In-service Inspection of Mooring Hardware for Floating Structures

API RECOMMENDED PRACTICE 2I
THIRD EDITION, APRIL 2008

REAFFIRMED, JUNE 2015

energy API

AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, D.C. 20005, standards@api.org.

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Introduction

The third edition of API RP 2I is an extension of the second edition, which addresses in-service inspection of mooring components for MODUs only. Major changes of this edition include:

- inspection guidelines for steel permanent moorings on permanent floating installations are added;
- inspection guidelines for fiber ropes used for permanent and MODU moorings are included;
- special guidance for MODU mooring inspection in the areas of tropical cyclones is provided.

The third edition was developed in response to the need for inspection guidelines of permanent and fiber rope moorings in addition to MODU moorings. The additional guidelines are based on study results of joint industry projects (JIPs) and industry experience accumulated in the last 15 years operating a large number of MODUs and permanent floating installations. 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, comments and suggestions toward broadening and refining these guidelines are encouraged.

In-service Inspection of Mooring Hardware for Floating Structures

1 Scope

1.1 General

This recommended practice provides guidelines for inspecting mooring components of mobile offshore drilling units (MODUs) and permanent floating installations. Although this document was primarily developed for the moorings of MODUs and permanent floating installations, some of the guidelines may be applicable to moorings of other floating vessels such as pipe-laying barges and construction vessels. Furthermore, some of the guidelines may be applicable to secondary or emergency moorings such as moorings for jack-up units, shuttle tanker moorings, and dynamic positioning (DP) vessel harbor mooring.

The applicability of this document to the moorings of other floating vessels is left to the discretion of the user.

1.2 Purpose

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.

1.3 Inspection Philosophy and Exception to This Document

1.3.1 Inspection Philosophy

The inspection philosophy of this document is to remove a mooring component with excessive deterioration from service. Based on this philosophy, a criterion of limiting the strength reduction to 10 % minimum breaking strength (MBS) was established in the first edition of this document. This criterion has been used by the industry for more than 20 years with generally satisfactory results, and it has become a long standing and widely accepted criterion.

1.3.2 Inspection and Design Check

It should be emphasized that this document does not address the critical design issues such as tension factor of safety and fatigue, although some discussion is given to the design issue of corrosion allowance. Any attempt to link inspection with these critical design issues will make discard criteria a moving target, depending on design assumptions, analysis software used, margin of safety, and location of the operation, etc. Setting an industry inspection standard in this case is impossible. The design check should be conducted separately. If the design check indicates that the reliability of the mooring system can be overly compromised, the acceptance of a mooring component that passes the discard criteria should be carefully re-evaluated. On the other hand, if the design check indicates that the mooring component is significantly over-designed, and it can tolerate much more damage than allowed by this document, design calculations should be submitted to the appropriate authority asking for permission to take exception to API 2I. This process has been used by the industry under various conditions, and some examples are provided below.

— A MODU chain was found to have a large number of loose studs that exceeded the discard criteria and therefore should be replaced. However, the chain was accepted for continued service based on: 1) Break test of samples taken from the problem area indicated the chain retained more than 90 % MBS. 2) A fatigue analysis, taking into consideration the additional stress concentration at the stud footprint due to loose stud, indicated sufficient fatigue life for continuous operation.

— A mooring component was found to have lost 15 % of its strength, well exceeding the discard criteria of 10% MBS. A design check indicated the factors of safety were twice the required factors of safety for the operation. The component was accepted for continued service.

1.3.3 Safety of Inspection Personnel

Safety should be given high priority during mooring inspection. If a certain recommended inspection procedure poses a significant risk of jeopardizing the health and safety of the inspection personnel, the procedure should be modified to minimize the risk. However an effort should be made to ensure the inspection objectives are not compromised.

1.4 Mooring Component Traceability and Inspection Documentation

Since the inspection philosophy of this document is to remove a mooring component with excessive deterioration from service, it is important to keep a complete and auditable record of the component history. This component history shall be maintained in accordance with Annex A and shall include manufacturing, inspection, usage, and retirement records.

In cases where a complete component history for in-service mooring components is not available, decisions to keep a component in service should be based on its present condition and experience with components in similar services. Furthermore, a lack of historical documentation does not eliminate the need to maintain on-going documentation for future use.

2 Guidelines for In-service Inspection of MODU Mooring Chain and Anchor Jewelry

2.1 Common Problems with MODU 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 aware of are described in 2.1.1 to 2.1.8.

2.1.1 Missing Studs

A studlink chain 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.

2.1.2 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.

2.1.3 Corrosion

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

2.1.4 Sharp Gouges

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

2.1.5 Loose Studs

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

2.1.6 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 1b.

2.1.7 Wear

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

2.1.8 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.

2.2 Recommended Inspection Method

2.2.1 General

Chain installed on MODUs can be inspected by the two methods discussed in 2.2.2 and 2.2.3.

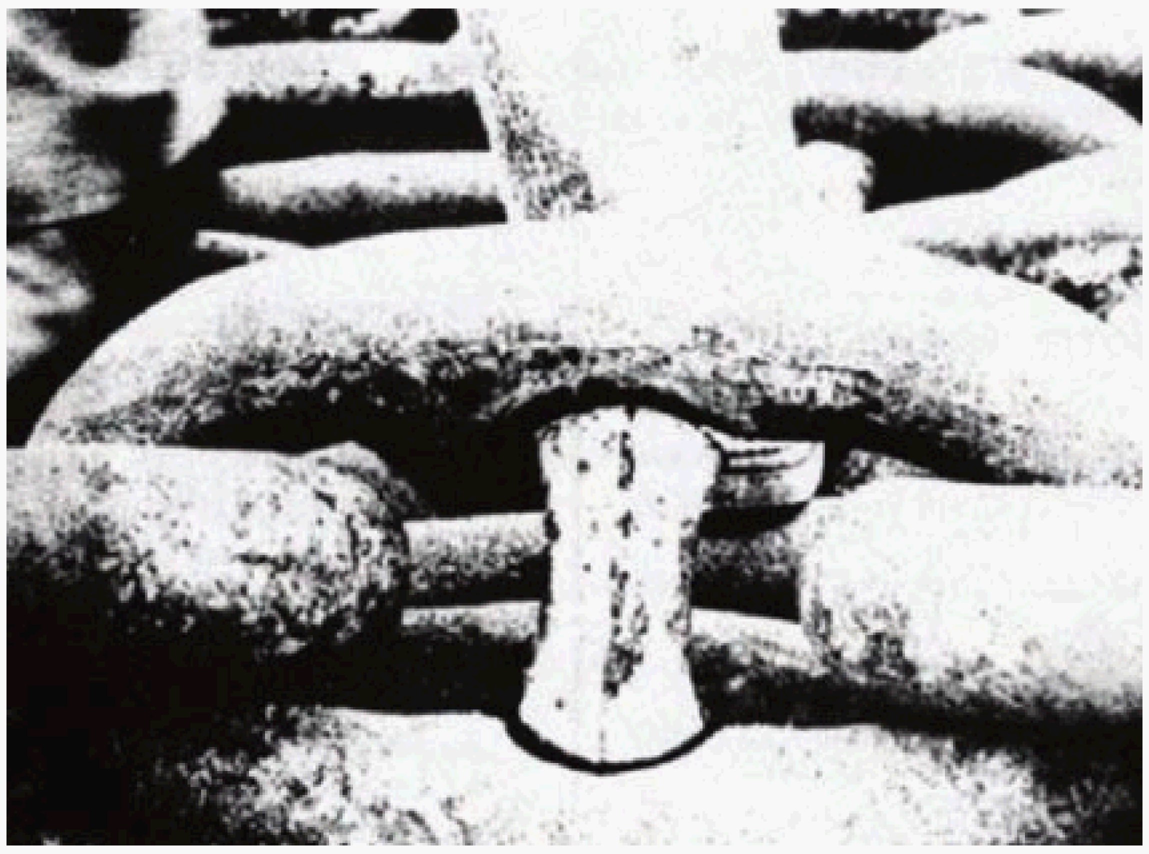
2.2.2 Dockside Inspection

As shown in Figure 3, the drilling vessel is taken into a dock, and the chain is laid out for inspection. Normally such chain inspection is carried out in conjunction 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, in this case, which should be accomplished under tension, would be inaccurate.

2.2.3 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.



a) Loose stud in 3-in. ORQ chain

b) Cracked stud weld in 3-in. ORQ chain

Figure 1—Typical Chain Stud Problems

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. Two disadvantages of the offshore inspection method and their correction measures are discussed in the following.

— Inspecting the last approximate 200 ft 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.

— Inspection of connecting links by MPI is suggested in 2.3. However, MPI is difficult and time consuming with the offshore inspection method; it could substantially increase workboat waiting time and delay the MODU 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 the chain inspection.

