Cordage Institute
International Guideline

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Fiber Rope
Inspection and Retirement Criteria

The Guideline that can Provide Enhanced Fiber Rope Durability and Important Information for the Safer Use of Fiber Rope

A Service of the

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Cordage Institute

International Guideline

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FIBER ROPE INSPECTION AND RETIREMENT CRITERIA

Guidelines to enhance durability and the safer use of fiber rope

⚠ WARNING

The use of rope and cordage products has inherent safety risks which are subject to highly variable conditions and which may change over time. Compliance with standards and guidelines of the Cordage Institute does not guarantee safe use under all circumstances, and the Institute disclaims any responsibility for accidents which may occur. If the user has any questions or uncertainties about the proper use of rope or cordage or about safe practices, consult a professional engineer or other qualified individual.

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1. INTRODUCTION

1.1 Purpose

Careful and frequent inspection of fiber rope, using procedures contained in this document, reflects prudent safety management required to protect personnel and property. This Guideline provides information and procedures to inspect ropes and to establish criteria for evaluation. This document provides inspectors with help to make reasonable decisions regarding retirement or continued use, including repairing or downgrading.

1.2 Basis for Inspection and Retirement

1.2.1 Fiber ropes are employed in a large variety of applications that differ greatly in the severity of use. In some applications, ropes can serve for many years. In more severe applications or under different conditions, the same rope may degrade rapidly. Also, ropes of different size, construction or material can show substantial differences in longevity in the same application. For each specific fiber rope application the user must establish a basis for retirement that considers conditions of use, experience with the application and the degree of risk present. See Section 4.4.

1.2.2 An inspector should always act conservatively when evaluating a rope and making recommendations for further use. Residual strength in a used rope can only be estimated and destructive test methods are required to be definitive. The visual or tactile methods described herein can only provide an estimate of rope condition.

1.2.3 Ropes that have been properly selected and used may be kept in service with some wear if inspected and evaluated in accordance with these guidelines.

1.2.4 This document provides guidance for situations where extensive usage history, documentation, inspection facilities and testing laboratories are available; however, this is most frequently not the case. Less comprehensive inspections are very worthwhile and should be carried out. Actions that are considered minimal are marked ◆.

1.3 Rope Materials and Construction

1.3.1 The ropes covered by these Guidelines are made from synthetic fibers suitable for use in rope or from natural (organic) fibers. For descriptions and performance data for synthetic fibers commonly used in rope refer to Ref. 1, CI 2003 "Fiber Properties".

1.3.2 Rope constructions include the following:

- 3 and 4 strand laid rope - Figure 1 **(**3 strand only shown)
- 8-strand plaited - Figure 2
- 8 and 12 strand single braid - Figure 3 (12 strand only shown)
- Double braid - Figure 4
- Wirelay - Figure 5
- Jacketed Industrial and Marine Ropes - Figure 6 (braided jacket construction is shown)
- Kernmantle (jacketed) Ropes - Figure 7 (rescue, climbing, rapelling)

1.3.3 This guideline may apply to ropes of other materials and constructions; however, the inspector should seek advice from the rope manufacturer or other knowledgeable source regarding rope types not specifically identified herein.

1.4 Thimbles

1.4.1 Thimbles are an important part of many rope applications. They are used to protect the eye termination of spliced ropes and grommets and should be inspected if present. Figure 8 and 9 show thimbles which are often used on fiber rope.

1.5 Limitations

1.5.1 This guideline does not cover the selection of rope types and materials for specific applications, nor does it provide procedures for safe operation and use. Persons selecting rope must consider their own experience or consult qualified persons, rope standards, manuals, regulations, operating guidelines or the rope manufacturer for information on selection and use of fiber rope. See Appendix A for a partial list of reference publications regarding rope use.

1.6 Order of Precedence

1.6.1 In the event of conflict between the information in this guideline and other guidelines, standards or regulations, the user must determine the order of precedence. When in doubt consult with appropriate authorities.

2. REFERENCES AND RELATED PUBLICATIONS

2.1 References

The following Cordage Institute (CI) and other publications provide additional information about the properties, testing, care and safe use of fiber ropes:

1. **CI 2003:** Fiber Properties (Physical, Mechanical and Environmental) for Cable, Cordage, Rope and Twine
2. **CI 1202:** Terminology for Fiber Rope
3. **CI 1500**: Test Methods for Fiber Ropes. Provides the test methods to determine both the basic and the more advanced physical properties of fiber ropes.
4. **CIB-1.4**: Fiber Rope Technical Information Manual (Cordage Institute). Contains basic information for the selection, application and safe use of rope.
5. **CIE-1:** Splicing Handbook, Second Edition, Barbara Merry. (Available from the Cordage Institute.)

2.2 Related Documents

See Appendix A for a list of other rope related publications that may be a useful supplement to this guideline.

3. TERMINOLOGY

3.1 Terms specific to this document.

<u>Qualified person</u>**:** A person who, by possession of a recognized degree or certificate of professional standing, or who, by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

Working load limit (WLL)**:** The working load that must not be exceeded for a particular application as established by a regulatory or standards setting agency. The WLL is calculated by dividing the new rope minimum break strength by a design factor. Absent any official publication of a WLL for an application, design factors should be established by a qualified person. Design factors for rope commonly vary between 5 and 12.

Visual inspection**:** Examination of the exterior or interior of a rope by visual methods, which may include magnification.

Tactile inspection**:** Manipulation of the rope by hand or other means to determine hardness and flexibility.

Overloading: Exceeding the WLL by 2 or more times or loading a rope to excess of 50% of its published breaking strength.

Shock loading: A sudden application of force at such a rate of speed that the rope can be seen to react violently. The dynamic effects can be estimated to be well in excess of the WLL. Arresting a falling weight is the most common example.

