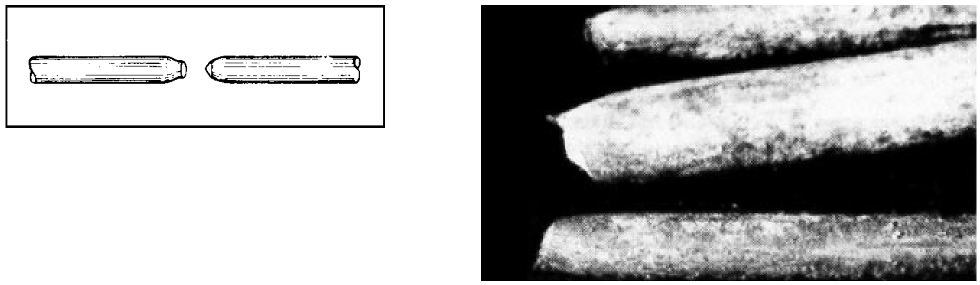
Wear of the crown wires of outer strands in the rope can be caused by rubbing against the fairlead sheaves or hard seafloor. In particular, external wear of mooring-wire rope can be caused by dragging the wire rope on hard seafloor during anchor deployment or retrieval.

Internal wear is caused by friction between individual strands and between wires in the rope, particularly when it is subject to bending. Internal wear is usually promoted by lack of lubrication.

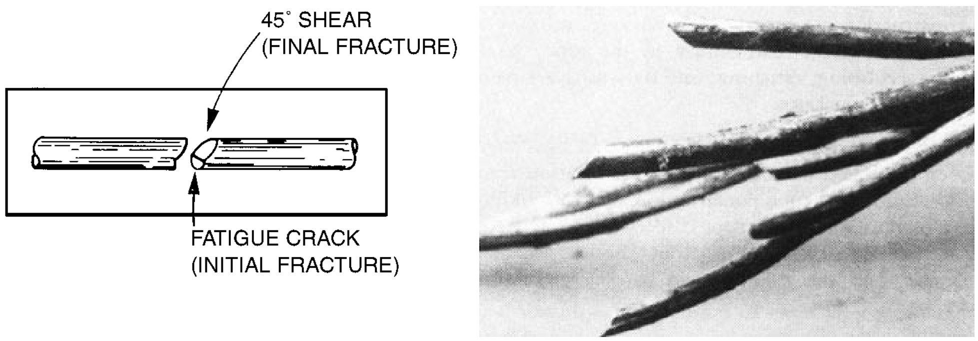
Wear reduces the strength of wire ropes by reducing the cross-sectional area of the steel. Progression of external wear is illustrated in Figure 13.

4.1.4 CORROSION

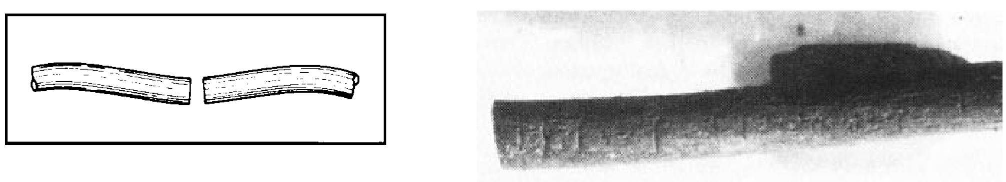
Corrosion in marine atmosphere not only decreases the breaking strength by reducing the metallic area of the rope,



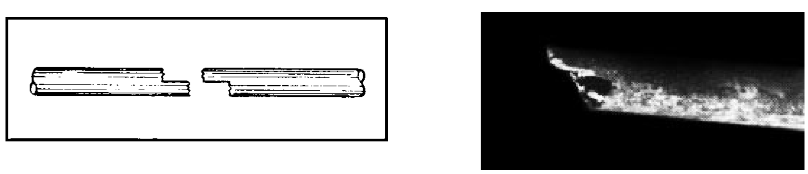
A. FAILURE DUE TO TENSILE OVERLOADING CHARACTERIZED BY THE CUP CONE CONFIGURATION



Fatigue failure—initial fracture from fatigue and final fracture by shear.



Fatigue failure—straight across.



Fatigue failure—Z-shaped.

B. FATIGUE FAILURES CHARACTERIZED BY NO REDUCTION IN CROSS SECTION AREA

Figure 10—Typical Wire Fractures

but also accelerates fatigue by causing an irregular surface that will invite stress cracking. Severe corrosion may reduce a rope's elasticity.

Corrosion of the outer wires as shown in Figure 14 may be detected visually. Progression of external corrosion is illustrated in Figure 15. Internal corrosion is more difficult to detect than external corrosion that frequently accompanies it, but the following indications may be recognized:

4.1.4.1 In positions where the rope bends around fairlead sheaves, a reduction in diameter usually occurs. However, in stationary ropes, an increase in diameter could occur due to the buildup of rust under the outer layer of strands, although this condition is rare for mooring-wire ropes.

4.1.4.2 Loss of gap between strands in the outer layer of the rope, frequently combines with valley wire breaks and loss of flexibility.

4.1.5 LOSS OF LUBRICATION

Proper and thorough lubrication is important to permit the wires and strands to work without excessive internal wear and to inhibit corrosion. Operating a wire rope in frequent bending service without lubrication will reduce its life to only a

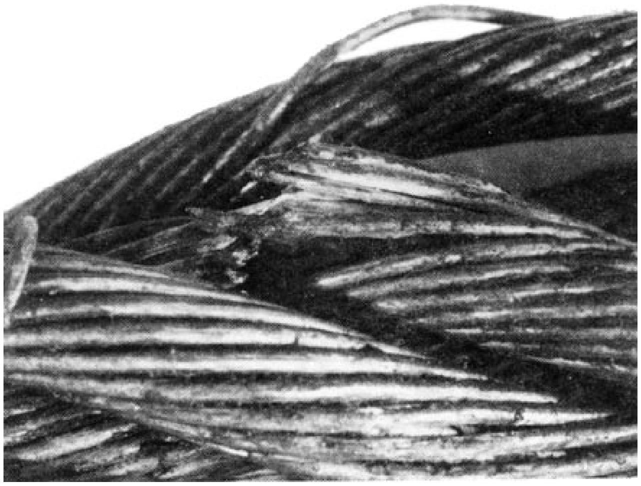


Figure 11—Locally Grouped Broken Wires

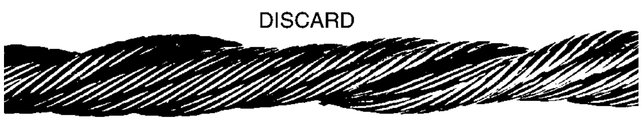


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Figure 12—Local Decrease in Rope Diameter

fraction of normal life because of internal wear. Figure 16 shows a large reduction of cross-sectional area due to internal wear in the wires of a wire rope that has lost internal lubrication. A nongalvanized mooring-wire rope working in a marine environment without lubrication can rapidly develop severe corrosion and fail in corrosion fatigue in a few months.

Loss of internal lubrication is normally caused by a washing out of lubricant during service. A great variety of lubricants are used in wire rope manufacturing, and some of the lubricants can be easily leached out by wave actions. Figure 17, Part a shows heavy internal corrosion in a mooring-wire rope caused by lack of internal lubrication. When an improper lubricant applied to the wire rope during manufacturing was rapidly lost in service, severe corrosion developed, leading to a mooring-line failure. On the other hand, as shown in Figure 17, Part c, a dismantled strand with lubrication on the internal wires shows no evidence of internal corrosion. Figure 17, Part b shows a dry rope with no internal lubrication. In this case, internal wear and corrosion are not obvious, but may soon develop.

External lubrication is difficult to maintain for mooring wire ropes. Some drilling contractors have a policy to relubricate wire ropes periodically. However, relubrication has not been proven to be effective in preventing internal corrosion, which is the main cause of many mooring-wire rope failures. In addition, relubrication may violate pollution control codes in many areas.