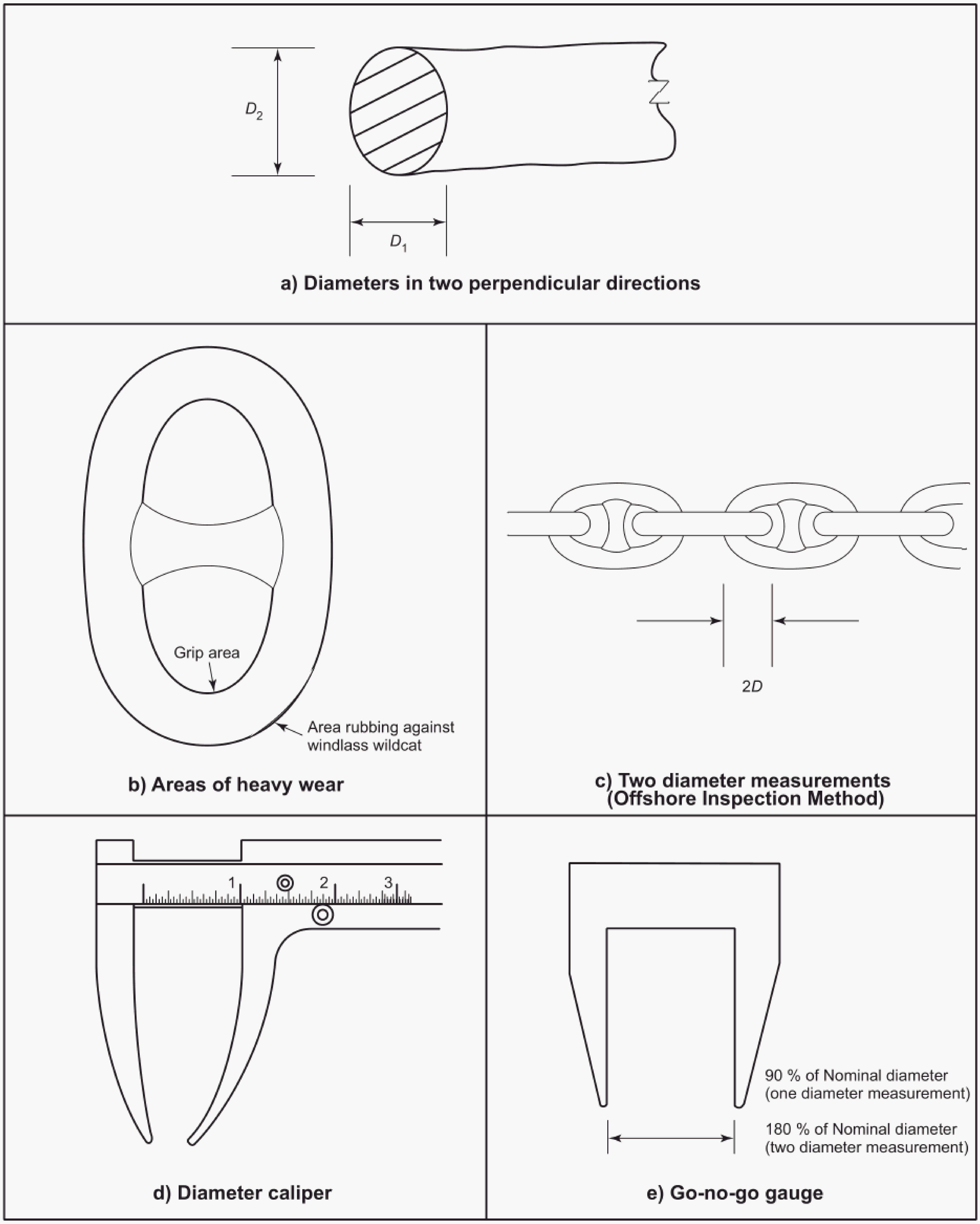


Figure 2—Chain Diameter Measurement

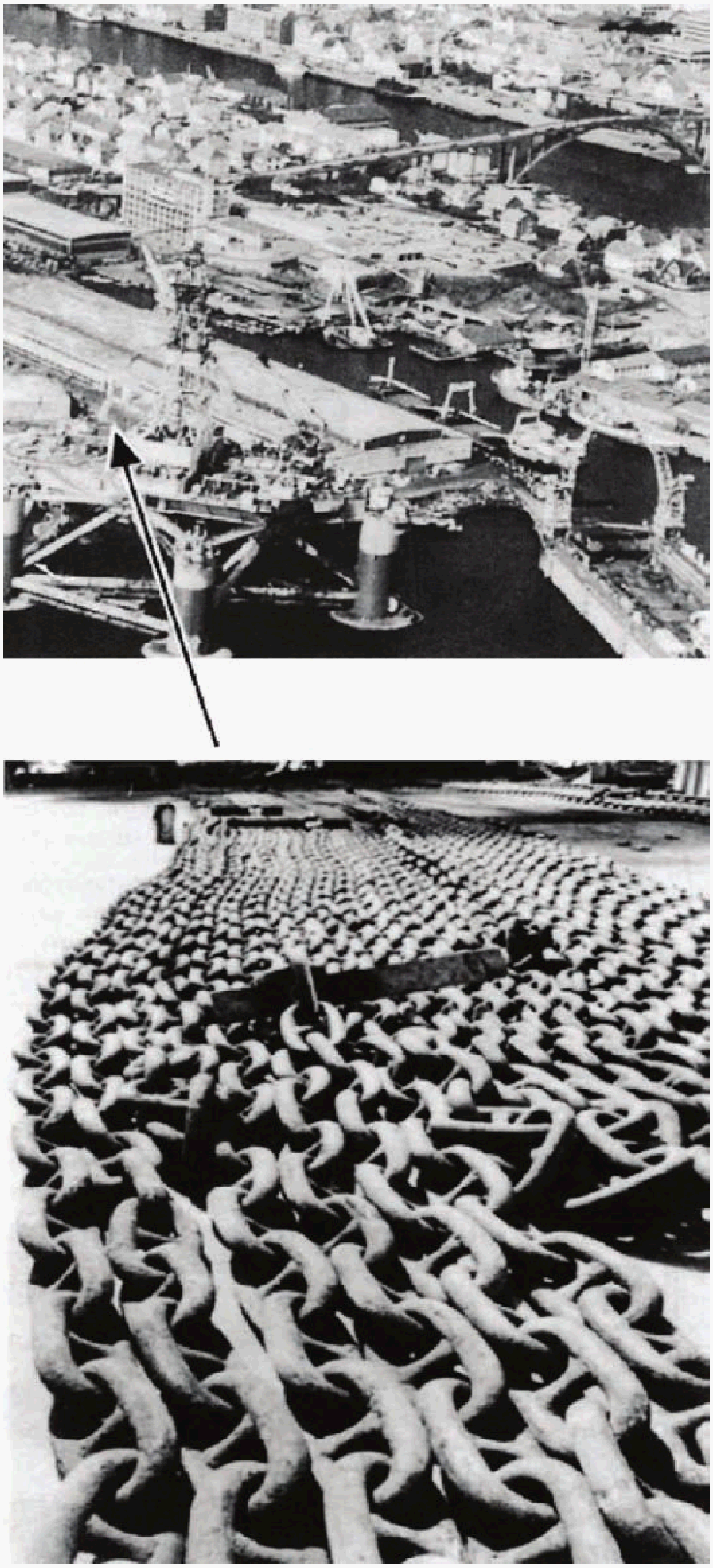


Figure 3—Dockside Inspection Method

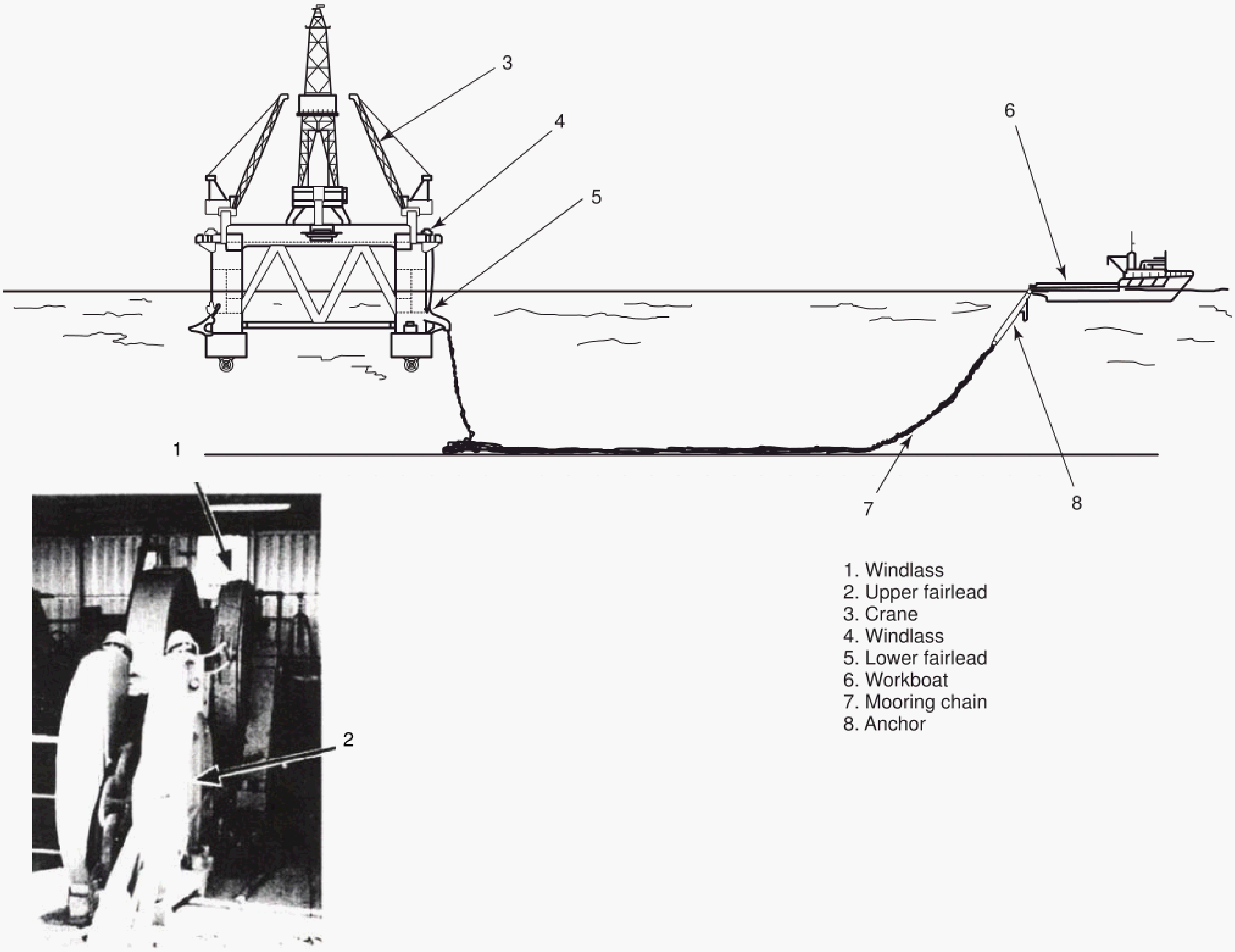


Figure 4—Offshore Inspection Method

2.3 Recommended Inspection Procedure

2.3.1 Personnel

2.3.1.1 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;

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

2.3.1.2 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 ft 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.

2.3.2 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 hose;

d) sandblasting equipment;

e) MPI equipment;

f) go-no-go gauge for chain diameter measurement (see Figure 2e);

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

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 (see Figure 2d);

m) measuring tape;

n) tape recorder;

o) spray paint;

p) camera;

q) lighting equipment.

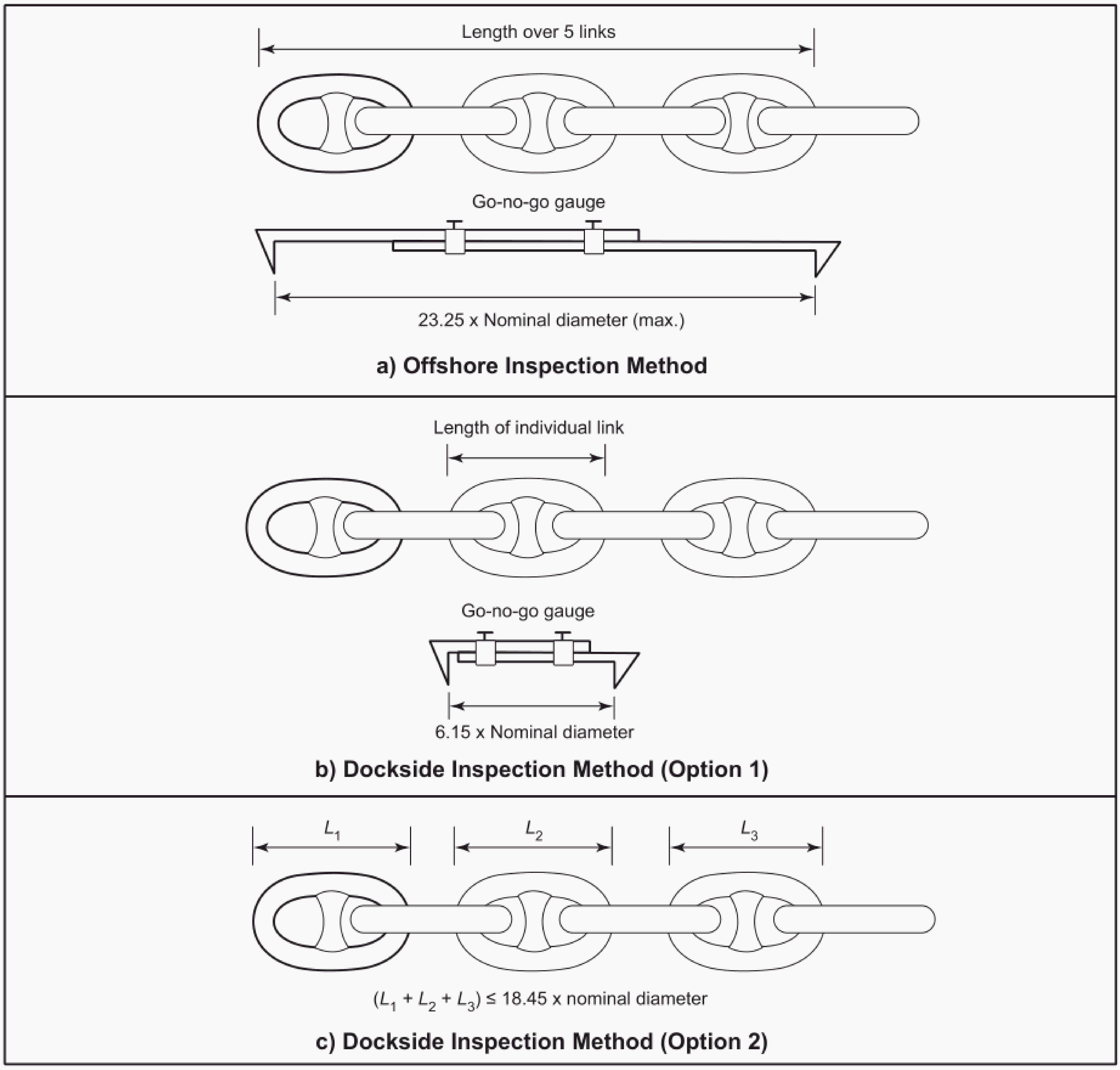


Figure 5—Chain Length Measurement

2.3.3 Arrangement

2.3.3.1 Dockside Inspection Method

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

2.3.3.2 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 semi submersible, 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.

2.3.4 Cleaning

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

2.3.5 Inspection Steps

2.3.5.1 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 ft 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.

2.3.5.2 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.

2.3.5.3 Measurement

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

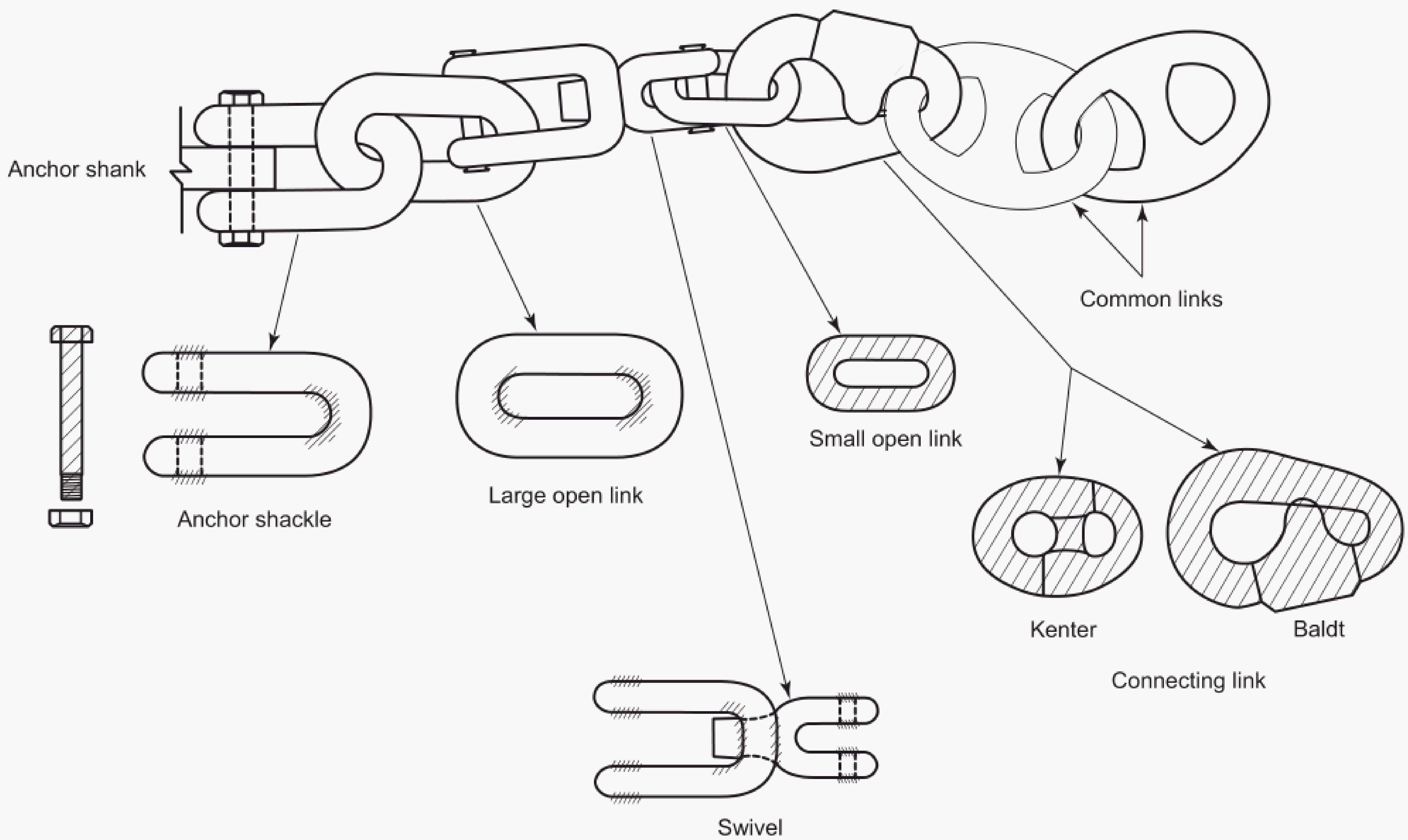
For chain diameters in two perpendicular directions as shown in Figure 2a, one should remove corrosion scale and marine growth before measuring diameters. The diameter measurement should be performed at the location with the worst reduction in cross-sectional area, which is normally the grip area or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

In the offshore inspection method, length over five links can be measured with a go-no-go gauge (see Figure 5a). 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 5b. Another option of chain length measurement for dockside inspection is shown in Figure 5c.