3.2 Other terms and definitions.

Other definitions for terms used in this Guideline may be found in Ref. 2, CI 1202, "Terminology for Fiber Rope".

4. INSPECTION AND RETIREMENT PROGRAM

4.1 General

The following sections present the requirements for an effective inspection and retirement program.

4.1.1 The user is responsible to establish a program for inspection and retirement that considers conditions of use and degree of risk for the particular application. A program should include:

- Assignment of supervisory responsibility. The user should assign an individual responsible for establishing the program, for training and qualifying inspectors and preserving records.
- Written procedures
- Training
- Record keeping
- Establishment of retirement criteria for each application.
- Schedule for inspections.

4.1.2 ◆ Ropes that secure or control valuable assets or whose failure would cause serious damage, pollution, or threat to life warrant more scrutiny than ropes in non-critical use. If a fiber rope is used in a highly demanding application, with potentially critical risks, the advice of a qualified person should be obtained when developing the specific inspection and retirement program.

4.1.3 The user should continue to revise and refine the program based on experience.

4.2 Training

4.2.1 ◆ Personnel assigned the responsibility for rope inspections should be properly trained to recognize rope damage and to understand the rope inspection procedures and retirement criteria contained in this guideline. The Cordage Institute can provide information on training resources.

4.3 Log and Record Keeping

4.3.1 An important tool for rope evaluation is a log. This will include data on the type of rope, time in service and description of intended use. The details of every inspection should be entered in the log as to date, location and conclusions. The log should include a regular inspection schedule. Typical logs are shown in Appendix B.

4.4 User Established Retirement Criteria

The user is responsible for inspecting and making decisions on the disposition of used rope, based on user established retirement criteria. Refer to Appendix C and the following key points.

4.4.1 User experience with the application shall be considered when preparing retirement criteria.

4.4.2 Any relevant regulatory standards and guides should be reviewed and the relevant requirements incorporated into the program

4.4.3 Examples of sources are:

American National Standards Institute (ANSI)
Occupational Safety and Health Administration (OSHA)
Code of Federal Regulations (CFR**)**

5. USED ROPE INSPECTION AND EVALUATION

5.1 Introduction

5.1.1 ◆ During the inspection, identify the rope specimen by a dated tag with separate designation codes for each specimen.

5.1.2 ◆ The inspector determines the disposition of each rope by comparing results of the evaluation to the user defined retirement criteria.

5.1.3 Complete used rope evaluation includes familiarization with rope history, visual and tactile inspection, and supplemental testing if necessary. A general knowledge of the usage history of the rope can aid the inspection process by identifying potential types or locations of damage. Supplemental testing may be necessary when more quantitative assessments are required; these may include destructive strength tests, microscopic examination or chemical analysis.

5.2 Review of Records and History

5.2.1 Ascertain the type and size of the rope and obtain the specifications for strength if possible.

5.2.2 ◆ Determine the conditions of use by witnessing the operation or by interviewing personnel.

5.2.3 ◆ Identify and quantify, if possible, unusual events that may have damaged the rope; such as, overloading, impact loading, long duration of sustained loading, sunlight or chemical exposure, and heat exposure.

5.2.4 Determine the time in service.

5.2.5 ◆ If a rope log is available, examine it for rope identification, specifications and history. Try to verify that the data matches the specimen.

5.3 Inspection Process

5.3.1 Prepare Inspection Record Sheets or make entries in a log (refer to Section 4.3). Fill-in known rope information, such as: type, diameter/circumference, fiber material, length, manufacturer, length and type of service. Add name of the inspector, date and location.

5.3.2 Photograph the rope if appropriate.

5.3.3 ◆ Lay out the rope in a straight line, on a smooth surface, under hand tension. Attempt to apply enough tension to straighten the rope (in increments if space is limited). Small diameter ropes may be inspected by pulling segments hand-over-hand. For long lengths of larger ropes, it is best to utilize a mechanical advantage to apply light tension on the rope while it is being inspected.

5.3.4 If a rope is long, it may be marked and coded in evenly spaced intervals. For easier identification, mark each fifth and tenth length interval more strongly. If the rope is very dirty, intervals could be marked by using knotted twine pieces passed through the rope. Tape is also appropriate if wrapped completely around the rope

5.3.5 ◆ Visually examine, stepwise, the entire rope length for detectable damage and deterioration; include eye splices and/or end-to-end splices [long or short]. Record all findings; identify end-to-end location of detectable damage areas.

5.3.6 ◆ Sight the rope down its length as you would a plank or mast. Inspect for high or low strands and randomly uneven cross sections. Look for twist in braided and plaited ropes, and corkscrewing in stranded ropes.

5.3.7 ◆ For ropes small enough for a tactile inspection, feel for unevenness, rough spots and stiff (lacking flexibility) sections.

5.3.8 Measure the rope circumference. Determine the circumference in a number of places, in particular in any damaged areas. This is most easily done with a thin whipping twine, thin metal or fabric tape measure or a pi-tape, wrapped around the rope with slight hand tension. Make note of nominal circumference, and any point on the rope where the circumference varies more than 10 percent from what is found on most of the rope. Ropes may decrease in circumference if well used and may be less than specified for new ropes.

5.3.9 Look for variations in the lay length (in a twisted rope) or pick length (in a braided or plaited rope). Apply a small tension to the rope and check this length at various locations along the rope. Note any appreciable deviations in lay or pick length. This length should not vary by more than ± 5 percent over the rope length. On long specimens, the tension must be high enough to minimize the effects of friction with the ground

5.3.10 ◆ Examine the rope for abrasion, cuts, broken yarns. Make a note of the type, location and level of damage such as, number of broken or noticeably damaged yarns, depth and length of abrasion or wear spots, frequency and spacing of damage, if damage is one strand or multiple strands. Estimate the loss of strength by comparing abraded or cut fibers as a percentage of the rope diameter or strand diameter. Lengthwise damage of several adjacent strands should be summed the same as if it were around the circumference.