SLIGHT FLATS ON OUTER WIRES. LITTLE REDUCTION IN ROPE DIAMETER

INCREASED LENGTH OF FLATS ON INDIVIDUAL OUTER WIRES

FLATS ON INDIVIDUAL WIRES LONGER, AFFECTING ALL CROWN WIRES IN EACH STRAND. MARKED REDUCTION IN ROPE SIZE

FLATS ON INDIVIDUAL WIRES NOW ALMOST CONTINUOUS—STRANDS APPEAR SLIGHTLY FLATTENED AND WIRES ARE NOTICEABLY THIN

FLATS TOUCH EACH OTHER, WIRES BECOMING SLACK WITH AN ESTIMATED REDUCTION IN SIZE OF 40%

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Figure 13—Progression of Wear in Wire Rope

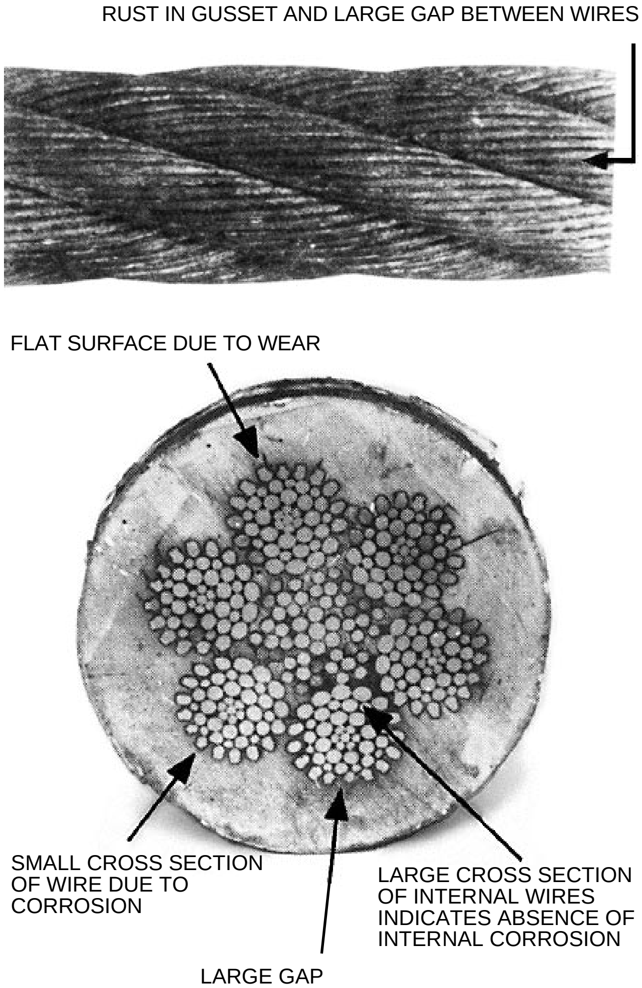

Figure 14—Wire Rope with Heavy External Corrosion

4.1.6 DEFORMATION

Distortion of the rope from its normal construction is termed *deformation* and may result in an uneven stress distribution in the rope. Kinking, bending, scrubbing, crushing, and flattening are common wire rope deformations.

A kink is a deformation in the rope created by a loop that has been tightened without allowing for rotation about its axis. Unbalance of rope construction due to kinking will make a certain area of the rope disproportionately susceptible to excessive wear (see Figure 18, Part a). Bends are angular deformations of the rope caused by external influence (see Figure 18, Part b).

Scrubbing and crushing of wire rope as shown in Figure l9, Parts a, b, and c can be caused by improperly winding the rope on the winch drum. Flattening of wire rope (see Figure 19, Part d) may occur if the rope escapes from the winch drum and is pinched between the drum and another member. These problems are normally caused by a malfunction of the

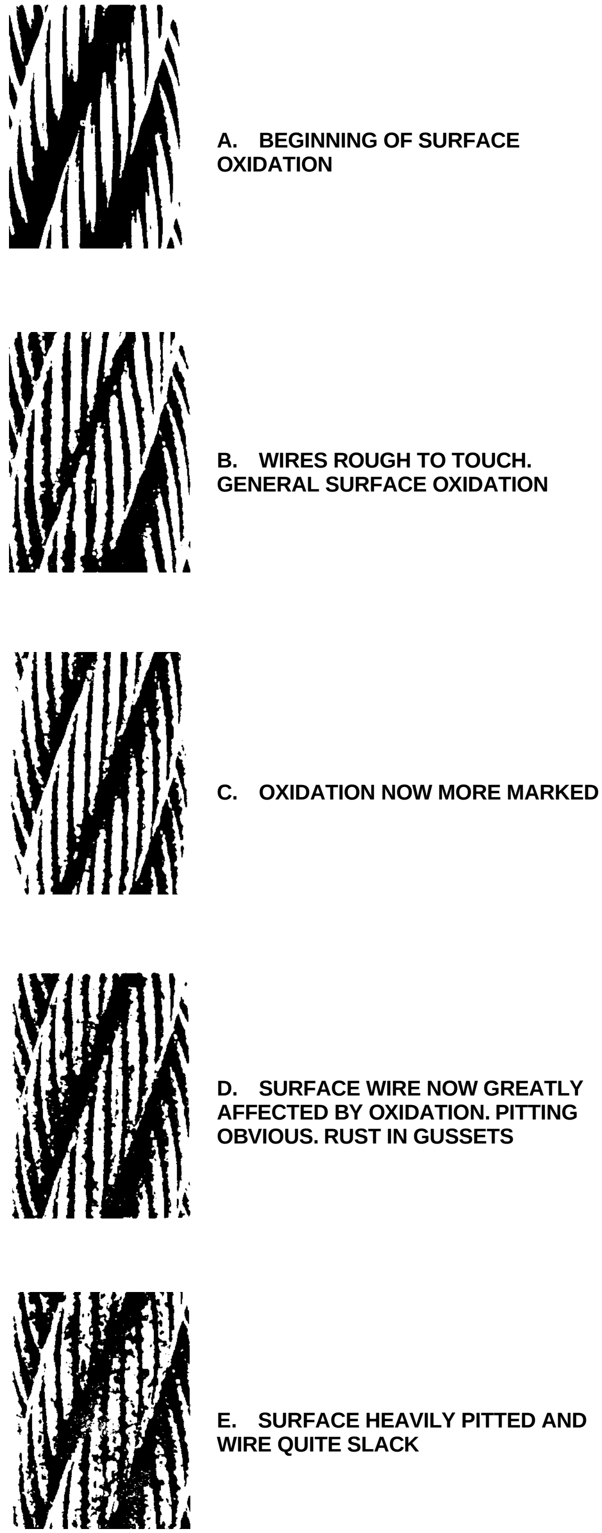

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Figure 15—Progression of External Corrosion

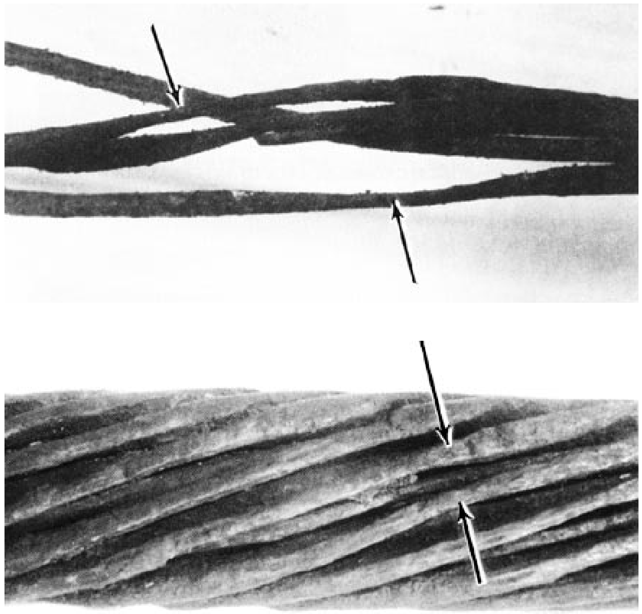


Figure 16—Wear of Internal Wires Caused by Lack of Lubricant Between Wires

level wind or failure to maintain proper line tension while winching.

Wire ropes with only slight deformations would lose no significant strength. Severe distortions, however, can accelerate wire rope deterioration and lead to premature rope failure.

4.1.7 THERMAL DAMAGE

Serious heat damage to a mooring wire rope is rare in normal service. Nevertheless, prompt attention should be given to any indication that excessively high or low temperature has caused damage to the rope.

Minor variations in temperature may affect the lubricant. When heated, some lubricants become thin and drip off; and when cooled, some oils and greases stiffen and lose lubricity.