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

2.3.5.4 Anchor and Anchor Jewelry Inspection

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 should be based on ASTM E709 [13].



NOTE Shaded areas inspected by MPI, visual inspection for the rest.

Figure 6—Inspection of Anchor Jewelry

The inspector should visually inspect the anchors after cleaning, looking for structural cracks and noticeable deformations such as bending of the anchor shank or fluke. Attention should be given to welds, corners, and areas of high stress. If a crack is suspected in an area of high stress concentration, the area should be inspected by MPI.

MPI should be conducted under the supervision of an operator's representative or a representative from a recognized classification society. 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.

2.3.5.5 Winching Equipment Inspection

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

2.3.5.6 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;

f) locations and types of connecting links and anchor jewelries, abnormalities detected and corrective measures taken;

g) MPI results;

h) recommendations for further action to be taken.

2.4 Guidelines for Rejecting Chain Components

Chain components having any of the following problems should be removed.

a) A missing stud.

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

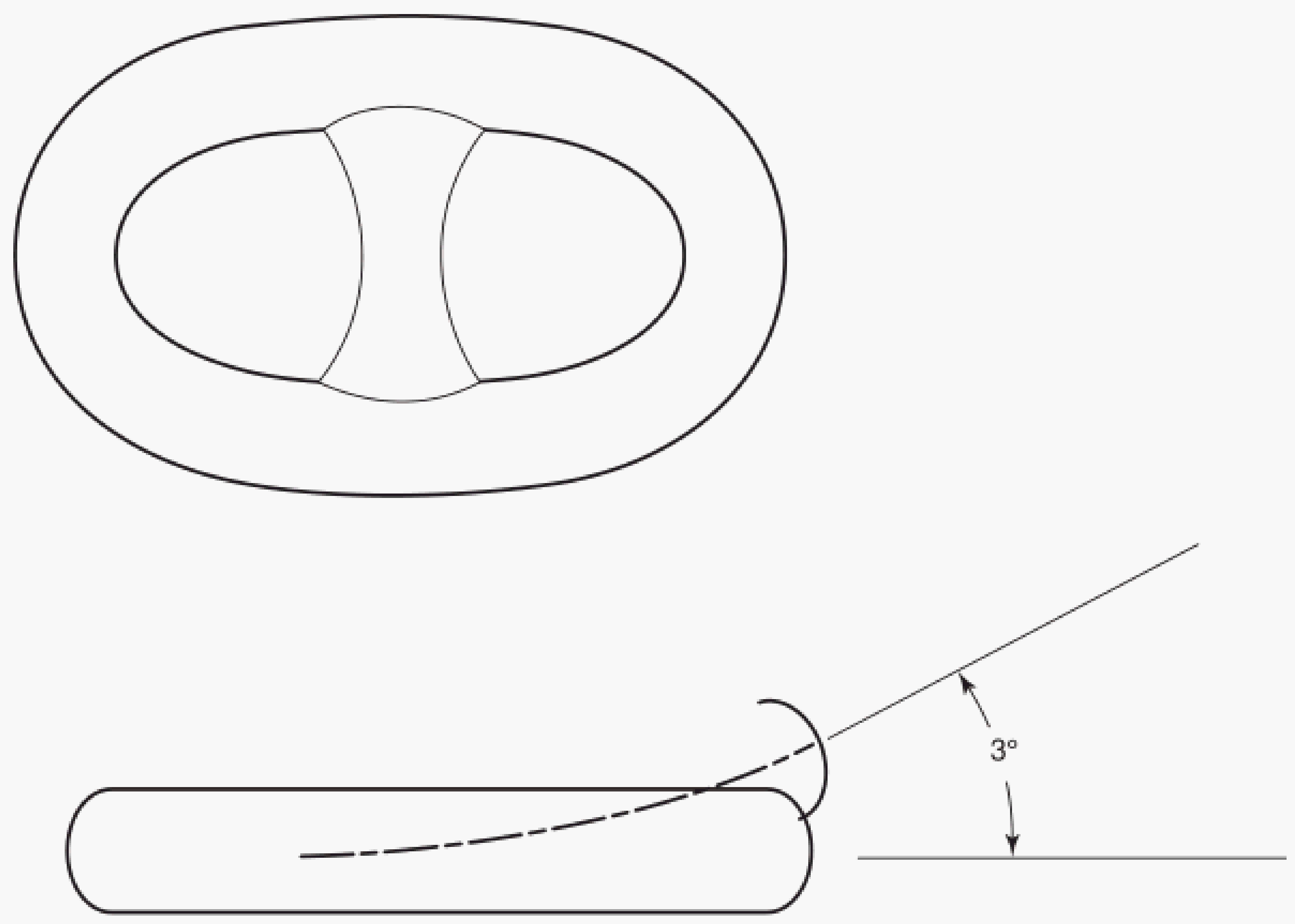


Figure 7—Discard Criterion for Bent Links

c) An average of two measured diameters less than 95 % of the nominal diameter (about a 10 % reduction of cross-sectional area) or a diameter in any direction less than 90 % 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 % 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 $^{1}/_{8}$ in. (3 mm) axially or more than $^{3}/_{16}$ in. (5 mm) laterally in any direction (see Figure 8a), rejection of the link should be considered. Similarly, if a gap of more than $^{1}/_{8}$ in. (3 mm) 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 8b).

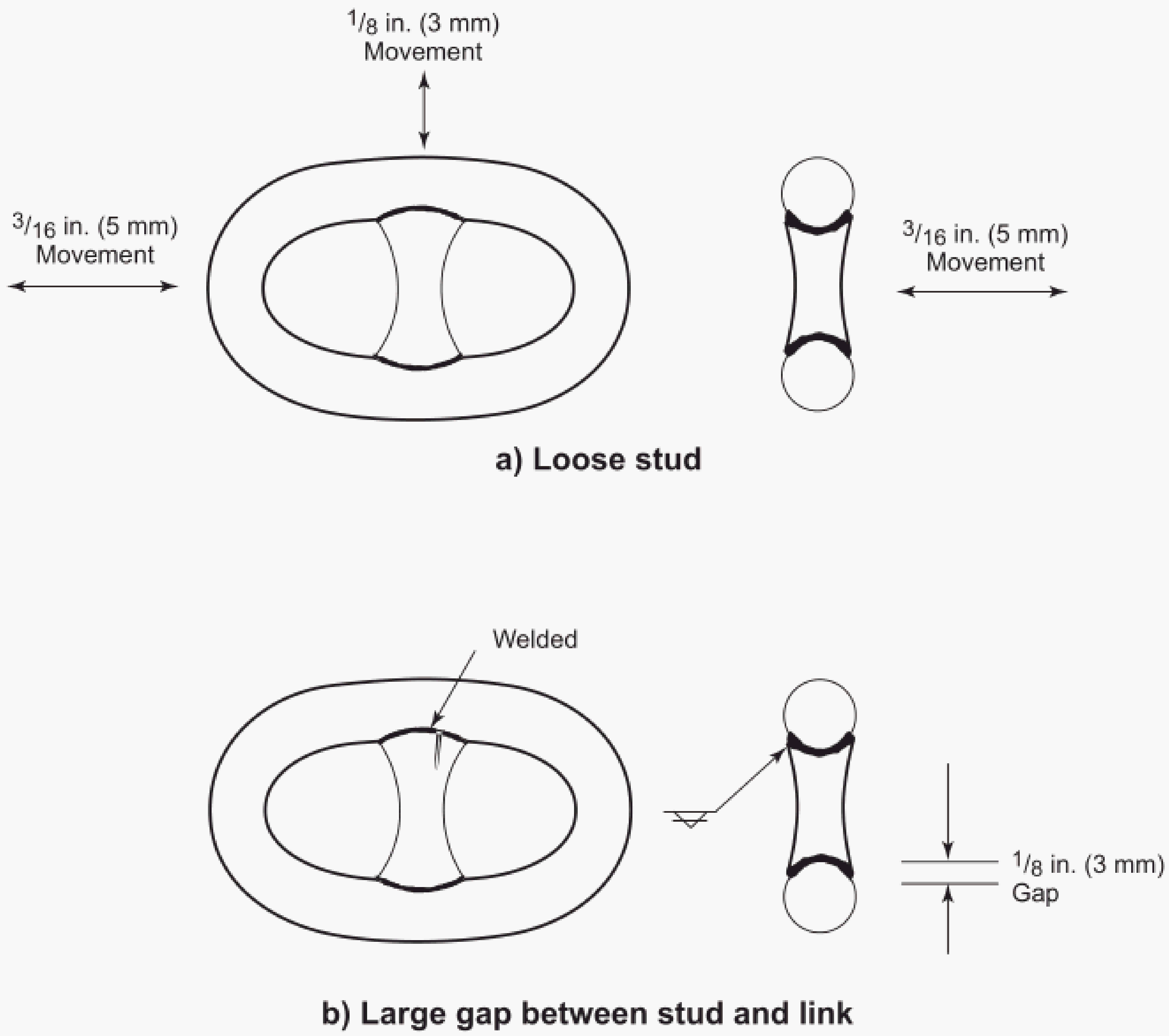


Figure 8—Examples of Severely Loose Studs

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 % 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.

— Reduction in cross-section area due to wear and grinding is more than 10 %. This is equivalent to a 5 % reduction in the average diameter for distributed wear or grinding.

— Reduction in diameter or critical thickness in any direction is more than 10 %.

j) Cracks in anchor or noticeable anchor deformation, which impact anchor performance, such as bending of anchor shank or fluke. Cracks are acceptable if they can be repaired by proper welding procedure.

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

Nominal Diameter (in.)	Length over 5 Links (23.25*D*, in.)	Length of Individual Link (6.15*D*, in.)
2	46.5	12.3
2 1/8	49.4	13.1
2 1/4	52.3	13.8
2 3/8	55.2	14.6
2 1/2	58.2	15.4
2 5/8	61.0	16.1
2 3/4	64.0	16.9
2 7/8	66.8	17.7
3	69.8	18.5
3 1/8	72.7	19.2
3 1/4	75.5	20.0
3 3/8	78.5	20.8
3 1/2	81.4	21.5
3 5/8	84.3	22.3
3 3/4	87.2	23.1
3 7/8	90.1	23.8
4	93.0	24.6
4 1/8	95.9	25.4
4 1/4	98.8	26.1
4 3/8	101.7	26.9
4 1/2	104.7	27.7
4 5/8	107.4	28.4
4 3/4	110.5	29.2
4 7/8	113.3	30.0
5	116.3	30.8
5 1/8	119.2	31.5
5 1/4	122.0	32.3
5 3/8	125.0	33.1
5 1/2	127.8	33.8
5 5/8	130.8	34.6
5 3/4	133.7	35.4
5 7/8	136.6	36.1

2.5 Guidelines for Chain Repair, Removal, and Replacement

2.5.1 Removal of Individual Links

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

2.5.2 Removal of Chain Sections

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.

2.5.3 Limit in Number of Connecting Links

The number of connecting links in a mooring line should not exceed an average of one per 400 ft of 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.

2.5.4 Removal of Whole Chain

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.

2.5.5 Re-welding of Loose Stud

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

— welding in the field may produce hard heat-affected zones that are susceptible to cold cracking;

— 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.

2.5.6 Grinding

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.

2.5.7 Replacement of Mooring Jewelry

Replacements for mooring jewelry such as connecting links, anchor shackles, swivels, wire rope sockets, and pelican hooks should meet or exceed the original design and manufacture requirements.

2.6 Recommended Inspection Schedule

A chain inspection schedule should be based on the age, condition and operational history of the chain (ground chain versus rig chain over fairleader under high load) and type of operation.

The recommended major inspection intervals are given in Table 2 and may be modified based on the condition and previous inspection history of the chain. As a minimum, a full visual inspection of all mooring lines, including connectors and jewelry must be conducted as per the frequency in Table 2. If deterioration is found during inspection, defined as a difference between the as-built and current condition but within the tolerance prescribed by API 2I, then the inspection interval should be reduced to effectively monitor the condition of the components and ensure they are fit for intended service at all times. However, the major inspection interval shall never exceed five years.