5.3.11 Check any broken rope specimens in detail. A meaningful inspection must include both ends of a broken rope. Note location and nature of break. If possible, identify the conditions that caused the damage, such as rough hardware surfaces, points of contact, excessively sharp bends, or introduction of twist from winching practices.

5.3.12 ◆ Open the rope and examine the interior. Turn twisted rope slightly to open the interior for observation. Push on single braided or plaited ropes and/or use a fid to open the interior to view. On double braided ropes, push on the rope and use a fid to open a small hole to view the core. Be careful not to pull strands excessively. Look for broken filaments, fuzzy areas, kink bands.

5.3.13 ◆ Check braided ropes for hardness. Pushing on the rope should cause the braids to open. Braided ropes should be supple and bend easily. They should flatten slightly when compressed laterally

5.3.14 ◆ Check Kernmantle, jacketed ropes or double braids for core breaks. This is manifested by sudden reduction in diameter and can be felt by running hands over the rope.

5.4 Destructive Testing

5.4.1 For more definitive estimate of residual strength, a portion of the rope or its components (yarns or strands) can be removed and tested for residual strength. For used ropes from the same or similar applications, periodic destructive testing for strength and elongation can provide important data for purposes of evaluation. Samples from the actual rope or its components can be tested to provide comparative data. Testing may use the procedures of Ref. 3, CI 1500, “Test Methods for Fiber Rope”. Used rope and rope component testing and evaluation should be directed by a qualified person.

6. TYPES AND EFFECTS OF DAMAGE

Appendix C provides evaluation guidance for the various types of damage. The applicable section letter in this appendix is shown in brackets [ ] after the title.

6.1 Introduction [A]

Knowing the causes and appearance of damage is essential to a good rope inspection and essential in determining retirement criteria. This section describes the most common causes of rope damage and describes the effects. Appendix D contains pictures or diagrams illustrating these conditions.

Smaller ropes, due to their reduced bulk, suffer a proportionately larger loss of strength than larger ropes due to cuts, abrasion, and environmental exposure. Extra attention is recommended when inspecting small diameter ropes.

6.2 Excessive Tension / Shock Loading [B]

6.2.1 Overloading or shock loading a rope above a reasonable working load limit can cause significant loss of strength and/or durability. However, the damage may not be detectable by visual or tactile inspection. The usage history of a rope is the best method to determine if excessive tension or shock loading has occurred. Overloading and shock loading are difficult to define and the inspector must take a conservative approach when reviewing the history of the rope. Repeated overloading will result in similar damage as that caused by cyclic fatigue as described in Section 6.3. Shock loading may cause internal melting of fiber.

6.3 Cyclic Tension Wear [C]

6.3.1 ◆ Ropes that are cycled for long periods of time within a normal working load range will gradually lose strength. This loss of strength is accelerated if the rope is unloaded to a slack condition or near zero tension between load cycles. The subsequent damage is commonly referred to as fatigue. Although there are various mechanisms for the breakdown of synthetic fibers under cyclic tension, the most common is fiber to fiber abrasion. See Figure D-001 where long term loading and unloading has caused a breakdown of yarns in the outer braid of a double braided rope (lower picture). This rope was also extremely hard due to internal compaction of broken fibers. Compare to the upper picture of relatively new rope which was soft and flexible.

6.3.2 ◆ Braided ropes develop many broken filaments at the crossover points of strands in the braid due to fiber-on-fiber abrasion. Occasionally, the broken ends of yarns may appear as if cut square (a magnifying glass may be necessary). These broken filaments give the rope a fuzzy appearance on the outside and over the entire length that was under load; this can be so extreme as to obscure the underlying braid structure. Figures D-002 shows extreme examples of braided ropes that exhibit excessive damage from frequent loading and unloading.

6.3.3 ◆ For braided ropes, broken filaments within the rope can also mat, entangle and/or leave a powdery residue. Extreme internal filament breakage will make the rope very hard, lose flexibility and be noticeably larger in diameter (with a subsequent reduction in length); it may be so hard that it is impossible to pry the rope open to examine the interior structure. Melted fiber and fusion may be observed in the core rope or between core and cover. See Figure D-003 for exposing the inside of the structure.

6.3.4 ◆ For 3 strand twisted and 8-strand plaited ropes most of the wear will occur on the inside of the rope where the strands rub on each other. Broken, matted filaments and a powdery residue may be observed. Figure D-004 shows how to expose the inside of the structure by pushing on the rope and possibly exposing one strand. For laid ropes, twist the rope in the opposite direction of the lay.

6.3.5 Wirelay and Kernmatle ropes usually have a non-load bearing jacket and must be examined under the jacket. Broken filaments, powdery residue or fusion may be observed if the interior can be examined.

6.4 External Abrasion [D]

6.4.1 ◆ Most external abrasion is localized. Gouges and strips along one side of the rope are common; these display cut fibers and are often accompanied by fusion. Damage sufficient to degrade the rope is usually obvious. More uniform abrasion may be seen in ropes that are used over fixed objects that bear along a considerable portion of its length, Figure D-005. Also, dragging over a rough surface will show uniform abrasion. External abrasion can be distinguished from cyclic fatigue since the interior of the rope will not have damage and the damage is rarely uniform as seen in Figures D-006, D-007 and D-008.

6.4.2 ◆ The surface of the rope may be melted and appear black due to sliding while bent over surfaces when under high tension. See Figure D-010.