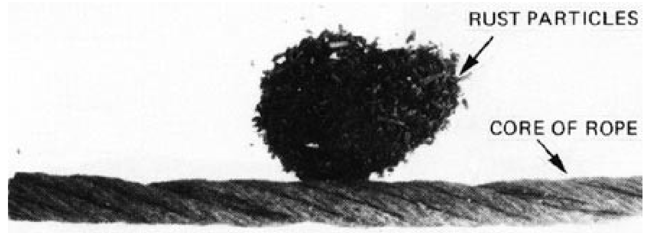
Sustained usage at temperatures in excess of 400°F may cause metallurgical changes in a wire rope, with accompanying tensile and fatigue strength reductions. Such temperatures can occur in electrical arcing or exposure to fire, flame, or hot gases. Discoloration of the metal can indicate thermal damage.

The effect of temperatures below 0°F on wire rope is unclear except for their known detrimental effect on lubricants. No published data on wire rope performance at low temperatures and under normal loads is known.

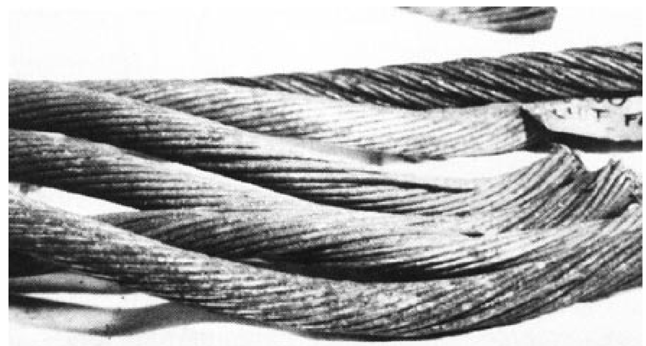
4.2 Recommended Inspection Method

4.2.1 GENERAL

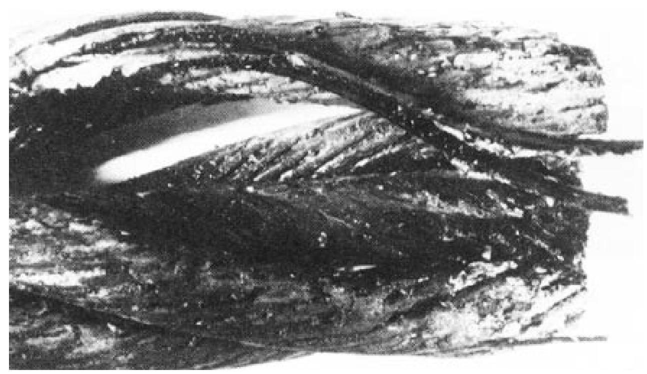
In-service wire rope for mobile offshore drilling units is usually inspected with the assistance of a workboat as shown



A. HEAVY CORROSION CAUSED BY LACK OF INTERNAL LUBRICATION



B. DRY ROPE WITH NO INTERNAL LUBRICATION. INTERNAL WEAR AND CORROSION ARE NOT OBVIOUS BUT MAY SOON DEVELOP



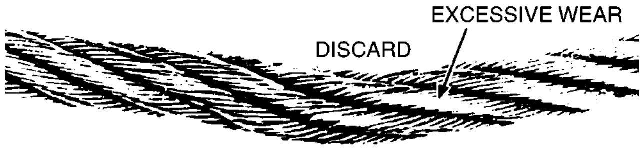
C. ROPE WITH PROPER INTERNAL LUBRICATION. NO INTERNAL WEAR AND CORROSION EXPECTED

Figure 17—Effect of Internal Lubrication on Wire Rope

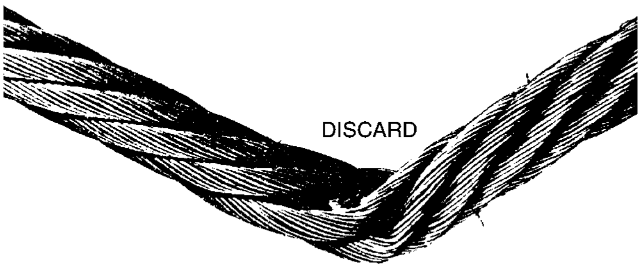
in Figure 20. Two common methods for wire rope inspection are described below.

4.2.2 INSPECTION DURING ANCHOR RETRIEVAL

The wire rope is inspected in conjunction with anchor retrieval. Such inspection requires no additional equipment since a workboat is always available during anchor retrieval. However, the inspection can substantially slow down the anchor retrieval operation and delay a rig move schedule.



A. WEAR AND DEFORMATION CREATED AT A PREVIOUSLY KINKED PORTION OF ROPE



B. EXAMPLE OF SEVERE BEND

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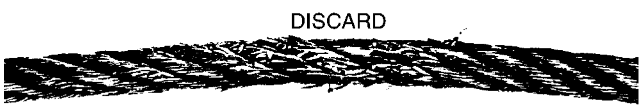
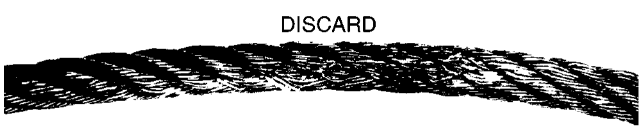
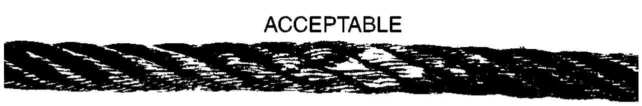
Figure 18—Kink and Bend of Wire Rope



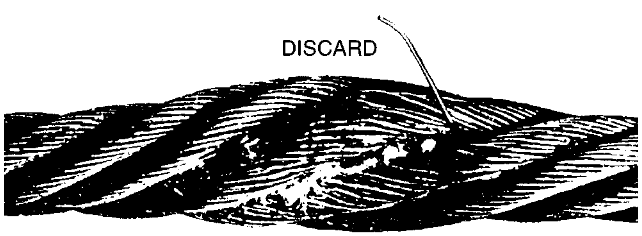
A. SCRUBBING AT CROSS-OVER OR FLANGE TURNBACK, LARGE NUMBER OF BROKEN WIRES



B. LAYER TO LAYER CRUSHING RESULTING IN BROKEN WIRES



C. LAYER TO LAYER CRUSHING



D. FLATTENED PORTION DUE TO LOCAL CRUSHING, CREATING UNBALANCE IN THE STRANDS AND ASSOCIATED WITH BROKEN WIRES

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Source: D Reprinted with permission of American Iron and Steel Institute, from *Wire Rope User's Manual,* © 1981 American Iron and Steel Institute.

Figure 19—Deformation Caused by Improper Drum Winding

4.2.3 DOCKSIDE INSPECTION

The drilling vessel stays in a dock or harbor for repair, special survey, and the like, and a workboat is contracted for the wire rope inspection. This method has two disadvantages. First, the inspection is economical only when it coincides with rig repair or special survey. Second, because the rig's location is close to land, the radius for workboat operation can be limited on one side of the rig. To inspect all mooring lines, rotating the rig 180 degrees would be necessary in some cases, and this would delay the inspection and increase operating costs. Therefore, inspection during anchor retrieval is preferred.

4.3 Recommended Inspection Procedure

4.3.1 PERSONNEL

The recommended inspection procedure includes the following personnel and their duties:

a. The winch operator runs and stops the winch on the order of the chief inspector.
b. The chief inspector coordinates the work among inspection personnel, gives orders to the winch operator, performs visual inspections and measurements, and rejects or accepts wire rope.
c. The assistant inspector keeps inspection records, performs visual inspections, and assists with measurements.
d. Roughnecks assist with inspections.

4.3.2 EQUIPMENT

The following equipment is often needed in wire rope inspection; its need and availability should be checked before the inspection is started.

a. Workboat.
b. Rope calipers (see Figure 21, Part b).
c. High-pressure hose.
d. Cutting torch.
e. Wire rope sockets and filler.
f. Lighting equipment.
g. Parallel-jaw pliers.
h. Camera.
i. Tape recorder.
j. Measuring tape.
k. Sheave gauge.

4.3.3 LENGTH OF ROPE COVERED BY INSPECTION

Although it is desirable to inspect the whole mooring line, it may be impractical in many cases because of operational constraints. As a general rule, inspection should cover at least the maximum outboard line length that could be deployed.