Guidance for conducting a major inspection is defined in 2.3 and rejection criteria are defined in 2.4.

Table 2—Chain Inspection Intervals

Number of Years in Service	Recommended Intervals Between Major Inspections [a]
0 to 3	36 months
4 to 10	24 months
over 10	8 months

[a] With a grace period not to exceed 4 months.

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

Special attention should be given to the long term operations where the inspection schedule is current at the start of the operation, but the inspection will expire during the operation. For example, a development drilling will take 18 months to complete, but the inspection will expire in 6 months after start of the operation. In this case, an inspection of the mooring system should be conducted before the MODU is moored on location or while the MODU is in operation.

2.7 Special Event Inspection

Rigorous mooring inspection is critical for operations in the areas of tropical cyclone where the probability of mooring failure can be much higher. Also guidance is needed to address the reuse of the components from a mooring damaged by a tropical cyclone. Additional guidance for MODU mooring inspection in these areas can be found in Annex B.

3 Guidelines for In-service Inspection of MODU Mooring-wire Rope and Anchor Handling Equipment

3.1 Common Problems with MODU 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.

3.1.1 Broken Wires

3.1.1.1 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.

3.1.1.2 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.

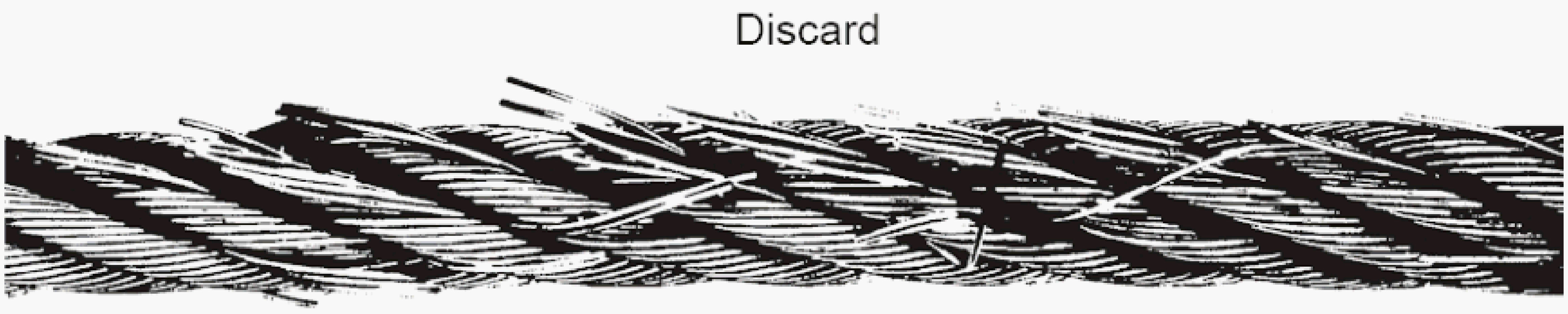
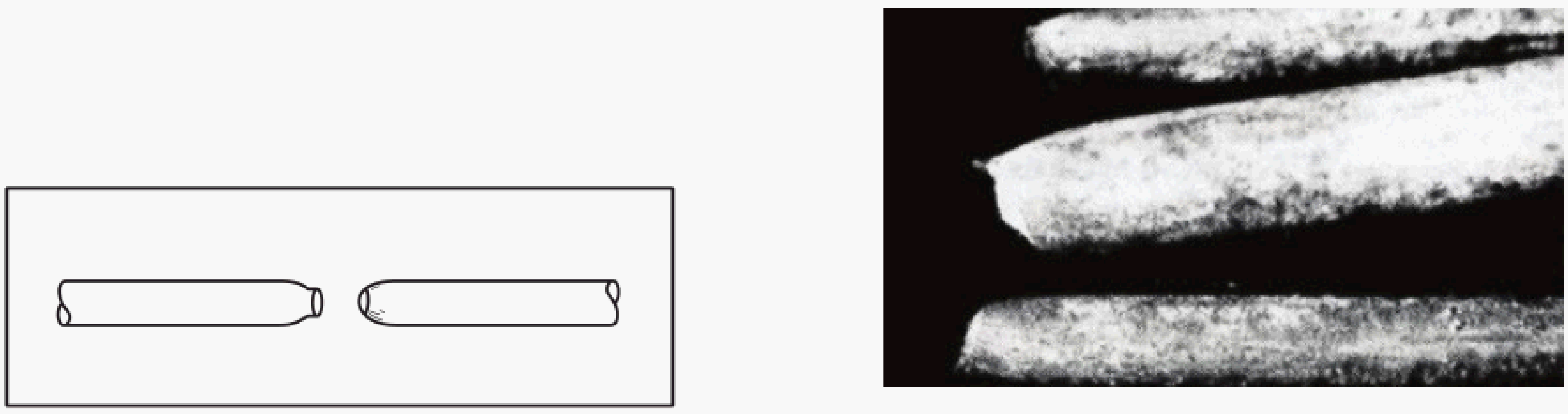
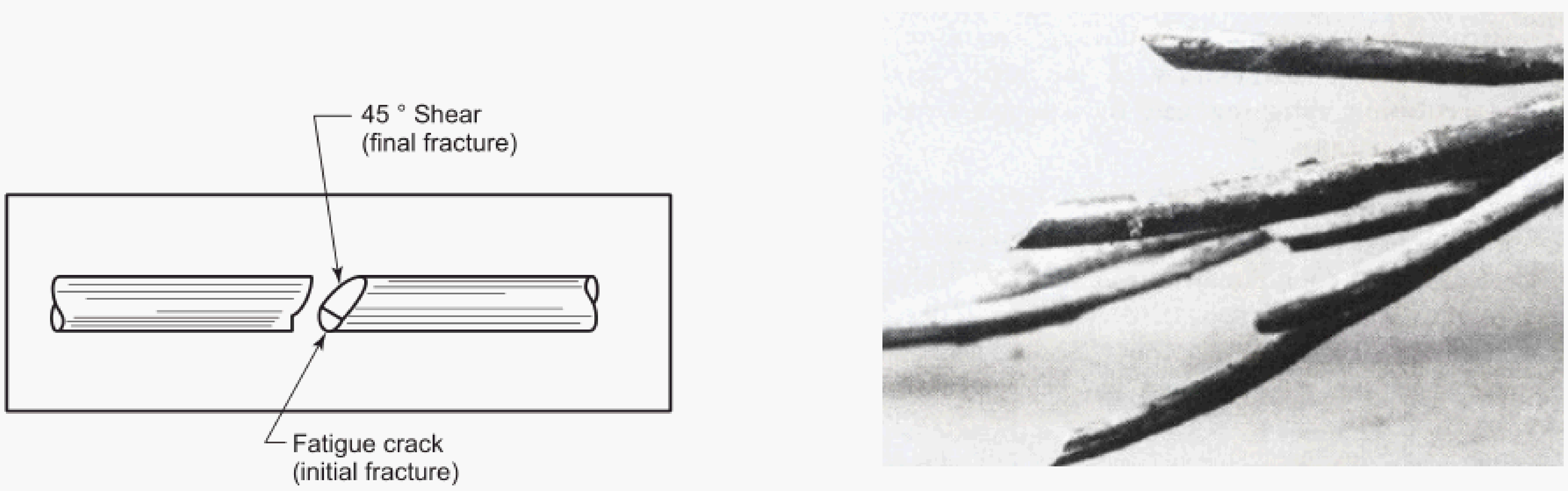


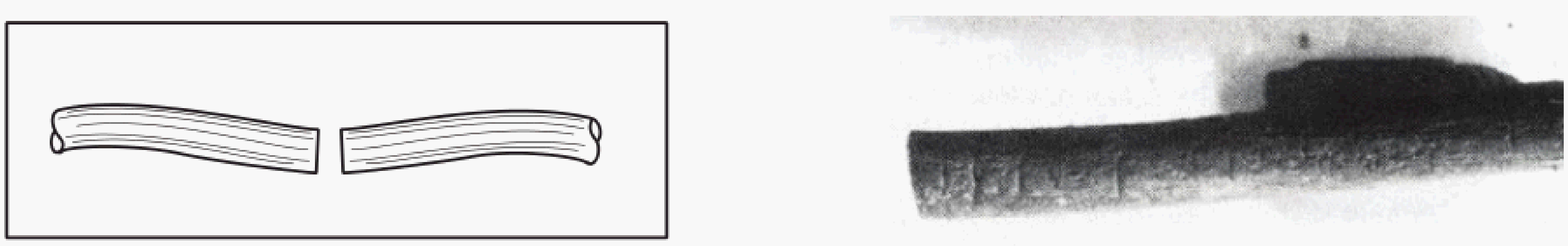
Figure 9—Examples of Distributed Crown Wire Breaks



a) Failure due to tensile overloading characterized by the cup cone



b) Fatigue failure-initial fracture from fatigue and final fracture by shear



c) Fatigue failure straight across

d) Fatigue failures characterized by no reduction in cross section area

Figure 10—Typical Wire Fractures

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.

3.1.1.3 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.

Figure 11—Locally Grouped Broken Wires

3.1.2 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.

Figure 12—Local Decrease in Rope Diameter

3.1.3 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.

3.1.4 Corrosion

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

— 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.

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

3.1.5 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 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 17a 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 17c, a dismantled strand with lubrication on the internal wires shows no evidence of internal corrosion. Figure 17b 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.

3.1.6 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) Slight flats on outer wires. Little reduction in rope diameter

b) Increased length of flats on individual outer wires

c) Flats on individual wires longer, affecting all crown wires in each strand. Marked reduction in rope size

d) Flats on individual wires now almost continuous - strands appear slightly flattened and wires are noticeably thin

e) 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

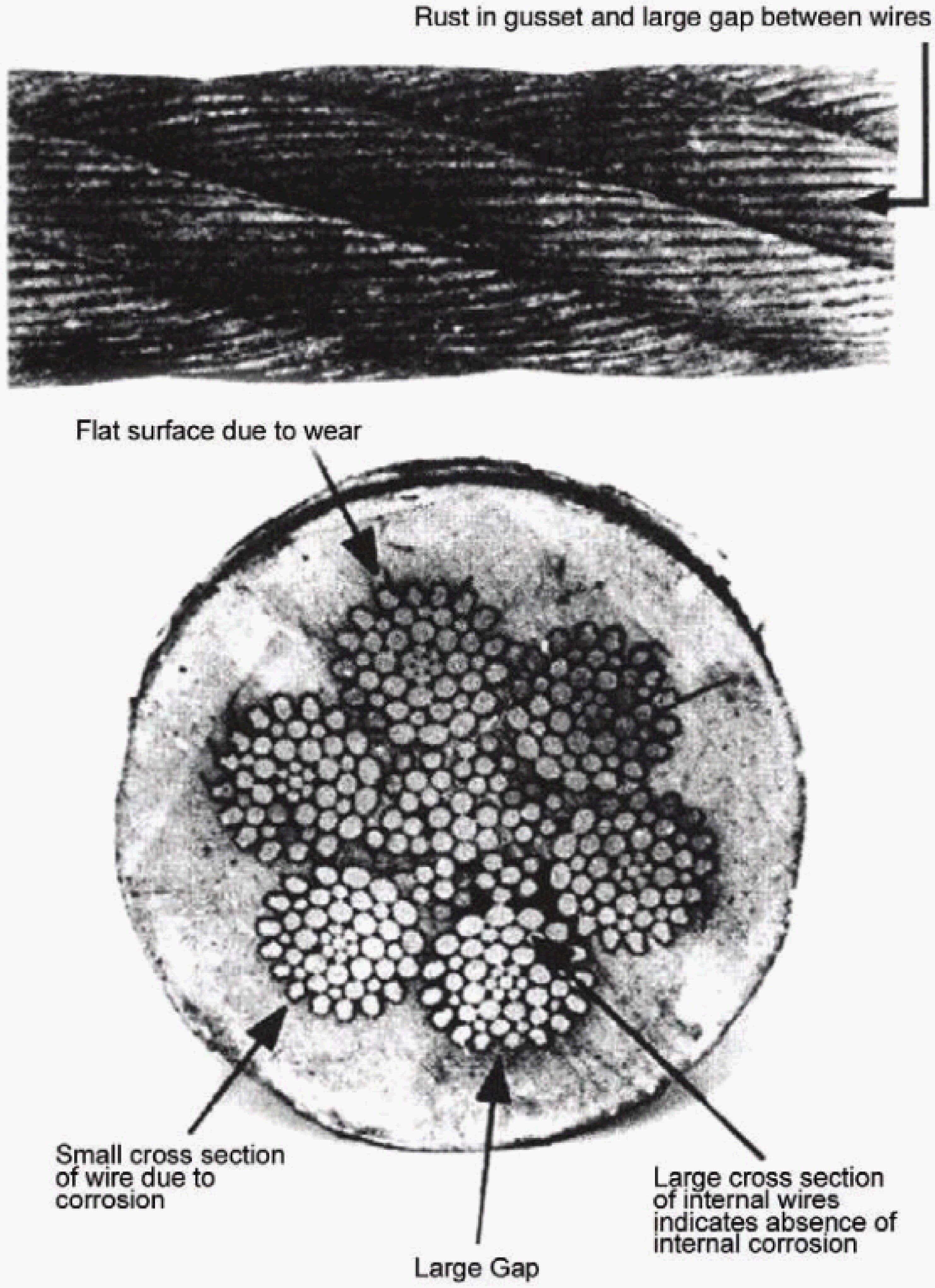


Figure 14—Wire Rope with Heavy External Corrosion

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 18a). Bends are angular deformations of the rope caused by external influence (see Figure 18b).