6.4.3 ◆ Jacketed ropes require inspection of the outer sheath. The load bearing core should not be exposed. Loose strands that may snag could be a consideration in some cases.

6.5 Cutting [E}

6.5.1 ◆ It is obvious during visual inspection to see where fibers have been cut sufficiently to degrade a rope. Damage assessment includes an evaluation of the amount of affected fiber, and location and orientation of the cut. For multiple cuts, the space between damaged areas is important. Figure D-011.

6.5.2 For jacketed ropes where the jacket is non-load bearing, a cut that does not damage the core will probably not affect the strength. See Figure D-012. However, core deformation or herniation could occur on subsequent use if the cover is not repaired. Cores can shift relative to the jacket; further inspection in the vicinity of the jacket should be performed to ensure integrity of the core. Cuts to jackets may cause other adverse effects such as handling difficulties, inability to slide through fittings smoothly, and exposing the core to grit.

6.6 Pulled Strands and Yarns [F]

6.6.1 ◆ Strands and rope yarns can be snagged and pulled out of the rope structure. The level of damage is a function of the percentage of the rope cross section that has been lost. See Figures D-013, D-014 and D-015.

6.6.2 Pulled strands in braided rope appear as in Figures D-014 and D-015.

6.7 Flex Fatigue – Pulleys, Rollers, Chocks, Fairleads, Blocks [G]

6.7.1 Constant bending of any type of rope causes internal and external fiber abrasion. This is frequently caused by running on pulleys. But, other types of flexing such as frequent bending over a small radius surface, can also cause fatigue damage. Flexing over fixed surfaces is often accompanied by surface wear, especially if sliding action is also present. Wear will appear on the surface of the contact area. The fibers will become matted on the surface and/or glazed from heat build-up, especially with ropes using polypropylene fibers. Broken filaments and fusion, as noted under Section 6.2, will be found inside the rope over the bending zone but not elsewhere in the rope. Figure D-016.

6.8 Spliced Eyes and Other Terminations [H]

6.8.1 ◆ Check for a properly made eye and end-for-end splices; splices should always be based on manufacturer's instructions, Cordage Institute Guidelines (CI 2100 through 2102), or sources such as Reference 5, CIE-1. A long splice for end-for-end is about 80% efficient; consider this when establishing a WLL. A properly made 3-strand eye splice is shown in Figure D-017.

6.8.2 ◆ Damage is common at splices. See figures D-018, D-019, and D-020. This area always needs to be examined closely. Look for broken strands at the leg junction (See Figure D-12)., surface wear in the back (apex) of the eye, flattening where the rope bears on pins or bollards, slippage of tucks in stranded or twisted ropes and displacement of core/cover for braided rope with buried splices.

6.8.3 ◆ Eye splices used on small pins (less than one to two times the rope diameter) are likely to have internal and external damage. See Figure D-020.

6.8.4 ◆ Tucks in 3 ,8 strand and tucks in tuck splices in single braided may have slipped in the splice. The buried leg in single and double ropes may have slipped. Freshly exposed fiber in tucks or buried legs will look clean or have a slightly different appearance where it has pulled out of the body of the rope. See Figure D-018, an example of a poorly made splice.

6.8.5 Lock stitching should be used with bury splices on single braided rope. Check to see if they are present. They are often found on double braided ropes. In both cases, they should not be broken

6.8.6 Parallel fiber ropes and some parallel strand ropes require a continuous whipping function. Damage that allows the whipping to come loose can be dangerous.

6.8.7 The following should be noted when inspecting thimbles.

- ◆ Inspect for corrosion, cracks or sharp edges that indicate weakness or the potential to cut or abrade the rope.
- ◆ Check that the groove in the thimble for the rope is slightly larger (5%-15%) than the rope when there is little or no tension.

- ◆ Check security of thimbles in the eye of a rope. Fiber rope thimbles, Figure 8, have ears that prevent the eye from turning in the thimble or allowing the thimble to fall out. If wire rope thimbles are used, they should be tight in the eye or lashed to the legs of the eye to prevent turning or falling out. Adhesives have also been used successfully to secure rope in a thimble
- Figure 9 shows a different approach to fiber rope thimble design. The round spool and hood eliminate the problems of turning and falling out.
- Fiber rope thimbles designed for nylon, polyester or polypropylene ropes may not have sufficient strength if used with very high strength fiber ropes. Heavy duty wire rope thimbles are suitable for these ropes when the fiber rope and wire rope size are the same. If data is available, determine strength compatibility.
- Thimble rated load must always exceed the WLL for an application. Ideally, if the breaking strength of a thimble is known, it should exceed the rope strength.
- ◆ In some cases, a thimble should be used but is not and excessive wear has occurred in the back of the eye. Figure D-021, upper, shows the rope eye directly on a shackle without a thimble. The rope is bent over about the same diameter as the rope itself. This can give adequate strength when the rope is new or for very few loadings, but wear can be rapid in severe applications. Figure D-021, lower, shows a wire rope thimble in the same application.

6.8.8 Other Terminations

◆ Mechanical, potted or other types of terminations may be used with fiber ropes if it can be verified that they have been qualified for the particular service and installed strictly in accordance with instructions provided by the manufacturer. These must be examined carefully in accordance with the recommendations of the manufacturer or qualified person. Always inspect the interface for abrasion where the rope joins the fitting.

6.9 Knots [I]

6.9.1 Some ropes are intended to be used with knots; examples are: rescue, climbing and arborist ropes. These ropes should be inspected for wear in the rope as it enters or exits the knot. See Figure D-022

6.9.2 ◆ Unless the application is specifically designed to use knots, they must not be used unless the working load is reduced by an appropriate amount (base on 50% of published rope strength unless specific contrary data is available). It is cause for retirement or downgrading if a knot is not called for and cannot be removed or the rope reveals structural damage due to knotting.