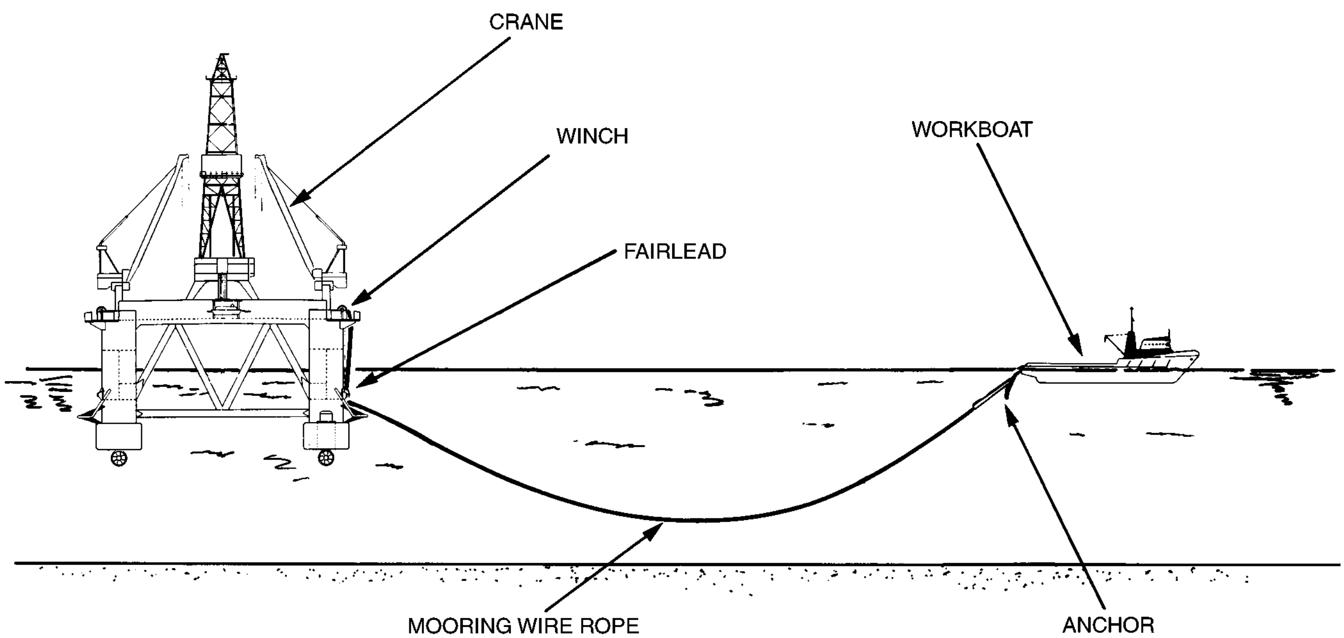


Figure 20—Wire Rope Inspection with the Assistance of a Workboat

The inspector should determine the length of rope covered by inspection based on rope deployment history and future operations plan.

4.3.4 ARRANGEMENT

Wire rope inspection is carried out with the assistance of a workboat as shown in Figure 20. The workboat first picks up the anchor and then moves away from the drilling vessel. At the same time, the drilling vessel pays out the mooring line until the predetermined outboard line length is reached. Then the workboat moves back slowly toward the drilling vessel while the winch on the vessel takes in the mooring line of no more than 30 feet per minute. For more thorough inspection, lower speed of 15 feet to 20 feet per minute is recommended.

The inspectors should stand close to the winch or wherever lighting is adequate and communication with the winch operator is convenient.

4.3.5 CLEANING

The portion of rope covered by mud should be cleaned with a high-pressure fire hose. Marine growth should be removed where measurements and close examinations are to be performed.

4.3.6 INSPECTION STEPS

4.3.6.1 Visual Inspection

While the line is slowly taken in, the inspectors should look carefully for signs of abnormalities such as broken wires, excessive wear, corrosion, or physical deformations. They shall examine closely any observed abnormality in the wire rope, with the line movement stopped. The inspector should record the nature of each observed abnormality and make appropriate measurements and estimates to quantify the damage.

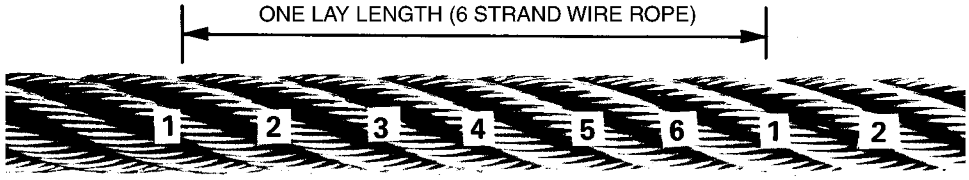
The termination should be closely examined, and the seizing at the termination should be removed to facilitate the detection of broken wires. Particular attention should also be given to the portion of rope against fairlead, previous problem areas, and areas in the splash zone.

4.3.6.2 Measurement

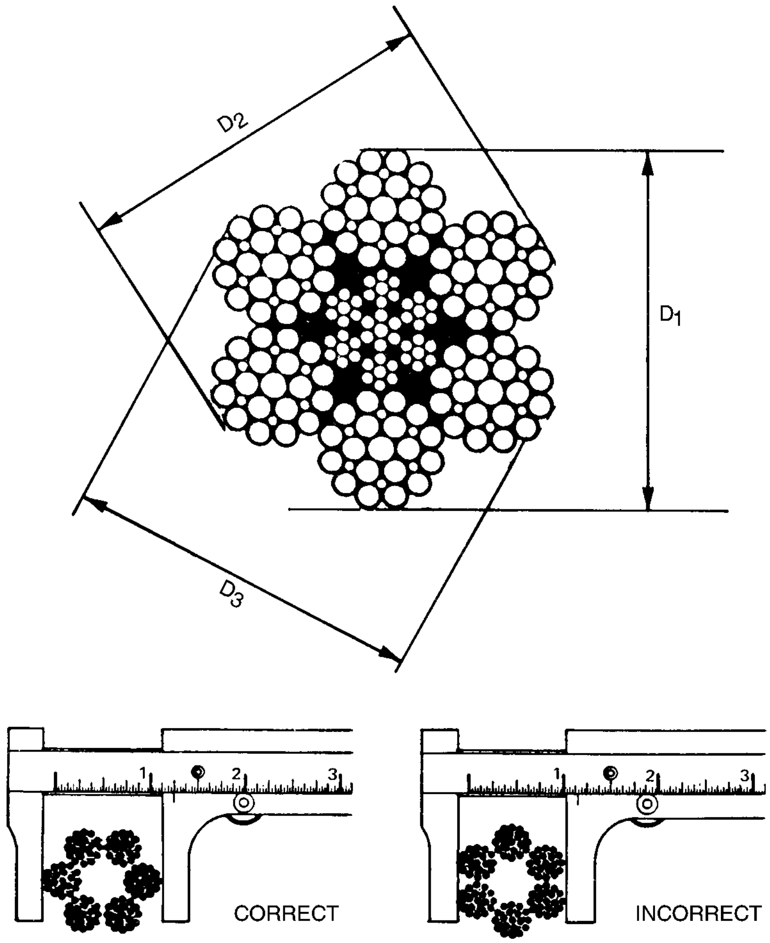
The inspector should measure the distance of three lay lengths and wire rope diameters in three directions as shown in Figure 21 at the beginning, middle, and the end of the portion of the rope being inspected. If substantial diameter reduction or rope stretching is found, further measurements should be taken along the line. In addition to these measurements, the general condition of the rope, such as degree of wear and corrosion at the three places, should also be recorded.

4.3.6.3 Internal Inspection

4.3.6.3.1 Selection of rope for internal inspection should be made as follows: If all the wire ropes onboard the vessel are made by one manufacturer, at least one mooring line should be inspected for internal corrosion. Internal inspection should first be performed on the oldest rope or the rope with the most severe external corrosion if the ages of the ropes are not known. If internal corrosion is detected in the first rope



A. DEFINITION OF LAY LENGTH



B. DIAMETER MEASUREMENT

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Figure 21—Lay Length and Diameter Measurement

internally inspected, internal inspection should be performed on the rest of the ropes.

If the ropes are made by more than one manufacturer, the preceding practice should be followed for the ropes made by each manufacturer.

4.3.6.3.2 The internal inspection procedure is as follows:

a. Cut a length of approximately 15 feet to 20 feet of rope at the end. Remove a 2-foot to 3-foot section from the cut end and dismantle it for inspection of internal wires (see Figure 22).

b. If internal corrosion is observed, repeat step a. until a good internal condition is found. The lengths of rope to be removed in subsequent cuttings should be determined by the inspectors.

c. If no internal corrosion is found, reterminate the rope with a socket and put it in service again. An example of acceptable internal conditions is illustrated in Figure 17, Part c. It may be advisable to remove a rope section of 20 feet from the cut end (see Figure 22). A break test performed for this rope section may provide useful information on the remaining strength of the rope.