Scrubbing and crushing of wire rope as shown in Figure 19a, 19b and 19c can be caused by improperly winding the rope on the winch drum. Flattening of wire rope (see Figure 19d) 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 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.

3.1.7 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.

a) Beginning of surface oxidation

b) Wires rough to touch. General surface oxidation

c) Oxidation now more marked

d) Surface wire now greatly affected by oxidation. Pitting obvious. Rust in gussets.

e) Surface heavily pitted and wire quite slack

Figure 15—Progression of External Corrosion

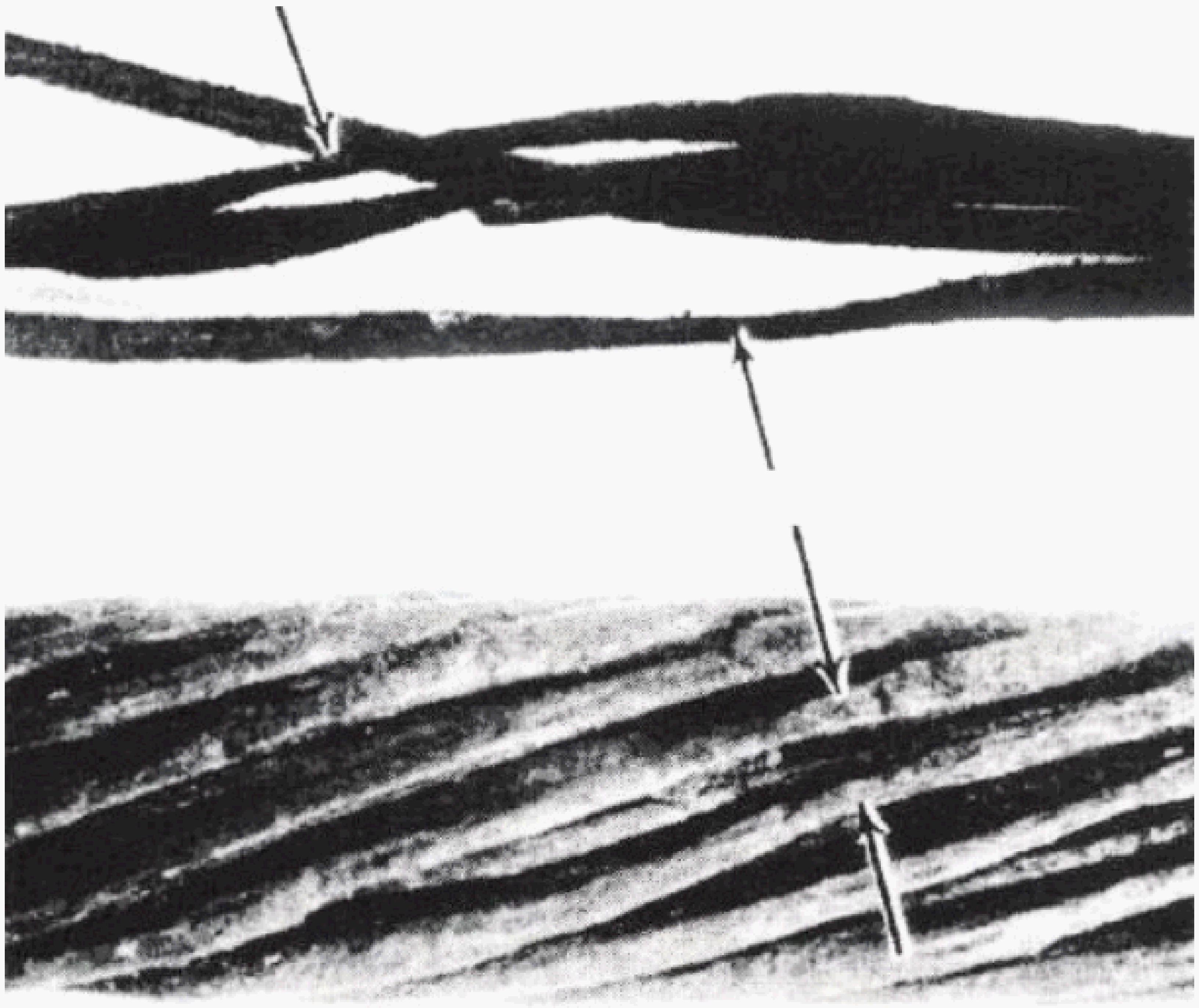


Figure 16—Wear of Internal Wires Caused by Lack of Lubrication Between Wires

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 ability to lubricate.

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.

3.2 Recommended Inspection Method

3.2.1 General

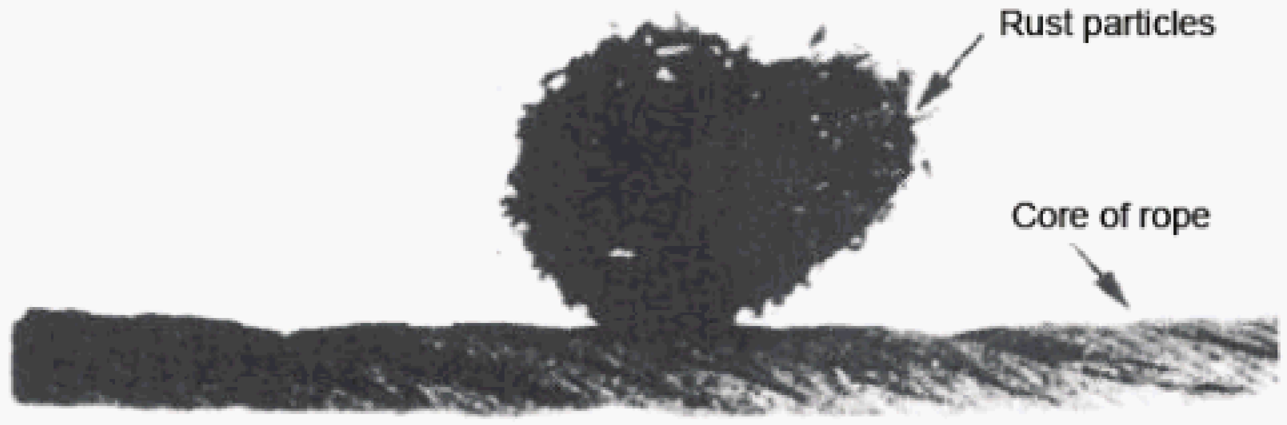
In-service wire rope for mobile offshore drilling units is usually inspected with the assistance of a workboat as shown in Figure 20. Two common methods for wire rope inspection are described in 3.2.2 and 3.2.3.

3.2.2 Inspection During Anchor Retrieval

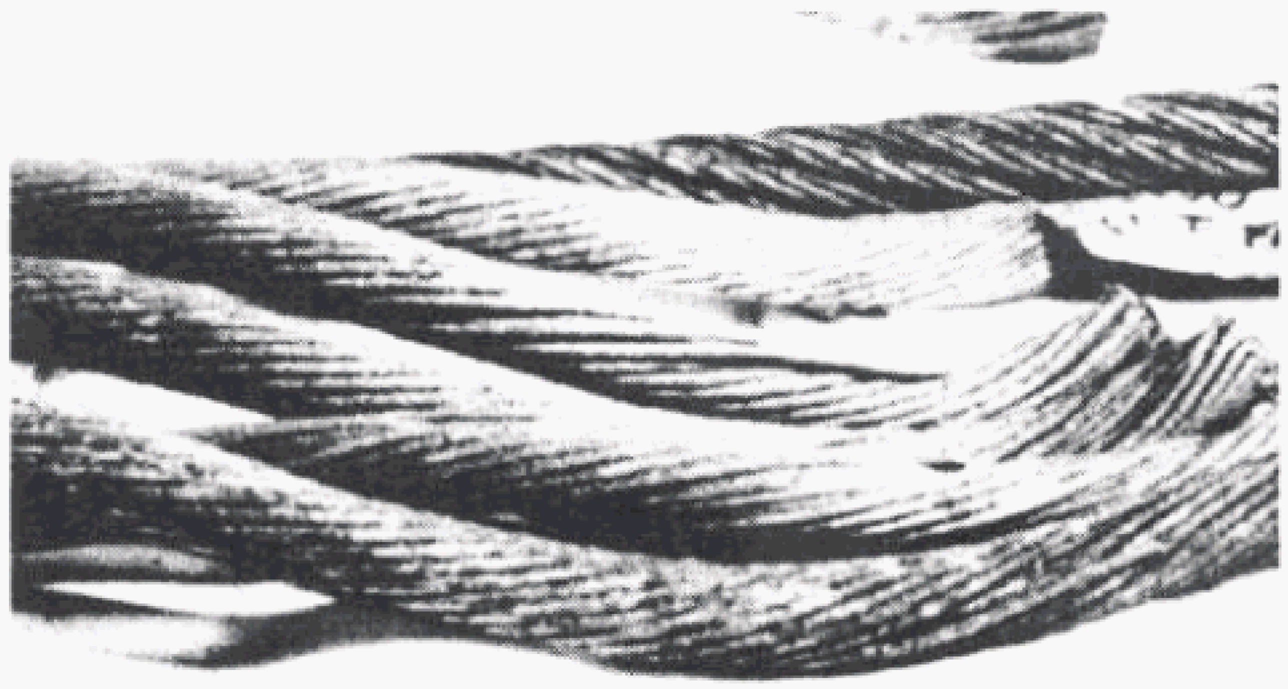
The wire rope is inspected in conjunction with anchor retrieval. Such inspection requires no additional equipment since a workboat is always available during anchor retrieval. However, the inspection can substantially slow down the anchor retrieval operation and delay a MODU move schedule.

3.2.3 Dockside Inspection

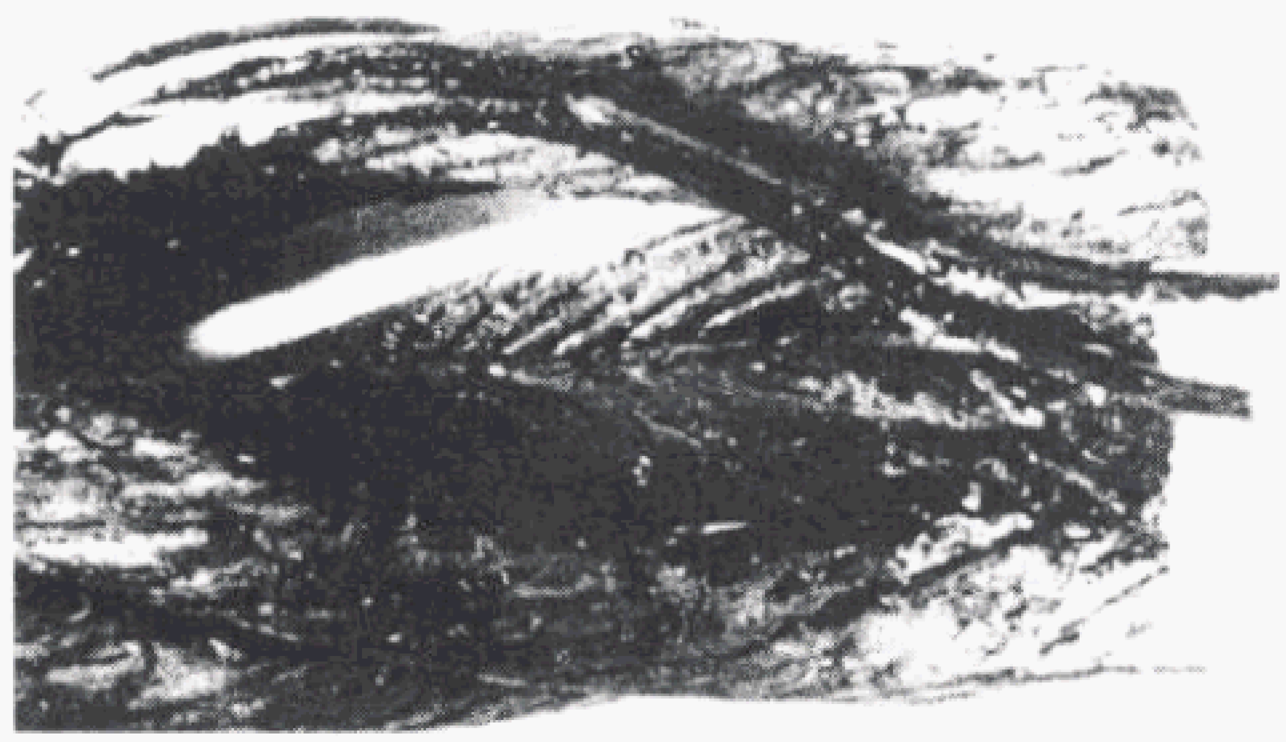
The drilling vessel stays in a dock or harbor for repair, special survey, and the like, and a workboat is contracted for the wire rope inspection. This method has two disadvantages. First, the inspection is economical only when it coincides with MODU repair or special survey. Second, because the MODU's location is close to land, the radius for



a) Heavy corrosion caused by lack of internal lubrication



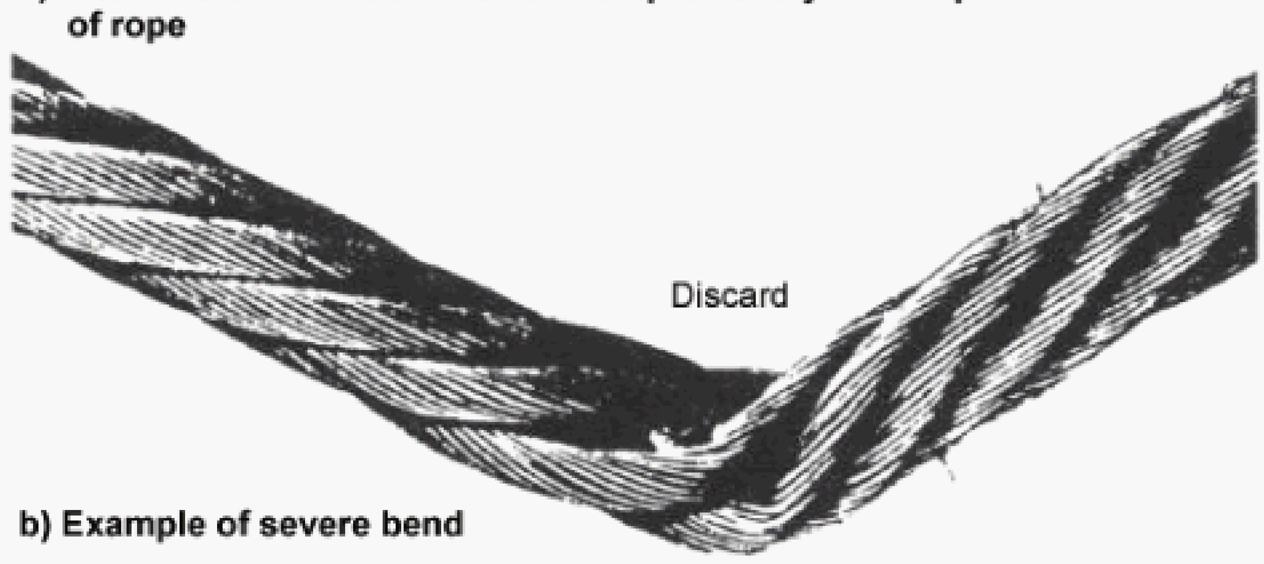
b) Dry rope with no internal lubrication. Internal wear and corrosion are not obvious but may soon develop.



c) Rope with proper internal lubrication. No internal wear and corrosion expected.