6.9.3 ◆ The inspector should endeavor to determine if a knot is suitable for the application and was properly tied.

6.10 Creep (cold flow) [J]

6.10.1 Ropes made of materials that creep (Reference 1) will be measurably longer if loaded continuously for long periods of time. Creep rates depend on the material, time, temperature and load relative to breaking strength. The inspector should research the loading history of the rope and determine if the fiber material is subject to significant creep at the operating conditions. Ropes made of HMPE and polypropylene are particularly susceptible and nylon is somewhat susceptible.

6.10.2 Ropes that fail due to creep often retain relatively high strength until they are very close to failure; thus the need to check for operating conditions that may suggest excessive creep.

6.10.3 Creep also reduces the elongation at failure during a strength test. Maintaining relative high stretch before failure is important in some applications. In most cases, loss of stretch can only be determined by a destructive test. Strength testing may not reveal the true condition of the rope unless stretch is also checked and compared to normal values.

6.10.4 Visual inspection for creep is only possible if the rope is cycled at moderate load a few times to set the structure; then gauge marks are placed on the rope and the length carefully measured under reference tension before it goes into service. The recorded length is then compared to the used length measured under the same reference tension.

6.11 Axial Compression and Kink Bands [K]

6.11.1 Ropes that have a braided or extruded jacket over an inner, load bearing core are subject to axial compression, as manifested by kink bands. This occurs mostly in ropes with a very tight jacket. In severe cases, the rope will have bulges in zones where kinks are concentrated (bulges often repeat at a uniform cycle length). If the inner core can be inspected, bands of kinked fibers or yarns that have a Z appearance may be seen. If damage is severe, the filaments at the Z points will be severed as with a knife. If the jacket cannot be opened for internal inspection, destructive inspection or testing may be the only means of evaluation.

6.11.2 Kink bands can also appear in splices of very high strength, high modulus ropes. This is an indication that serious damage could be present. Destructive testing may be the only means of evaluation.

6.12 Hockle, Twist, Kink or Corkscrew [L]

6.12.1 ◆ If a loop is introduced into a 3-strand rope (or other multi-strand laid rope), it will tend to hockle when tension is applied. Once set, hockles cannot be turned back to restore the rope structure and this indicates severe damage. See Figure D-023.

6.12.2 ◆ Some ropes will display a corkscrew appearance and must not be used unless restored to normal appearance. Figure D-024.

6.12.3 ◆ Braided and plaited ropes should display little or no twist, and those that do must not be used unless restored to normal appearance. Figure D-025

6.13 Sunlight Degradation [M]

6.13.1 ◆ Ultra-violet (UV) radiation from direct sunlight will cause brittle and weak outer rope yarns. UV degradation is difficult to inspect visually. Discoloration and brittleness in the filaments may be observed in some cases. Strength testing of a few surface fibers or the entire rope is required for a definitive assessment. Figure D-026.

6.13.2 The affect on the rope is much less as diameter increases. Damage to very small ropes can be rapid; ropes over 1 inch in diameter are much less affected. UV degradation is stronger in the lower latitudes and will progress with time of exposure. Non-load-bearing jackets or coatings will protect the core rope. Assessment can be difficult and advice of a qualified person should be sought if there is potential for UV damage.

6.14 Chemical and Heat Degradation [N]

6.14.1 ◆ Synthetic fiber materials generally resist chemical attack and heat exposure in normal circumstances but can be weakened in certain situations. Visual inspection may reveal discoloration and brittleness of the fibers. Melting, bonding of fibers, (Figure D-019) hardening or stickiness may be observed. However, these manifestations are not always present. The inspector should research the exposure history of the rope.

6.14.2 ◆ Nylon ropes, when wet, can be seriously degraded by long term contamination with rust. This can be detected by the reddish or brown color.

6.14.3 Fiber ropes stored at even moderately high temperatures for long periods of time can be degraded without any visual indication of damage.

6.14.4 Refer to CI 2003 for information on the temperature and chemical resistance of fiber materials.

6.15 Dirt and Grit [O]

6.15.1 ◆ Dirt and grit cause internal fiber abrasion in ropes that are in regular use. Most ropes can be forced open for internal inspection. A magnifying glass may be helpful for identification of fine particles. Figure D-027.

6.15.2 ◆ Sea water that has dried and has left a salt deposit can be damaging due to internal abrasion if the rope is used in the dry condition.

6.15.3 ◆ Oil and grease deposits, of themselves, do not damage most rope materials. However, they trap dirt and grit and may make the rope difficult or unpleasant to handle. The inspector needs to assess the effects in the light of the application.

7. DISPOSITION

7.1 Introduction

It is expected that a rope will be left in normal service if no significant damage is identified. However, when a rope is considered to be damaged, in accordance with the inspection and evaluation criteria, a decision must be made to repair, downgrade or retire the rope based on the results of the inspection.

7.2 Repair

7.2.1 If the rope shows severe damage only in a few concentrated areas, it may be possible to remove the damaged sections and resplice the rope. After completion of new eye splices or end-to-end splices, pretension or load cycle to set the splice if possible. For end-for-end splices, assume 100% strength for a short splice and 80% for a long splice.

7.2.2 Caution: Splicing of a heavily used rope may be impossible, or very difficult (double braided nylon rope can be particularly bad). In such cases, there is often a significant strength loss; consultation with a qualified person may be appropriate. For jacketed ropes where the core is the strength member, it may be possible to repair the jacket. Follow manufacturers' or other governing guidelines or directions of a qualified person.