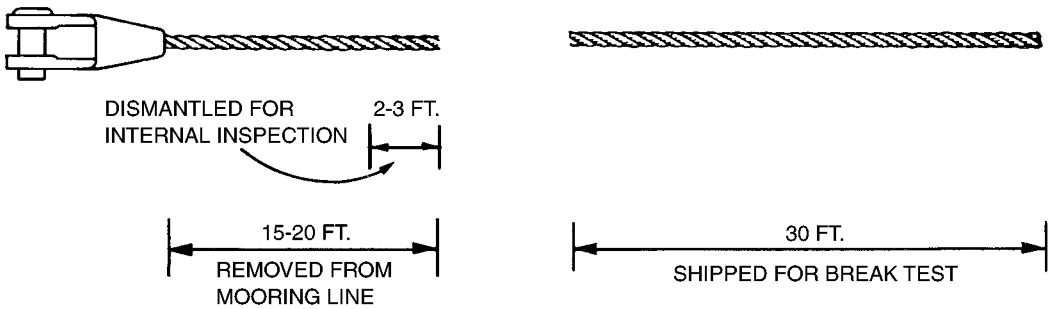


Figure 22—Internal Inspection of Wire Rope

4.3.6.4 Inspecting the Last Portion of Rope

Inspecting the last approximately 200 feet of wire rope is difficult for an all-wire-rope system. However, if the location of the wire rope can be reached by crane, and deck space on the vessel is available, the anchor and the last portion of the wire rope can be picked up and laid on deck by the crane for inspection. Otherwise, the anchor and the last portion of wire rope can be brought on board the workboat and inspected there.

4.3.6.5 Inspecting Anchor Jewelry and Miscellaneous Items

All anchor jewelry such as anchor shackles, swivels, open links, and connecting links should be inspected in the manner specified in Section 3.

Sockets for reterminating wire rope should be visually inspected. In addition, the eyes of the sockets should be examined by MPI. Open links, connecting links, and shackles used to connect wire rope, and chain should be inspected by the same method for anchor jewelry inspection (see Figure 6).

4.3.6.6 Inspection Record

The following should be recorded on the inspection record:

a. The manufacturer, size, construction, grade of steel, coating (galvanized or not), and age of the wire ropes.

b. The operation history, including inspection and failure history and previous operating locations.

c. The inspection date and names of inspectors.

d. Locations and nature of all wire rope abnormalities, and corrective measures taken.

e. Wire rope diameter and lay length measurements, and general conditions where the measurements are taken.

f. Recommendations for further action to be taken.

4.4 Guidelines for Rejecting Wire Rope

4.4.1 GENERAL

A wire rope should be rejected when any of the following conditions is found. In each case, the rope should be replaced or the damaged portion removed as prescribed.

4.4.2 DISTRIBUTED CROWN BROKEN WIRES

The number of visible broken wires distributed within a lay length reaches or exceeds the limits presented in Table 3. These limits are equivalent to about an 8 percent reduction in cross-sectional area of the rope or a 10 percent reduction in strength when unbalance of load is taken into consideration. Rope constructions listed in Table 3 are commonly used in mooring wire ropes and are illustrated in Figure 23. (A lay length is the distance parallel to the axis of the rope in which a strand makes one complete helical convolution about the core. For a six-strand regular lay rope, a lay length is about 6 times to 7 times the nominal diameter, as shown in Figure 21, Part a).

Table 3—Criteria for Crown Broken Wires

Rope Construction	Number of Outer Wires in a Strand	Number of Distributed Broken Wires in One Lay Length	Number of Adjacent Broken Wires in One Strand	Number of Broken Wires at Termination
6 x 26	10	8	3	3
6 x 25 or 6 x 31	12	10	4	4
6 x 36	14	13	5	5
6 x 41 or 6 x 49	16	17	6	6
6 x 46	18	21	8	8
Equivalent reduction in cross-sectional area[a]		8%	3%	3%

[a]This information can be used to calculate the allowable number of broken wires for rope constructions not listed in this table.

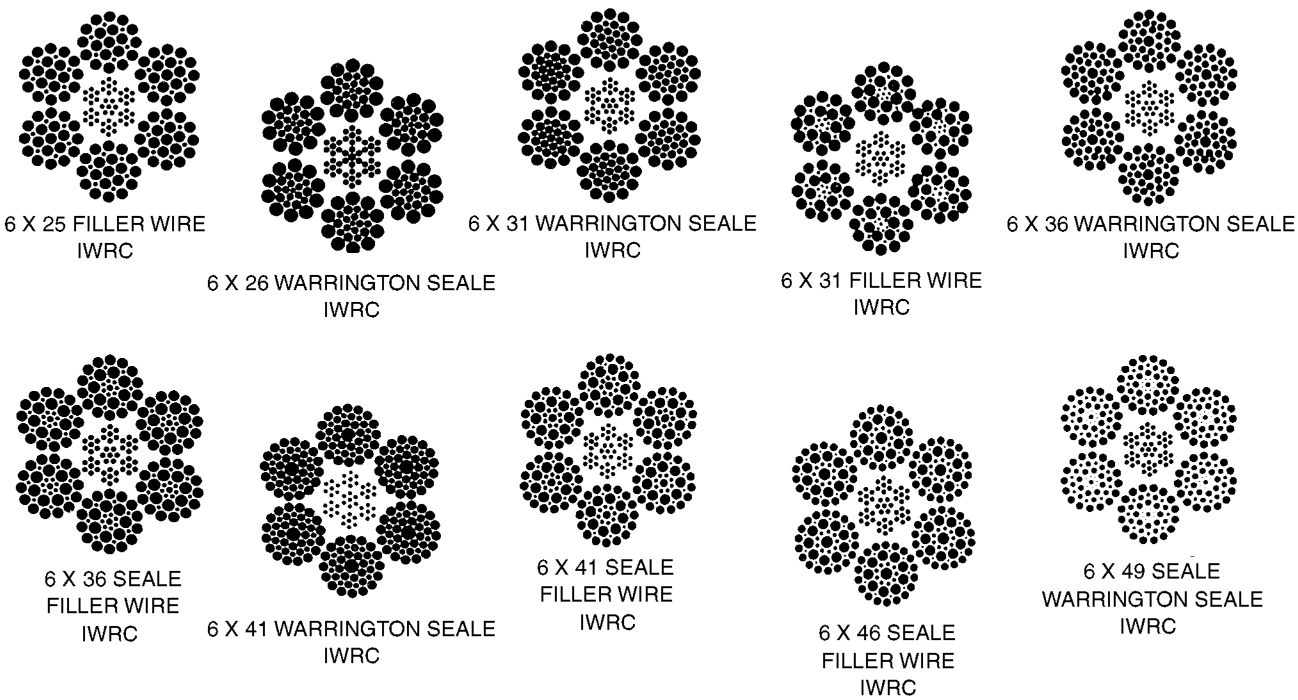


Figure 23—Common Rope Constructions for Mooring Applications

4.4.3 GROUPED BROWN BROKEN WIRES

In this group, the number of adjacent broken wires in one strand reaches or exceeds the limits presented in Table 3. These limits are equivalent to about a 3 percent reduction in the cross-sectional area of the rope or a 17 percent reduction in the cross-sectional area of the strand. This criterion applies to damages concentrated in a small area of a strand as shown in Figure 11.

4.4.4 VALLEY BROKEN WIRES

In this group, two adjacent wires are broken in the valley. A valley break is initiated at the interface between two strands. One should discern a valley break from a wire break that is initiated at the crown of a strand first, and broken off at the valley later.

4.4.5 BROKEN WIRES AT TERMINATION

In this group, the number of broken wires within 12 inches of the termination reaches or exceeds the limits presented in Table 3. These limits are equivalent to about a 3 percent reduction in cross-sectional area of the rope.

Rope replacement is normally not required for this condition, but a minimum of 15 feet of rope at the end should be removed and the rope reterminated. Both spelter (zinc) poured and resin sockets are acceptable. Recommended procedures for retermination of wire rope can be found in Appendix B.

4.4.6 WEAR AND STRETCH

In this group, the average of the three measured diameters is less than 94 percent of the nominal diameter.