Figure 17—Effect of Internal Lubrication on Wire Rope

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

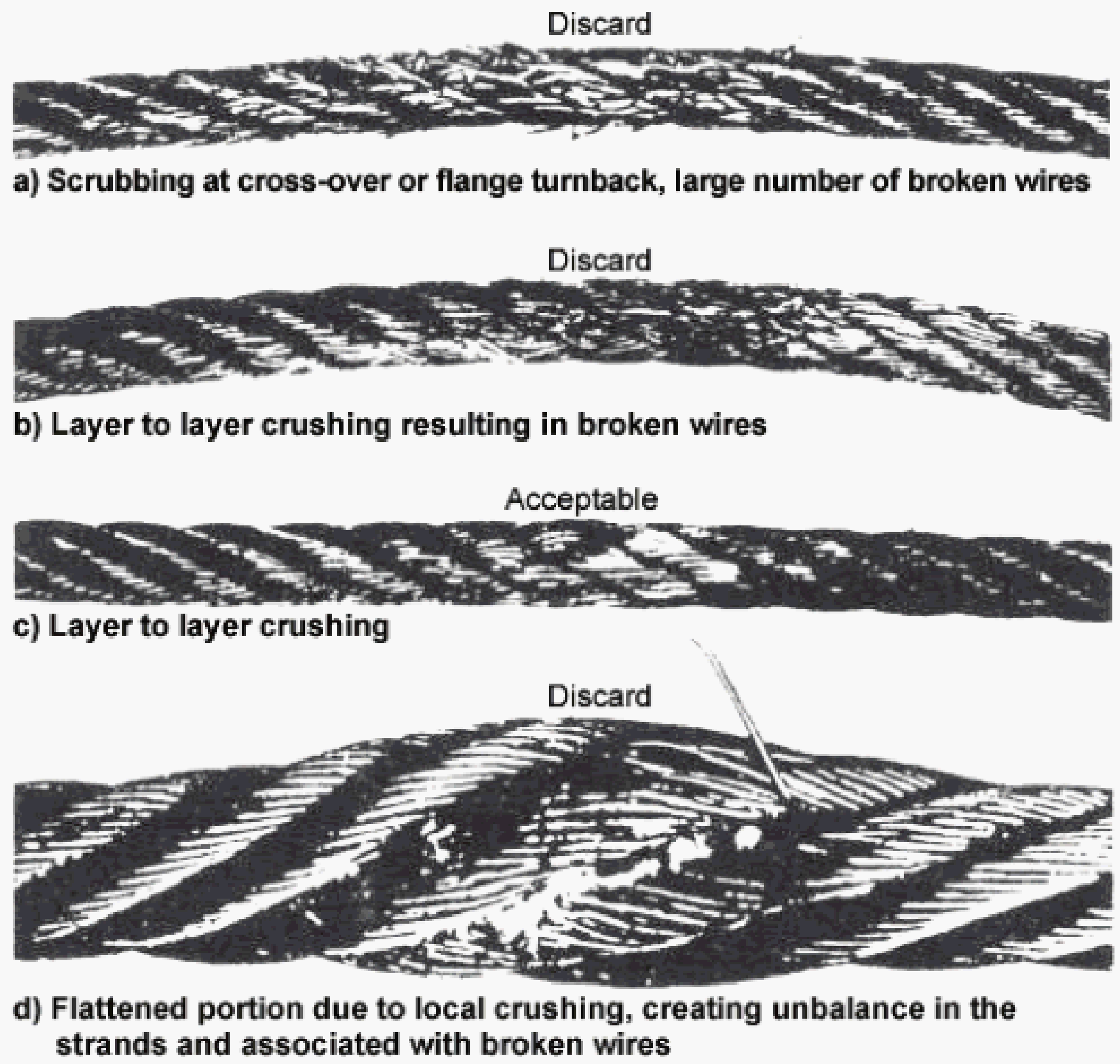

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Figure 19—Deformation Caused by Improper Drum Winding

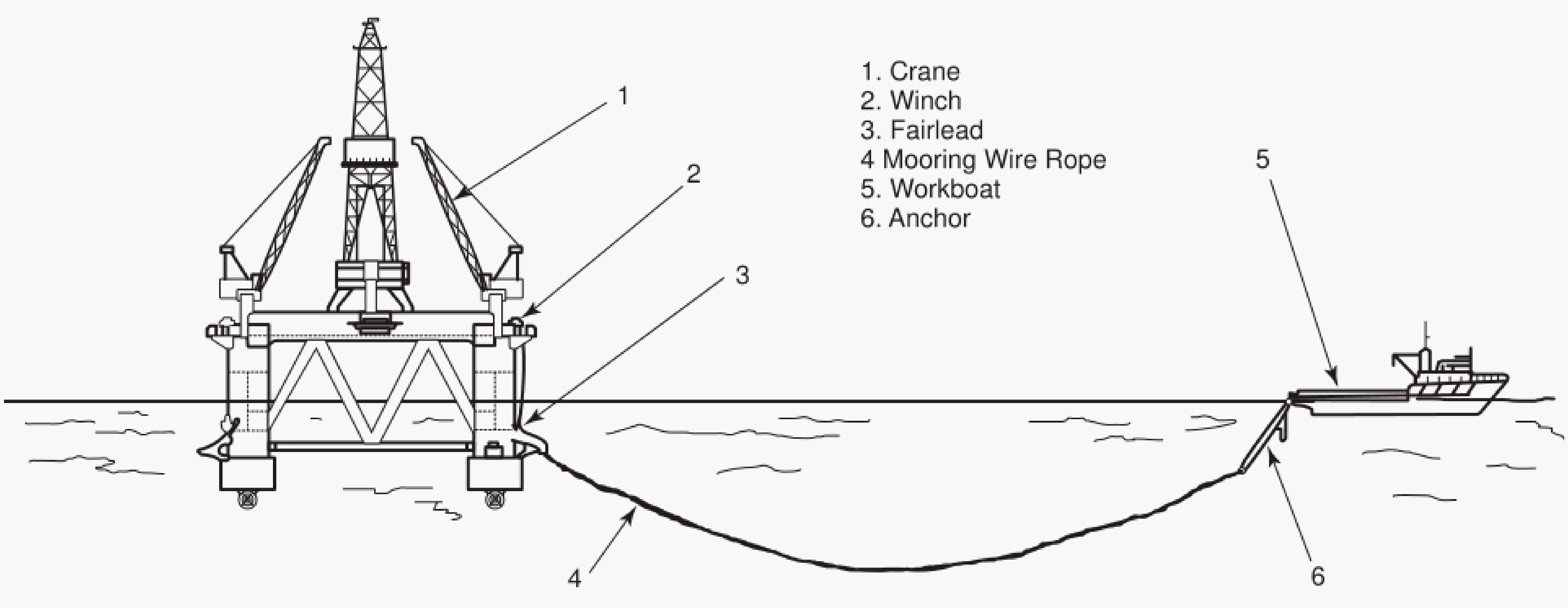


Figure 20—Wire Rope Inspection with Assistance of a Workboat

workboat operation can be limited on one side of the MODU. To inspect all mooring lines, rotating the MODU 180° would be necessary in some cases, and this would delay the inspection and increase operating costs. Therefore, inspection during anchor retrieval is preferred.

3.3 Recommended Inspection Procedure

3.3.1 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.

3.3.2 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 21b);

c) high-pressure hose;

d) cutting torch;

e) wire rope sockets and filler;

f) lighting equipment;

g) parallel-jaw pliers;

h) camera;

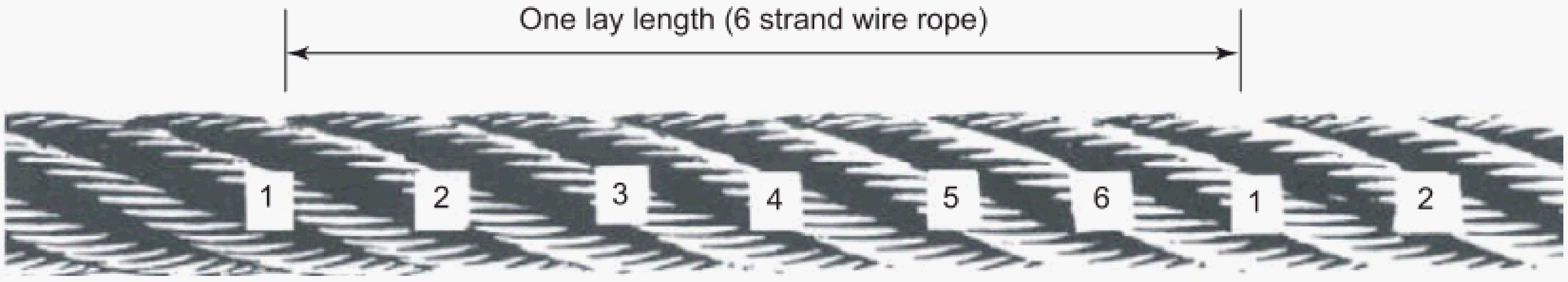
i) tape recorder;

j) measuring tape;

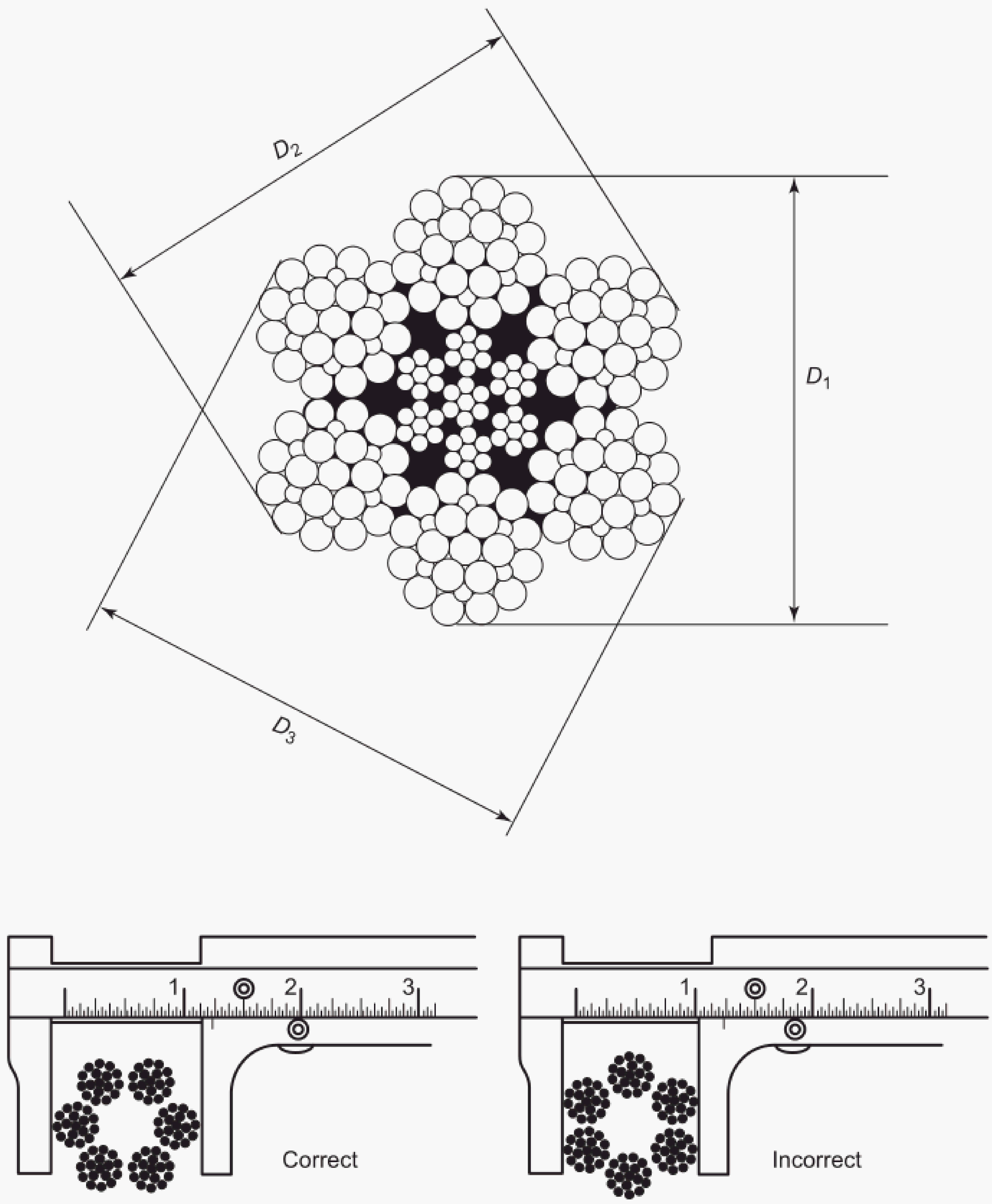
k) sheave gauge.