7.3 Downgrade

7.3.1 If a rope is damaged and cannot be repaired, the residual strength of a rope can only be estimated by the inspector. The decision to downgrade a rope must be made very conservatively.

7.3.2 Destructive strength testing of yarns or of a specimen of the rope can be utilized to estimate residual strength when making the decision to downgrade. Test ropes in accordance with Cordage Institute Standard Test Method CI 1500-(current).

7.3.3 Using estimates of the reduced breaking strength of a degraded rope, the inspector or user must determine a working load limit (WLL) based on a design factor established by the user.

7.3.4 The user must make certain that downgraded ropes do not find their way into the original or other applications that require full strength.

7.3.5 Downgrading may also apply to ropes that have been repaired by splicing as used rope splices may have questionable strength.

7.4 Retire

7.4.1 Rope must be retired if it is damaged and cannot otherwise be repaired or a use cannot be found for it in a downgraded condition.

7.4.2 Retired ropes must be disposed of in accordance with any applicable regulations and rendered unsuitable for future use.

8. KEYWORDS

Rope
Rope inspection
Fiber rope
Used rope
Thimbles

APPENDIX A

RELATED DOCUMENTS

The following Cordage Institute (CI) and other publications provide additional information about the properties, testing, care and safe use of fiber ropes:

1. **ASME B30.9** Sling Standard, Chapter 4 (Synthetic Fiber Rope Slings)
2. **ASTM D4268** (current): Test Methods for Testing Fiber Rope. Provides the test methods to determine the basic physical properties of fiber ropes.
3. **ASTM F1740** Standard Guide for Inspection (includes log example)
4. **CI 1201** (current): Fiber Ropes: General Standard. Covers general characteristics and requirements for all fiber cordage and ropes.
5. **CI 1401** (current): Safe Use Guidelines: Appendix (last page) to specific rope specifications issued by the Cordage Institute after 1995 (for instance CI 1201, cited above).
6. **CI Publication List** of standards for specific constructions and fibers.
7. **ISO 2307**

Documents listed above and references listed in Section 2.1 can be obtained from the following sources:

1. ASME (American Society of Mechanical Engineers), 345 East 47th Street, New York, NY 10017
2. ASTM (American Society for Testing Materials), 100 Bar Harbor Drive, West Conshohocken, PA 19428-2959
3. Cordage Institute, 994 Old Eagle School Road, Suite 1019, Wayne, PA 19087-1866; Phone: 610-971-4854; Fax: 610-971-4859; E-mail: info@ropecord.com; Web: www.ropecord.com.

APPENDIX B

SAMPLE MOORING LINE LOG

Vessel __________ I.D. NUMBER_____________

Size______________Fiber_______________Construction________________

Length__________Number Eyes_______Size Eyes___________/__________

Mfg or NSN____

Spliced by________________________Date________________________

Inspection Schedule ____

HISTORY

Date put in service___________ Mooring station______________________

Date	Inspection or Incident	Comments

TOWING LINE LOG

Vessel ___________ I.D. NUMBER_____________

Size______________Fiber______________Construction____________________

Length____________Type end fitting________________/________________

Mfg or NSN____

Spliced by__________________________Date__________________________

Inspection Schedule ____

HISTORY

Date put in service____________ Mooring station_______________________

Date	Inspection or Incident	Comments

APPENDIX C

EVALUATION GUIDE

DEFINITIONS

8-stand = 8-stand plaited ropes		**Damage Description =** A brief description of types of damage. See the section reference for a more detailed information.
3-strand = 3 and 4 strand laid ropes		**Repair - Yes =** Repair must be made to justify **No** recommendation in **Retire** column. See Section 7.2. Repairs may not be feasible in some cases.
All braids = 8 and 12 strand single braids and double braids		**Downgrade** - Ropes may find use in a less demanding or critical application. This is not recommended, however. See Section 7.3
Jacketed = Jacketed ropes with wire lay, parallel sub-rope, parallel strand or parallel fiber load bearing cores		**Retire - Yes =** Do not use for original application. **- Best action =** Preferred that rope be downgraded or retired.

A. INITIAL EVALUATION - GENERAL

Rope type	Damage Description	Sect. Ref	Fig. Ref.	Repair	Downgrade	Retire
All ropes	Rope displays moderate wear. No history of use, no records or no specifications. Time in service unknown. No severe damage. Potential personal injury or material damage exists if rope should break.	5.1.3 5.2	None	No	Possible	Best action

EVALUATION GUIDE

B. EXCESSIVE TENSION / SHOCK LOADING

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All ropes	History of excessive tension (for example, over 50% of published strength) or shock loading. No visible damage.	5.2	None	No	Possible	Best action
3-strand 8-strand All braids	Visible damage; i.e., broken strands, splice slippage, measurable creep or internal fusion. History of excessive tension or shock loading.	6.2.1	None	No	No	Yes
All ropes	Back of eye flattened and hard; cannot be softened	6.8.2 6.8.3	D-019	No	Possible	Best action

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C. CYCLIC TENSION WEAR

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All braids	Broken or seemingly cut outer filaments that are packed into the surface or protrude, uniformly over working length. Fuzzy appearance uniform over length. Broken internal filaments over length. Packing of broken filaments that hardens rope giving less than normal flexibility; rope cannot be pried open for internal inspection.	6.3.1 6.3.2 6.3.3 6.3.4 6.3.5	D-001 D-002 D-003	No	Possible	Best action
3-strand 8-strand	Broken, powdered or matted filaments at strand rub areas at center of rope. Twist or compress rope to expose interior between stands.	6.3.4	D-003 D-004	No	Possible	Best action
Jacketed Kernmantle	Broken filaments on interior filaments of core rope. Fusion or hard spots on core. Powdered, broken or matted filaments at cover/core interface.	6.3.5	None	No	No	Yes