4.4.7 INTERNAL CORROSION AND WEAR

In this group, internal corrosion and wear are observed. The wire rope shown in Figure 17, Part a is an example of extreme internal corrosion. However, a clear indication of internal corrosion and wear combined with a lack of lubrication is a justification for discard.

Where internal corrosion and wear are not obvious but internal lubrication is absent, as shown in Figure 17, Part b, the rope is acceptable for use temporarily; however, internal inspection should be repeated within six months.

4.4.8 DEFORMATIONS

Deformations include any of the conditions listed below:

a. Kinking.
b. Severe bending.
c. Severe scrubbing.
d. Severe crushing.
e. Severe flattening.

Since it is difficult to quantify wire rope deformations, the decision to accept or reject a deformed rope must depend on the experience and judgment of the inspector. As a point of reference, Figures 18 and 19 illustrate acceptable and unacceptable wire rope deformations.

4.4.9 CORE DETERIORATION

In this group, there is an abrupt reduction in the diameter (see Figure 12), which is usually accompanied by an increase in lay length.

4.4.10 SUMMARY

Each of the preceding guidelines deals with one type of wire rope damage, but sometimes several types of damage may occur in one area of a wire rope. Even though none of the guidelines is violated, the rope should be rejected when the combined effect of the damage jeopardizes the integrity of the rope. Consider a case, for example, where the number of distributed broken wires in one area of a rope is less than, but close to, the limit specified in Table 3, and in addition this area has considerable external corrosion and wear. In this case, the rope should be replaced as soon as possible.

4.5 Recommended Inspection Schedule

Inspection should be scheduled according to the conditions of the rope detected during the prior inspection. If the condition of the rope is close to a rejection criterion, more frequent inspections should be made. However, the inspection intervals should not exceed those specified in Table 4.

Table 4—Rope Inspection Intervals

Number of Years in Service	Maximum Intervals Between Major Inspections
0–2	18 months
3–5	12 months
over 5	9 months

4.6 Recommendations for Proper Use and Maintenance of Mooring-Wire Rope

Recommendations for proper use and maintenance of mooring-wire rope are as follows:

a. Reterminate mooring-wire rope on mobile offshore drilling units every 18 months. A minimum of 15 feet of rope should be cut and the rope reterminated.

b. When deploying wire rope on hard seafloor, maintain proper tension in the rope by applying the dynamic brake to avoid dragging the wire rope on the seafloor.

c. Maintain a tension when winching in the mooring lines.

d. Avoid, if possible, test loading anchors when the wire rope is at the riser point where a new layer starts on the winch drum.

e. Gauge the fairlead sheave grooves at convenient times, such as during special survey or rig repair. If the groove is substantially under gauge, replace or repair the fairlead sheave. The radius of the fairlead sheave groove should not be less than the minimum radius for worn groove specified in Table 5. Fairlead sheaves should also be carefully evaluated for oversize grooves which can also cause damage to the wire rope.

f. Check the level wind of the winch periodically to ensure its proper function.

4.7 Inspection of Anchor-handling Equipment and Termination of Pendant Wire Rope

4.7.1 INSPECTION

The anchor-handling equipment on the workboat should be inspected to ensure a safe operation. The discard criteria for mooring-wire rope would equally apply to wire ropes for pendant lines and work lines on a workboat. However, the inspection method, procedure, and schedule for pendant wire rope could be substantially different and should be determined by the operating personnel based on their experience, the pendant system, and the equipment on the workboat.

Miscellaneous connecting hardware, such as sockets, shackles, and connecting links for pendant lines and work lines, should be inspected in the same manner described in previous sections. Pelican hooks and similar devices for temporarily securing a pendant line should be examined by MPI.

4.7.2 TERMINATION

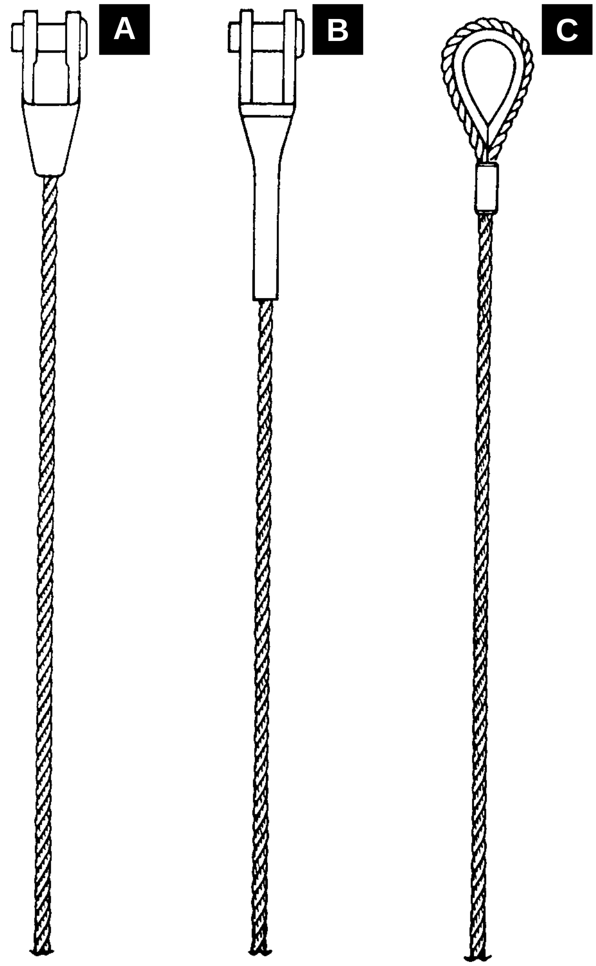
Three types of wire rope termination are acceptable for pendant lines: spelter-poured or resin socket, swagged socket, and thimbled mechanical splice, as shown in Figure 24. The swagged sockets and thimbled mechanical splices should be made at the manufacturers' facilities. Only the spelter-poured and resin sockets can be made in the field.

Recommended procedures for making spelter- (zinc-) poured socket and thermo-set resin socket can be found in Appendix B.

Table 5—Minimum Sheave-Groove and Drum-Groove Dimensions

Nominal Rope Diameter		Groove Radius			
		New		Worn	
inches	mm	inches	mm	inches	mm
¼	6.4	0.135	3.43	0.129	3.28
5⁄16	8.0	0.167	4.24	0.160	4.06
⅜	9.5	0.201	5.11	0.190	4.83
7⁄16	11	0.234	5.94	0.220	5.59
½	13	0.271	6.88	0.256	6.50
9⁄16	14.5	0.303	7.70	0.288	7.32
⅝	16	0.334	8.48	0.320	8.13
¾	19	0.401	10.19	0.380	9.56
⅞	22	0.468	11.89	0.440	11.18
1	26	0.543	13.79	0.513	13.03
1⅛	29	0.605	15.37	0.577	14.66
1¼	32	0.669	16.99	0.639	16.23
1⅜	35	0.736	18.69	0.699	17.75
1½	38	0.803	20.40	0.759	19.28
1⅝	42	0.876	22.25	0.833	21.16
1¾	45	0.939	23.85	0.897	22.78
1⅞	48	1.003	25.48	0.959	24.36
2	52	1.085	27.56	1.025	26.04
2⅛	54	1.137	28.88	1.079	27.41
2¼	58	1.210	30.73	1.153	29.29
2⅜	60	1.271	32.28	1.199	30.45
2½	64	1.338	33.99	1.279	32.49
2⅝	67	1.404	35.66	1.339	34.01
2¾	71	1.481	37.62	1.409	35.79
2⅞	74	1.544	39.22	1.473	37.41
3	77	1.607	40.82	1.538	39.07
3⅛	80	1.664	42.27	1.598	40.59
3¼	83	1.731	43.97	1.658	42.11
3⅜	87	1.807	45.90	1.730	43.94
3½	90	1.869	47.47	1.794	45.57
3¾	96	1.997	50.72	1.918	48.72
4	103	2.139	54.33	2.050	52.07
4¼	109	2.264	57.51	2.178	55.32
4½	115	2.396	60.86	2.298	58.37
4¾	122	2.534	64.36	2.434	61.82
5	128	2.663	67.64	2.557	64.95
5¼	135	2.804	71.22	2.691	68.35
5½	141	2.929	74.40	2.817	71.55
5¾	148	3.074	78.08	2.947	74.85
6	154	3.198	81.23	3.075	78.11

Note: Values given are applicable to grooves in sheaves and drums; they are not generally suitable for pitch design since this may involve other factors. Further, the dimensions do not apply to traction-type elevators; in this circumstance, drum- and sheave-groove tolerances should conform to the elevator manufacturer's specifications. Modern drum design embraces extensive considerations beyond the scope of this publication. It should also be noted that drum grooves are now produced with a number of oversize dimensions and pitches applicable to certain service requirements.