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



a) Definition of lay length



b) Diameter measurement

Figure 21—Lay Length and Diameter Measurement

3.3.4 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 at a rate of no more than 30 ft/min. For a more thorough inspection, a lower speed of 15 ft/min to 20 ft/min is recommended.

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

3.3.5 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.

3.3.6 Inspection Steps

3.3.6.1 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. When abnormalties are observed, line movement shall be stopped and the abnormalties closely examined. 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 the fairlead, previous problem areas, and areas in the splash zone.

3.3.6.2 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.

3.3.6.3 Internal Inspection

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 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.

The internal inspection procedure is as follows.

a) Cut a length of approximately 15 ft to 20 ft of rope at the end. Remove a 2-ft to 3-ft 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 17c. It may be advisable to remove a rope section of 30 ft from the cut end (see Figure 22). A break test performed on this rope section may provide useful information on the remaining strength of the rope.

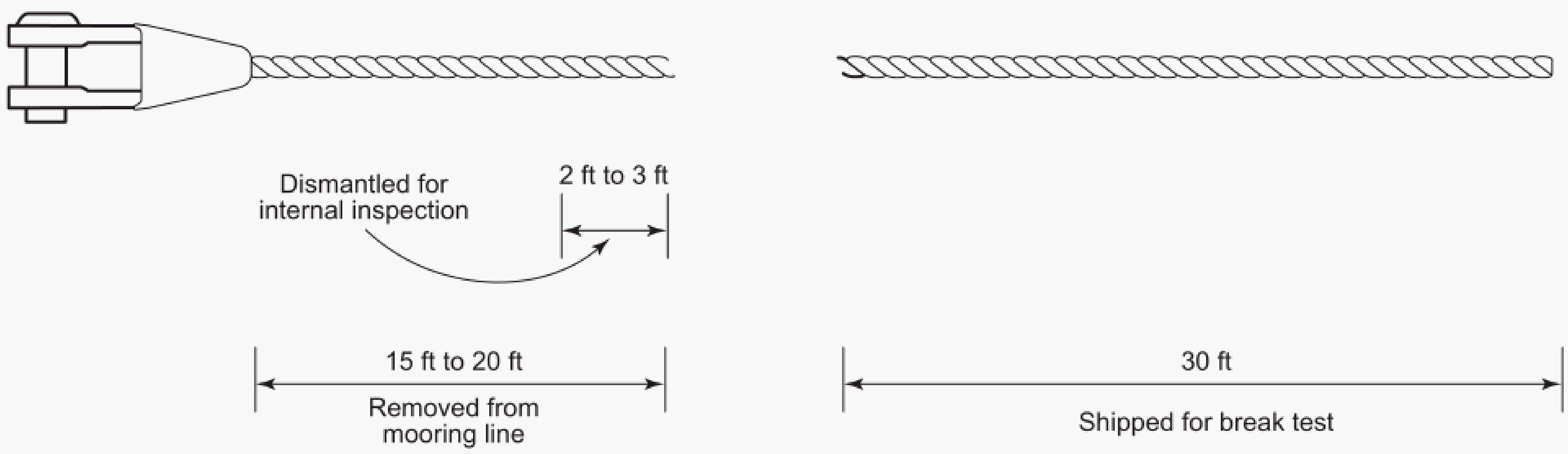


Figure 22—Internal Inspection of Wire Rope

3.3.6.4 Inspecting the Last Portion of Rope

Inspecting the last approximately 200 ft 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.

3.3.6.5 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 2. 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 used for anchor jewelry inspection (see Figure 6).

3.3.6.6 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.

3.4 Guidelines for Rejecting Wire Rope

3.4.1 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.

3.4.2 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 % reduction in cross-sectional area of the rope or a 10 % 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 to 7 times the nominal diameter, as shown in Figure 21a.)

3.4.3 Grouped Crown 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 % reduction in the cross-sectional area of the rope or a 17 % 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.

3.4.4 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.

3.4.5 Broken Wires at Termination

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

Rope replacement is normally not required for this condition, but a minimum of 15 ft 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 the *Wire Rope Users Manual* [12].

3.4.6 Wear and Stretch

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

3.4.7 Internal Corrosion and Wear

In this group, internal corrosion and wear are observed. The wire rope shown in Figure 17a, 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 17b, the rope is acceptable for use temporarily; however, internal inspection should be repeated within six months.

3.4.8 Deformations

Deformations include any of the conditions:

a) kinking;

b) severe bending;

c) severe scrubbing;

d) severe crushing;

e) severe flattening.

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 × 26	10	8	3	3
6 × 25 or 6 × 31	12	10	4	4
6 × 36	14	13	5	5
6 × 41 or 6 × 49	16	17	6	6
6 × 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.

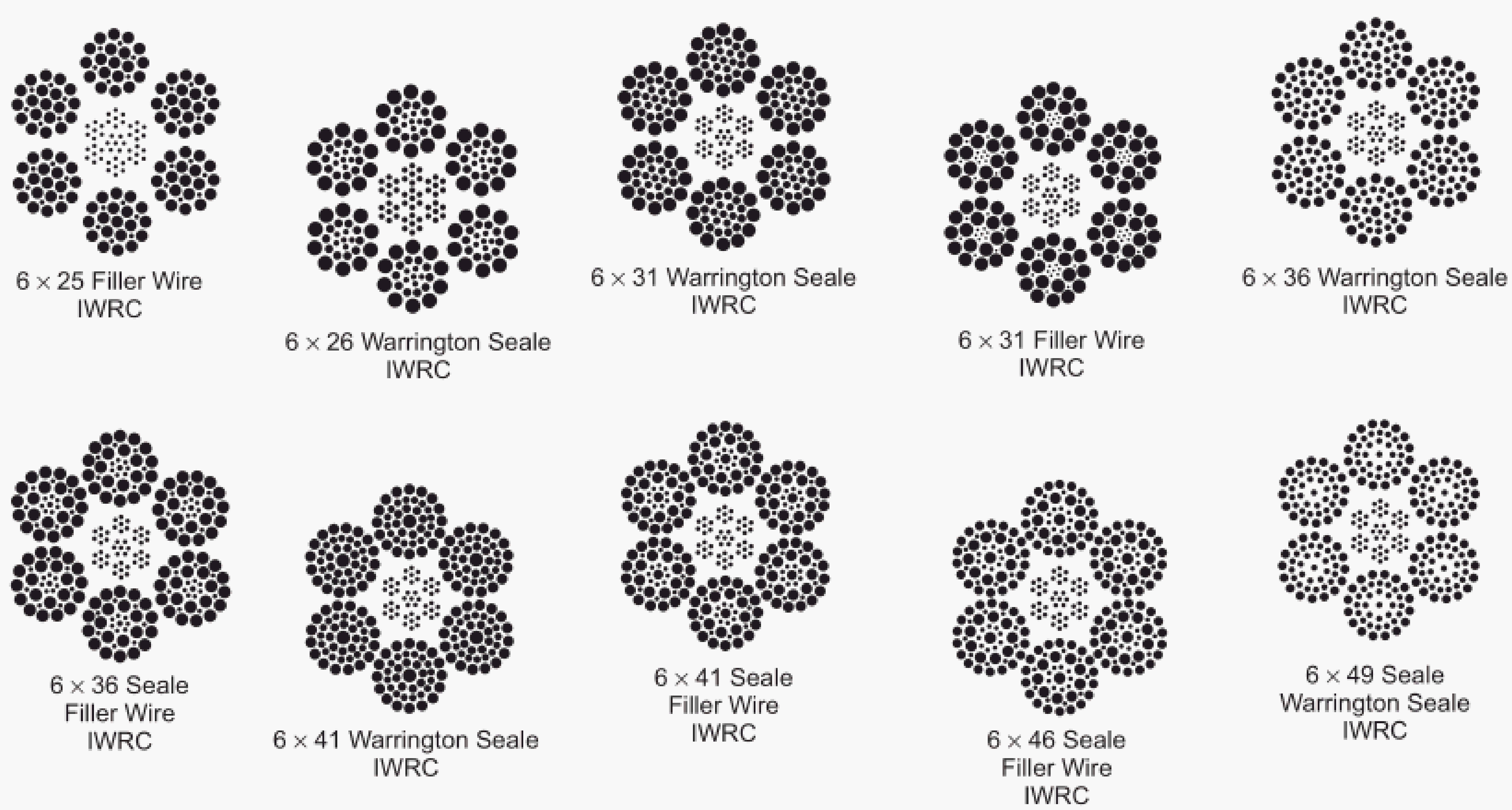


Figure 23—Common Rope Constructions for Mooring Applications

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.

3.4.9 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.

3.4.10 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.

3.5 Recommended Inspection Schedule

A wire rope inspection schedule should be based on the age, condition and operational history of the wire rope (ground wire rope versus rig wire rope over fairleader under high load) and type of operation.

The major inspection should be scheduled according to the conditions of the wire rope detected during the prior inspection. The recommended major inspection intervals are given in Table 4 and may be modified based on the condition and previous inspection history of the wire rope. As a minimum, a full visual inspection of all mooring lines, including connectors and jewelry must be conducted as per the frequency in Table 4. If deterioration is found during inspection, defined as a difference between the as-built and current condition but within the tolerance prescribed by API 2I, then the inspection interval should be reduced to effectively monitor the condition of the components and ensure they are fit for intended service at all times.

Guidance for conducting a major inspection is defined in 3.3 and rejection criteria are defined in 3.4.

Table 4—Wire Rope Inspection Intervals

Number of Years in Service	Recommended Intervals Between Major Inspections [a]
0 to 2	18 months
3 to 5	12 months
over 5	9 months

[a] With a grace period not to exceed 4 months.

In addition to the major inspections, wire rope and connecting hardware should be checked for visible defects frequently during anchor retrieval.

Special attention should be given to the long term operations where the inspection schedule is current at the start of the operation, but the inspection will expire during the operation. For example, a development drilling will take 18 months to complete, but the inspection will expire in six months after start of the operation. In this case, an inspection of the mooring system should be conducted before the MODU is moored on location or while the MODU is in operation.

3.6 Special Event Inspection

Rigorous mooring inspection is critical for operations in the areas of tropical cyclone where the probability of mooring failure can be much higher. Also guidance is needed to address the reuse of the components from a mooring damaged by a tropical cyclone. Additional guidance for MODU mooring inspection in these areas can be found in Annex B.

3.7 Recommendations for Proper Use and Maintenance of MODU 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 when necessary. A minimum of 15 ft 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 MODU 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 the *Wire Rope Users Manual* [12]. 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.