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EVALUATION GUIDE

D. EXTERNAL ABRASION

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
Double braids	Outer braid worn away by less than 10% of the circumference or 10% over one fourth of strands along the length; core not exposed significantly.	6.4.1	D-005 D-006 D-007	No.	Possible	Best action
Double braids	Outer braid worn away by more than 10% of the circumference or over one fourth of the strands along the length; core exposed.	6.4.1	D-005 D-006 D-007	No	No	Yes
3-strand 8-strand plait 12-strand braid	10% loss of fiber cross-section in whole rope or in an individual strand cross-section. Crowns of strands badly worn reducing strand diameter by more than 10%.	6.4.1	D-005 D-006 D-008 D-009	No	Possible	Best action
All ropes	Localized hard or burn areas, area less than 15% of rope circumference in width; penetration less than 5% of rope diameter.	6.4.2	D-010	No	No	No
All ropes	Localized hard or burn areas, area more than 15% of rope circumference in width; or length in excess of one half number of strands; and penetration more than 5% of rope diameter.	6.4.2	D-010	No	No	Yes

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Jacketed Kernmantle	Load bearing component (core of jacketed rope) is damaged by more than 5% of the cross sectional area.	6.4.3	None	No	Not recommended	Best action
Jacketed or Kernmantle -Jackets	When core undamaged, non-load bearing jacket abrasion assessment depends on the criticality of coverage for a particular application. Loss of 10% of strands at one area is cause for concern but occasional breakage of jacket strands along length is probably not so critical.	6.4.3	None	Not recomm-ended	Possible	Case by case

APPENDIX C

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E. CUTTING

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
Double braids	Outer braid cut by less than 5% of the circumference or 10% of diameter of one fourth of number of total strands along one cycle length; core not exposed.	6.5.1	None	Tuck loose ends	No	No
Double braids	Outer braid cut by more than 5% of the circumference or 10% of diameter of one fourth of number of total strands along one cycle length; core not exposed.	6.5.1	None	No	No	Yes
3-strand 8-strand plait 12-strand braid	10% loss of fiber cross-section in whole rope or in an individual strand cross-section	6.5.1	D-011	No	Possible	Best action
3-strand 8-strand plait	Over 10% loss of fiber cross-section section in whole rope or in an individual strand cross-section	6.5.1	D-011	No	No	Yes
Jacketed	Loadbearing component (core of jacketed rope) is damaged by more than 5% of the cross sectional area.	6.5.2	D-012	No	Possible	Best action

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Jacketed Ropes - Jackets	Core undamaged. Jackets are not load bearing. Damage assessment depends on the criticality of coverage for a particular applications. Also, jackets might be repaired .	6.5.2	D-012	Possible	Possible	Case by case

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EVALUATION GUIDE

F. PULLED STRANDS AND YARNS

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
3-Strand 8-Strand	Rope yarns may be pulled out from main strands. Less than 10% of rope yarns in a strand are out of place	6.6.1	D-013	Yes	No	No
8-Strand Braids	Main strands, less than 15% of number present are pulled out of position a moderate amount can be worked back into the rope to conform to the original structure	6.6.1 6.6.2	D-013 D-014 D-015	Yes	No	No
8-Strand Braids	Main strands are pulled out of position, more than 20% of number present or so much that they cannot be worked back into the rope to conform to the original structure	6.6.1 6.6.2	D-013 D-014 D-015	No	Possible	Best action
Double braids Jacketed ropes	Inner core protrudes through jacket. Rope can be massaged back into original structure without kinking.	6.6.1	D-012	Yes	Possible	Best action
Double braids Jacketed ropes	Inner core protrudes through jacket. Rope cannot be massaged back into original structure without kinking. displays moderate wear		D-012	No	No	Best action

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EVALUATION GUIDE

G. FLEX WEAR ON PULLEYS, ROLLERS, CHOCKS AND FAIRLEADS

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All braids	Broken outer filaments that are packed into the surface with fuzzy appearance uniform over flex length. Broken internal filaments over flex length. Packing of broken filaments that hardens rope giving less than normal flexibility; rope cannot be pried open for internal inspection. Non-recoverable flattening.	6.7.1	None	No	Possible	Best action
3-strand 8-strand	Broken filaments and evidence of wear on strand crowns on surface on flex length. Broken filaments and powder at strand rub points at center of rope. Internal fusion.	6.7.1	None	No	Possible	Best action
Jacketed	Broken filaments and evidence of wear on surface in flex length. Broken filaments on interior filaments of core rope. Fusion or hard spots on core. Powder or broken filaments at cover/core interface. Figure shows core with jacket removed.	6.7.1	D-016	No	No	Yes

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H. SPLICED EYE – WEAR, FABRICATION, THIMBLES

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All ropes	Improperly made splices. Check for correct fabrication. Refer to qualified person, manuals or published procedures. Old splice can be cut out and new one made.	6.8.1 6.8.5 6.8.6	D-017 D-018	Yes	Possible Splices in used rope often not reliable	Best action
All Ropes	Surface abrasion or cut damage in splice eye. See Sections C & D above	6.3.2 6.3.3 6.4.1	D-019	No	Possible	See C & D
3-strand 8-strand Braids	Splice has slipped. Strand tails have pulled back into rope. Old splice can be cut out and new one made.	6.8.4	None	Yes	Possible Splices in used rope often not reliable	Best action
Braids	Leg junction shows cut or ragged strands. Old splice can be cut away and new splice made	6.8.2	D-020	Yes	Possible Splices in used rope often not reliable	Best action
All ropes	Damaged or improper splice cannot be remade with confidence that strength is not compromised.		None	No	No	Yes