A. SPELTER POURED OR RESIN SOCKET (MANUFACTURED OR FIELD MADE)

B. SWAGGED SOCKET (MANUFACTURED ONLY)

C. THIMBLED MECHANICAL SPLICE (MANUFACTURED ONLY)

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Figure 24—Acceptable Terminations for Pendant Wire Rope

APPENDIX A—RECOMMENDED PROCEDURES FOR MAGNETIC PARTICLE INSPECTION (MPI)

The following procedures are recommended for MPI:

a. Use qualified MPI inspectors such as those qualified to ASNT Level II or equivalent.

b. Sandblast surfaces to receive MPI inspection if practical. For areas where sandblasting is not feasible, degreasers, high pressure water equipment, and hand and power wire brushes can be used for surface preparation.

c. Use electromagnetic yokes to achieve magnetization if practical. The use of prods is not advised. Continuous, rather than residual, magnetization is recommended during inspection. Other techniques can be applied by agreement.

d. Use unrectified single-phase AC current. If this current is not available, other types of current can be used.

e. Demonstrate proper magnetization and areas of coverage in calibration tests using test specimens containing cracks or a magnetic field strength indicator.

f. Use a contrast coating before inspection to enhance indications. Suggested color combinations include yellow coating for black particles, and white or yellow coating for red particles. The coating should cover the area to be inspected, but not the area of contact with the yoke.

g. Use wet magnetic particles from mist-driven applicators or squeeze bottles. Identify all indications directly on the steel surface for subsequent evaluation. Carry out grinding or repair only by agreement.

h. Demagnetization is normally not necessary. It is performed only under special circumstances.

i. Refer to ASTM E709 or equivalent specifications for MPI procedural details not covered herein.

APPENDIX B—SOCKETING

B.1 Zinc-poured Socketing

The following steps should be carefully adhered to in the order given.

a. Measure the rope ends to be socketed. The rope end should be of sufficient length so that the ends of the unlaid wires (from the strands) will be at the top of the socket basket. (see Figure B-1, View l).
b. Apply serving at base of socket. Apply a tight wire serving band at the point where the socket base will be, for a length of two rope diameters. (see Figure B-1, Views 2 and 3).
c. Broom-out strand wires. Unlay and straighten the individual rope strands and spread them evenly so that they form an included angle of approximately 60 degrees. Unlay the wires of each individual strand for the full length of the rope end—being careful not to disturb or change the lay of the wires and strands under the serving band. Unlay the wires of an independent wire rope core in the same manner. A fiber core should be cut out and removed as close to the serving band as possible (see Figure B-1, View 3).
d. Clean the broomed-out ends. A suggested cleaning solvent for this step is SC-5 methyl chloroform. It is also known under the names Chlorothane VG and 1-1-1 Trichlorethane.

CAUTION: Breathing the vapor of this solvent is harmful; it should only be used in a well-ventilated area. Be sure to follow the solvent manufacturer's instructions, and carefully observe all instructions printed on the label.

Swish the broomed-out rope end in the solvent, then brush vigorously to remove all grease and dirt—making certain that the wires are clean to the very bottom close to the serving band (Figure B-1, View 4). Additionally, a solution of muriatic acid may also be used. If, however, acid is used, the broomed-out ends should be rinsed in a solution of bicarbonate of soda so as to neutralize any acid that may remain on the rope. Care should be exercised to prevent acid from entering the core; this is particularly important if the rope has a fiber core. Where it is feasible, the best and preferred cleaning method for rope ends prior to socketing is ultrasonic cleaning. After this cleaning step, place the broomed-out end upright in a vise, allowing it to remain until all solvent has evaporated and the wires are dry.

Solvent should never be permitted to remain on the rope or on the serving band since it will run down the wires when the rope is removed from the vise.
e. Dip the broomed-out rope ends in flux. Prepare a hot solution of zinc-ammonium chloride flux comparable to Zaclon K. Use a concentration of 1 pound of zinc-ammonium chloride to 1 gallon of water; maintain this at a temperature of 180°F to 200°F. Swish the broomed-out end in the flux solution, then place the rope end upright in the vise until such time as the wires have dried thoroughly (see Figure B-1, View 5).
f. Close rope ends and place socket. Use clean wire to compress the broomed-out rope end into a tight bundle that will permit the socket to be slipped on easily over the wires (see Figure B-1, View 6). Before placing the socket on the rope, make certain that the socket itself is clean and heated. This heating is necessary in order to dispel any residual moisture, and to prevent the zinc from cooling prematurely.

CAUTION: Never heat a socket after it is placed on the rope. To do so may cause heat damage to the rope.

After the socket is on the rope end, the wires should be distributed evenly in the socket basket so that zinc can surround each wire. Use extreme care in aligning the socket with the rope's centerline and in making certain that there is a minimum vertical length of rope extending from the socket, that is equal to about 30 rope diameters (see Figure B-1, View 7).

Seal the socket base with fire clay or putty, but make certain that this material does not penetrate *into* the socket base. Should this occur, it would prevent the zinc from penetrating the full length of the socket basket thereby creating a void that would collect moisture after the socket is placed in service.
g. Pour the zinc. The zinc used should meet ASTM Specification designation B6 Grade (1) High Grade, and Federal Specification QQ-Z-351-a Amendment I, Interim Amendment 2. Pour the zinc at a temperature of 950°F to 970°F (see Figure B-1, View 8); make allowances for cooling if the zinc pot is more than 25 feet from the socket.

CAUTION: Do not heat zinc above 1200°F, or its bonding properties will be lost.

The zinc temperature may be measured with a portable pyrometer or a Tempilstik. Remove all dross before pouring. Pour the zinc in one continuous stream until it reaches the basket top and all wire ends are covered; there should be no "capping" of the socket.
h. Remove serving. Remove the serving band from the socket base; check to make certain that zinc has penetrated to the socket base (see Figure B-1, View 9).
i. Lubricate the rope. Apply wire rope lubricant to the rope at the socket base and on any rope section where the original lubricant may have been removed.

B.2 Thermo-set Resin Socketing

B.2.1 PROCEDURES

Before proceeding with a thermo-set resin-socketing procedure, check manufacturer's instructions carefully. Give particular attention to selecting sockets that have been specifi-