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

3.8.1 Inspection

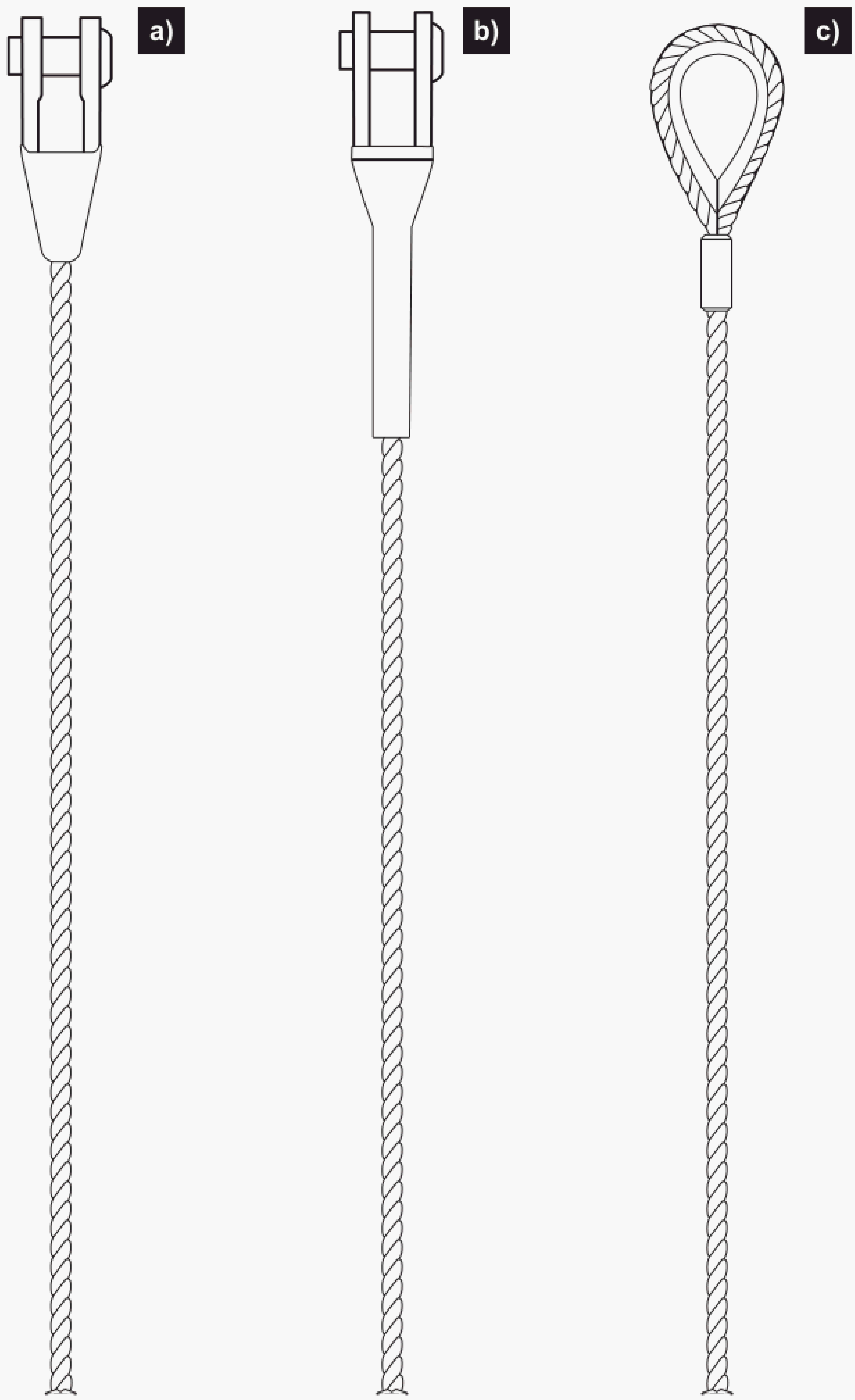
The anchor-handling equipment on the workboat should be inspected to ensure a safe operation. The discard criteria for mooring-wire rope would equally apply to wire ropes for pendant lines and work lines on a workboat. However, the inspection method, procedure, and schedule for pendant wire rope could 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. Shark's jaw, pelican hook and similar stopping devices for temporarily securing a pendant line should be examined by MPI.

3.8.2 Termination

Three types of wire rope termination are acceptable for pendant lines: spelter-poured or resin socket, swaged socket, and thimbled mechanical splice, as shown in Figure 24. The swaged 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 the *Wire Rope Users Manual* [12].



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

4 Inspection of Steel Components for Permanent Moorings

4.1 General

Inspection of steel components for MODU moorings is addressed in Section 2 and Section 3. This section covers inspection of steel components for permanent moorings. The inspection requirement for permanent mooring systems is similar in many ways to those for MODUs, but the method of inspection is very different. Monitoring and inspection of permanent mooring systems thus require different techniques.

4.2 Difference Between MODU and Permanent Mooring Inspection

The differences between inspecting MODU and permanent moorings are described in the following.

— MODUs are typically moored temporarily on location, and the mooring system is retrieved periodically and therefore is available for direct inspection in a dry and accessible location. Permanent mooring systems are normally not retrieved during their service life so all inspections must be performed *in situ* and rely primarily on limited diver access and/or ROV inspection.

— Deterioration of permanent mooring components can be concentrated in a few locations such as wear at the fairlead/stopper and seafloor touchdown point and corrosion at the splash zone. Deterioration of MODU mooring components is normally more evenly distributed.

— The design of a permanent mooring system requires adequate fatigue life, wear and corrosion protection or allowance. These are normally not required for MODU moorings.

— For permanent moorings, connectors and other mooring jewelry need to be designed to ensure robustness over the life of the field. The connecting hardware for MODU moorings can be inspected or replaced periodically.

4.3 Typical Components in Permanent Moorings

4.3.1 Chain

The mooring chain can be either studless or studlink chain.

4.3.2 Wire Rope

The wire rope can be of either six-strand or spiral strand construction. Spiral strand can be sheathed with a polyurethane cover or unsheathed. The wire rope segments are typically terminated with a socket that allows connection to other segments or a triplate.

4.3.3 Connectors

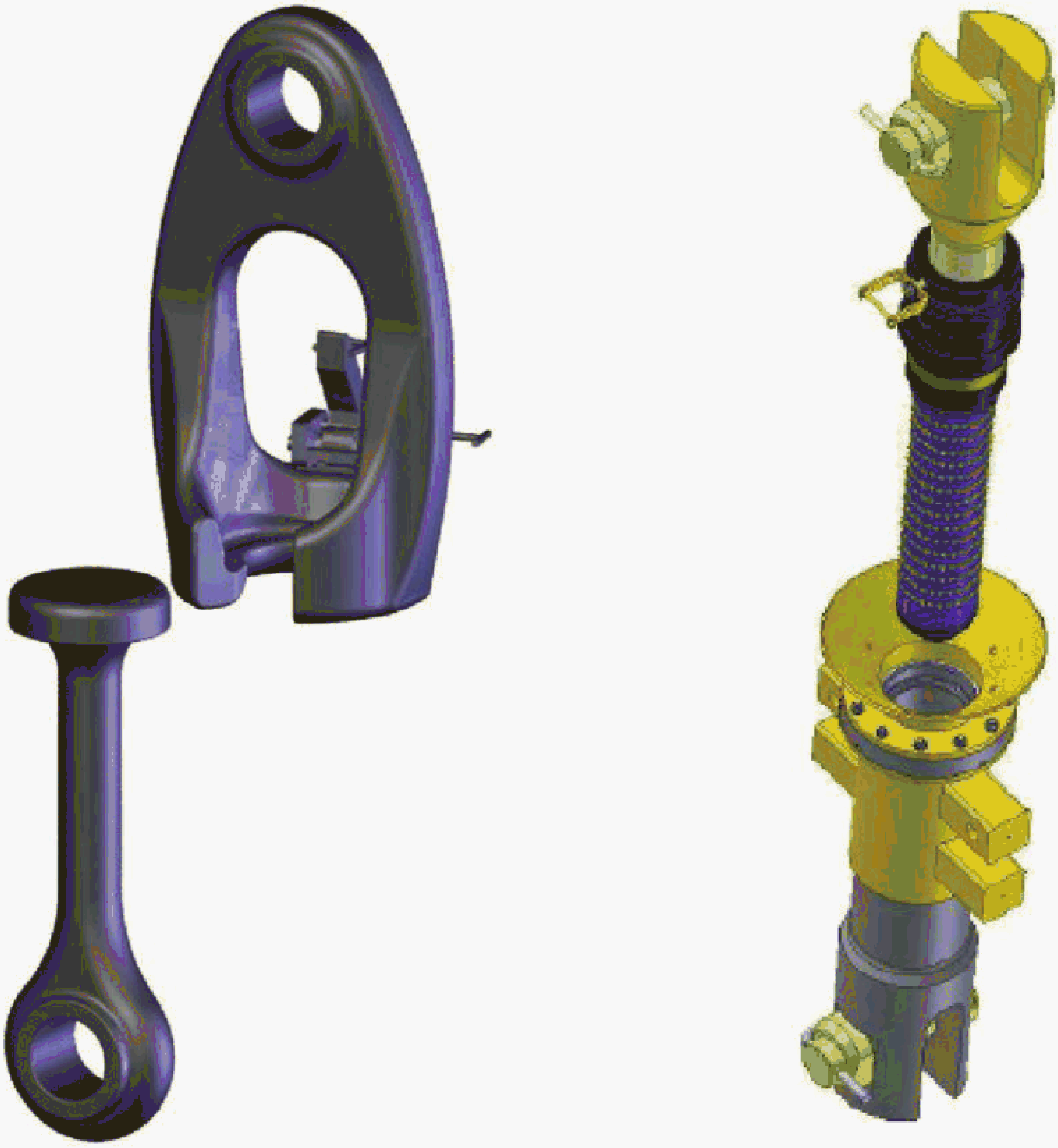
Various permanent connectors are used to connect segments of chain and/or wire rope to one another, either directly or via a triplate. The connectors are typically ‘D’ type or ‘H’ shackles with a pin and nut used to complete the connection.

4.3.4 Subsea Connectors

These connectors are typically used to facilitate installation of deepwater anchor legs or to allow easy replacement of mooring components. Two example connectors are the ‘Delmar’ and the ‘Ballgrab’ connectors (see Figure 25). These connectors are often located near the anchors.

4.3.5 Catenary Weights (‘Clump Weights’) or Drape Chains

These are sometimes used to increase the weight per unit length of the anchor leg near the touchdown region. These ‘weights’ are connected to the anchor leg components using connectors like shackles or triplates.



a) Delmar connector

b) Ballgrab connector

Figure 25—Examples of Subsea Connectors

4.3.6 Mid-water Support Buoys

These buoys can be of syntactic foam or steel construction and are used to help support the anchor leg system to reduce the load on the floating facility. These buoys are typically connected to triplate or other connection interface.

4.4 Mooring Component Information

Certain information should be collected and provided to the inspector before start of the inspection. Following are some examples, which may not represent a complete list.

— *Chain*. Type (studless or studlink), grade, diameter (nominal and bar) and other link dimensions, segment length, MBS, manufacturer and year made.

— *Wire rope*. Construction (six-strand or spiral strand), jacket (sheathed or unsheathed), corrosion protection (galvanized wires, zinc filler wires, anodes on socket, blocking compound), termination (socket type, tri-plate, etc.), diameter (bare, with jacket), segment length, MBS, manufacturer and year made, re-tension hardware.

— *Connectors*. Type ('D' or 'H' shackles, Kenter), size, MBS, and location.

— *Subsea connectors*. Type ('Delmar', 'Ballgrab', etc.), manufacturer and year made, size, inspection requirements by manufacturer, and location.

— *Catenary weights*. Type ('clump weights' or drape chain), weight, and location.

— *Mid-water support buoys*. Type (syntactic foam or steel), buoy dimensions, net buoyancy, location, and connecting hardware.

— *All components*. Previous inspection report(s), including details of past found anomalies, as available.

4.5 Inspection Objective, Type, and Schedule

4.5.1 Inspection Objective

Permanent mooring components are normally designed to allow for some wear and corrosion, so the inspection is usually to confirm that the wear and corrosion is within the design values over the life of the field. In addition, the inspection is performed to monitor the integrity of the connections of the individual components. As the majority of the mooring system is below the sea surface, the inspection is usually conducted by divers in shallow water and by ROV in deepwater. The inspection is mainly visual with photographs, video, and inspectors comments taken. The inspection can also include measurements of component diameter or depth based on the inspection plan. It is sometimes desirable to measure the potential across various mooring components to provide some insight into the possibility of corrosion occurring.

For permanent moorings, the component deployed lengths and weights are well documented and generally accurate, and the installation is also performed generally with high accuracy. This allows the use of measured catenary properties (length, depth at known reference, angle at the fairlead, tension, etc.) to help monitor and diagnose the mooring system. This information can be effectively used to estimate mooring system performance and to make a decision if any adjustments are warranted.

4.5.2 Inspection Type

Inspection and monitoring of a permanent mooring system occur in several stages over its lifecycle. The first occurs right after mooring installation and floater hook-up when an as-built survey is conducted. Mooring systems are also inspected periodically at various levels of detail based on Class or project/operating company requirements. In addition some operators may inspect the mooring system after large storms or other events that warrant inspection (dropped objects, phased installation of risers, etc.).

4.5.2.1 As-built Survey

An as-built survey should be performed for the permanent mooring system once it is hooked-up to the platform and tensioned to the design values. The survey is primarily conducted to confirm that the anchor legs are connected as designed, to check or monitor for damaged during installation, and to ensure that the permanent twist in the anchor legs is within the design/installation margins. The as-built survey also serves as the baseline for comparison for all subsequent scheduled inspections over the service life of the installation, and the inspection should be documented accurately and with sufficient detail.

— *Wire rope*. Construction (six-strand or spiral strand), jacket (sheathed or unsheathed), corrosion protection (galvanized wires, zinc filler wires, anodes on socket, blocking compound), termination (socket type, tri-plate, etc.), diameter (bare, with jacket), segment length, MBS, manufacturer and year made, re-tension hardware.

— *Connectors*. Type ('D' or 'H' shackles, Kenter), size, MBS, and location.

— *Subsea connectors*. Type ('Delmar', 'Ballgrab', etc.), manufacturer and year made, size, inspection requirements by manufacturer, and location.

— *Catenary weights*. Type ('clump weights' or drape chain), weight, and location.

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4.5.3 Inspection Schedule

Inspection schedule may vary from project to project, based on type of mooring, area and nature of operation, seafloor condition, water depth, and class requirements, etc. Following are minimum requirements.

4.5.3.1 As-built Survey

As-built survey should be conducted within three months or as soon as practical after completion of initial hookup of the mooring system with the floating vessel. Additional survey should be performed after subsequent installation activities (riser hookup, etc.) that may have significant impact on the mooring system.

4.5.3.2 Periodic Survey

Periodic surveys should be conducted no less than once every five years.

A visual inspection should be conducted annually for the above water mooring components, including chain or wire rope, winches or windlasses, deck sheaves, stoppers, and fairleads or bending shoes.

4.5.3.3 Special Event Survey

A special event survey should be considered after severe storms or other events that warrant inspection (dropped objects, collision, and contact with work wire, etc.).

4.5.4 Inspection Record

The following should be recorded on the inspection record:

a) the component information as listed in 4.4;

b) the operation history, including inspection and failure history and previous operating locations;

c) the inspection date and names of inspectors;

d) type of inspection (as-built, periodic, or special survey) and inspection method (in air, diver, or ROV);

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