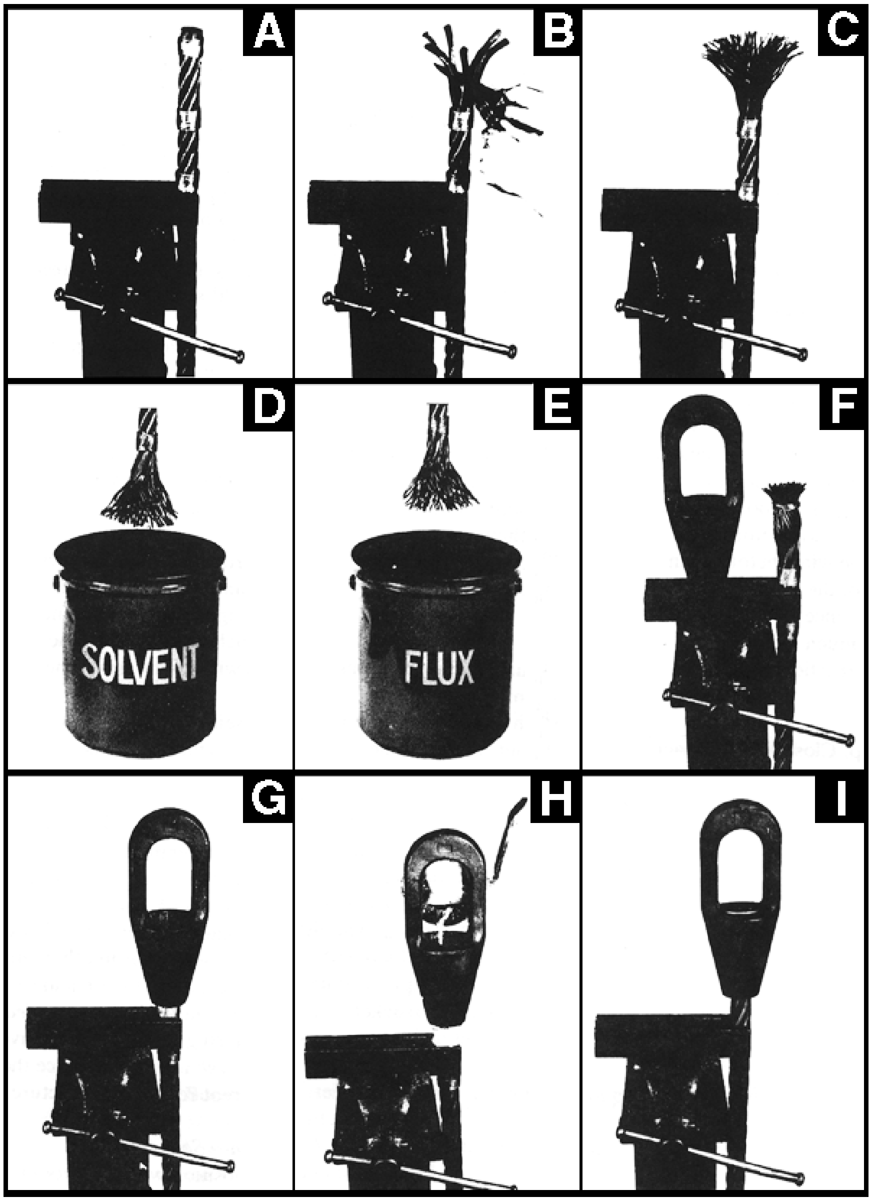

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Figure B-1—Zinc-poured Socketing Procedure

cally designed for resin socketing. Follow the steps, outlined below, or manufacturer's directions, in the order given.

a. Seizing and cutting the rope. Follow rope manufacturer's directions for a particular rope size or construction with regard to the number, position, length of seizings, and the seizing-wire size. The seizing, located at the base of the installed fitting, must be positioned so that the ends of the embedded wires will be slightly below the level of the top of the fitting's basket. The best means to cut the rope is with an abrasive wheel.

b. Opening and brooming the strand wires. Before opening the rope end, place a short temporary seizing directly above the seizing that represents the broom base. Temporary seizing prevents brooming the wires the full length of the basket and also prevents loss of lay in the strands and rope outside the socket. Remove all seizing between the end of the rope and the temporary seizing. Unlay the strands comprising the rope. Starting with the IWRC, or strand core, open each strand of the rope and broom or unlay the individual wires. When the brooming is completed, wires should be distributed evenly within a cone so that they form an included angle of approximately 60 degrees. Some types of sockets will require a somewhat different brooming procedure, in which case the manufacturer's instructions should be followed.

Note: (Note: A fiber core in the rope may be cut at the base of the seizing; some prefer to leave the core in. Consult the manufacturer's instruction.)

c. Cleaning the wires and fittings. Different types of resin with different characteristics require varying degrees of cleanliness. In some cases, merely using a soluble cleaning oil has been found effective. For one type of polyester resin, on which over 800 tensile tests on ropes in sizes ¼ inch to 3 ½ inch diameter were made without failure in the resin socket attachment, the cleaning procedure was as follows:

Clean wires thoroughly so as to obtain resin adhesion. Ultrasonic cleaning in recommended solvents such as trichloroethylene, 1-1-1 trichloroethane, or other non-flammable grease-cutting solvents is the preferred method of cleaning the wires in accordance with OSHA Standards. Where ultrasonic cleaning is not available, brush or dip-cleaning in trichloroethane may be used, but fresh solvent should be used for each rope and fitting and discarded after use. After cleaning, the broom should be dried with clean compressed air or in other suitable fashion before proceeding to the next step. The use of acid to etch the wires before resin socketing is *unnecessary and not recommended*. Also, the use of a flux on the wires before pouring resin should be avoided since *this adversely affects resin bonding to the steel wires*. Since there is much variation in the properties of different resins, manufacturers' instructions should be carefully followed.

d. Closing rope ends and placing socket. Place rope in a vertical position with the broom end up. Close and compact the broom to permit insertion of the broomed end into the base of the fitting. Slip the fitting on, removing any temporary banding or seizing as required. Make certain that the broomed wires are uniformly spaced in the basket, with wire ends slightly below the top edge of the basket, and that the axis of the rope and the fitting are aligned. Seal the annular space between the base of the fitting and the exiting rope to prevent leakage of the resin from the basket. A non-hardening butyl rubber-base sealant is satisfactory for this purpose. Make sure that the sealant does not enter the base of the socket so that the resin will be able to fill the complete depth of the socket basket.

e. Pouring the resin. Controlled heat-curing (no open flame) at a temperature range of 250°F to 300°F is recommended. If ambient temperatures are less than 60°F, this is *required!* When controlled heat curing is not available and ambient temperatures are not less than 60°F, the attachment should not be disturbed, and tension should not be applied to the socketed assembly for at least 24 hours.

f. Lubrication after socket attachment. After the resin has cured, relubricate the wire rope at the base of the socket to replace any lubricant that may have been removed during the cleaning operation.

g. Acceptable resin types. Commercially-available resin properties vary considerably. Hence, it is important to refer to the individual manufacturer's instructions before using any one type. General rules cannot, of course, be established.

When properly formulated, most thermoset resins are acceptable for socketing. These formulations, when mixed, form a pourable material which will harden at ambient temperatures, or upon the application of moderate heat. No open flame or molten metal hazards exist with resin socketing since heat-curing, when necessary, requires a relatively low temperature (250°F to 300°F) obtainable by electric resistance heating.

Tests have demonstrated that satisfactory wire rope socketing performance can be obtained with resins having characteristics and properties as follows:

B.2.2 GENERAL DESCRIPTION

The resin shall be a liquid thermoset material that will harden after being mixed with the correct proportion of catalyst or curing agent. The following properties should be noted:

a. Properties of liquid (uncured) material. Resin and catalyst are normally supplied in two separate containers. After thoroughly mixing them together, the liquid can be poured into the socket basket. Liquid resins and catalysts shall have the following properties:

1. Viscosity of the resin-catalyst mixture. Viscosity should be 30–40,000 CPS at 75°F immediately after mixing. Viscosity will increase at lower ambient temperatures, and resin may need warming prior to mixing in the catalyst if ambient temperatures drop below 40°F.
2. Flash point. Both resin and catalyst shall have a minimum flash point of 100°F.
3. Shelf life. Unmixed resin and catalyst shall have a minimum of 1-year shelf life at 70°F.
4. Pot life and cure time. After mixing, the resin-catalyst blend shall be pourable for a minimum of 8 minutes at 60°F and shall harden in 15 minutes. Heating of the resin in the socket to a maximum temperature of 250°F is permissible to obtain full cure.

b. Properties of cured resin. The following should be noted concerning properties of cured resin:

1. Socket performance. Resin shall exhibit sufficient bonding to solvent-washed wire in typical wire rope end fittings to develop the nominal strength of all types and grades of rope. No slippage of wire is permissible when testing resin-filled rope socket assemblies in tension. After testing, however, some "seating" of the resin cone may be apparent and is acceptable.

   Resin adhesion to wires shall be capable of withstanding tensile-shock loading.
2. Compressive strength. The minimum allowable compressive strength for fully cured resin is 12,000 pounds per squaring.
3. Shrinkage. Maximum allowable shrinkage is 2 percent. To control shrinkage, an inert filler may be used

in the resin provided that viscosity requirements as specified in B.2.2.a are met.

4. Hardness. The desired hardness of the resin is in the range of Barcol 40–55.

B.2.3 RESIN-SOCKETING COMPOSITIONS

Manufacturer's directions should be followed in handling, mixing, and pouring the resin composition.

B.2.4 PERFORMANCE OF CURED-RESIN SOCKETS

Poured-resin sockets may be moved after the resin has hardened. If one follows the ambient- or elevated-temperature cure, as recommended by the manufacturer, resin sockets should develop the nominal strength of the rope and have the capability of withstanding shock loading to a degree sufficient to break the rope without cracking or breakage. Manufacturers of resin-socketing material shall be required to test these criteria before resin materials will be approved for rope-socketing use.

A FINAL NOTE OF CAUTION: The foregoing discussion is a generalized description of but one of many commercially available thermo-set resins suitable for wire rope socketing. Characteristics of these products vary significantly and each must be handled differently. Thus, as noted earlier, specific information of any kind concerning any resin must be obtained from the individual manufacturer before setting up a resin-socketing procedure.

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