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Thimbles	Thimbles have sharp edges or corrosion. Thimble loose in eye. Rope does not fit thimble. Thimble can be replaced. Assess rope damage in accordance with Sections C & D.	6.8.7	None	Yes	No	No
Thimbles	Thimbles may be required. Eye damage may be occur because thimble is not used. Minor rope damage is present; thimble can be added.	6.8.7	D-021	Yes	No	No
Other Termin-ations	Mechanical, potted and terminations other than splices with or without thimbles should be verified as to strength capability. Action as indicated if in doubt unless fitting can be replaced by splicing.	6.8.8	None	No	No	Yes

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I. KNOTS

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All Ropes that can be spliced	A knot has been used instead of a splice and cannot be removed or replaced by a splice. No damage at knot. Assume strength has been reduced 50% and calculate working load limit on this basis - compare to actual and check if greater.	6.9.1 6.9.2 6.9.3	D-022	No	Possible	Best action
All Ropes that can be spliced	Knot/s have been placed in body of rope between splices and cannot be removed without damage or, if they are, the length previously in the knot is abraded or kinked.	6.9.2	None	No	No	Yes
Ropes for use with knots, not spliceable	Working load limit is based on 50% of published breaking strength. Little (10% or less) fiber damage at knot.	6.9.2	D-022	No	No	No
Ropes for use with knots, not spliceable	Working load limit is based on 50% of published breaking strength - compare to actual and found not acceptable or there is in excess of 10% fiber damage at knot.	6.9.2	D-022	No	Possible	Yes

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J. **CREEP** (cold flow)

Rope type	**Damage Description**	**Sect. Ref**	**Fig. Ref**	**Repair**	**Downgrade**	**Retire**
All ropes	Rope is very close to or exceeds the creep limit set by the user or rope maker. Creep is checked by procedures set by user or rope maker and found to be near limit.	6.10.1 6.10.2 6.10.3	None	No	No	Yes
All Ropes	Rope type is subject to creep and history of use shows that it may have experienced excessive creep. Rope has been used for extended time at high loads expected to cause creep.	6.10.1	None	No	Possibly	Best action

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K. AXIAL COMPRESSION AND KINK BANDS

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
Jacketed	Body of rope shows distinctive periodic bulges along its length. Internal inspection is not possible.	6.11.1	None	No	Possible	Yes
Jacketed	Internal inspection reveals distinctive Z shaped kink bands in portions of the load bearing core. More than 10% of the cross section is affected. These tend to repeat in a regular pattern along the length	6.11.1	None	No	No	Yes
Splices	Splices in ropes made of high modulus fiber may exhibit kink bands. Damage is very difficult to access without destructive testing.	6.11.2	None	No	No	Yes

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L. HOCKLE, TWIST, KINK OR CORKSCREW

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
3-strand Ropes	A loop has been pulled tight causing hockle; rope structure cannot be turned back easily without leaving the rope distorted.	6.12.1	D-023	No	No	Yes
3-strand Ropes	3-strand ropes display a corkscrew appearance when laid out straight and without tension. Corkscrew can be removed by twisting in opposite direction.	6.12.2	D-024	Yes	No	No
3-strand Ropes	3-strand ropes display a corkscrew appearance when laid out straight and without tension. Corkscrew cannot be removed by twisting in opposite direction (often result of bad splice or manufacturing defect).	6.12.2	D-024	No	Possibly	Best action
3-strand Ropes	Rope is unlaid (strands do not stay together).	6.12.3	None	No	No	Yes
3-strand	Swivel has been used with 3-strand ropes	6.12.3	None	No	No	Yes
8-strand All braids	Rope has been used in series with wire rope without a swivel (unless wire is non-rotating)	6.12.3	None	No	No	Yes
Braided and plaited ropes	Discernable twist when laid out straight, even under tension. Twist can be removed by twisting in opposite direction.	6.12.3	D-025	Yes	No	No

All ropes	Kinking is present. Kink will not disappear completely when slight tension is applied or springs back when tension is removed. Rope is hard and flattened at kink.		None	No	No	Yes

M. SUNLIGHT DEGRADATION

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
Polypropylene Ropes	Polypropylene rope with many brittle and broken filaments on the surface	6.13.1	D-026	No	No	Yes
All ropes without non-load bearing jackets	Ropes less than 1 inch diameter that are known to have had extensive exposure (year or more) to bright sunlight. Especially nylon, aramid and polypropylene.	6.13.1 6.13.2	None	No	Possible	Best action
All ropes with non-load bearing jackets	Jacket completely covers the rope, or can be patched to cover the rope, and is not subject to severe wear. Underlying core has been protected.	6.13.1	None	Yes	No	No
All ropes with non-load bearing jackets	Jacket appears severely affected and cannot be repaired. Jacket shows signs of sunlight degradation and is subject to rough service.	6.13.1	None	No	No	Yes

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EVALUATION GUIDE

N. CHEMICAL AND HEAT DEGRADATION

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All Ropes	Known that there has been significant exposure to chemicals and/or high temperatures. No information from qualified persons or rope manufactures	6.14.1 6.14.3 6.14.4	None	No	No	Yes
All ropes	Discoloration, brittle fibers, fusion, bonding of fibers together, hardness. Chemical exposure is suspected.	6.14.1	None	No	No	Yes
Nylon rope	Rope has been used or stored when wet in contact with iron or steel that is rusted. Rope is reddish or brown. The condition has existed for an extended period.	6.14.2	None	No	No	Yes

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O. DIRT AND GRIT

Rope type	Damage Description	Sect. Ref	Fig. Ref	Repair	Downgrade	Retire
All Ropes	Ropes exhibit grit or silt deposits on the inside. Broken or powdery fiber material may be present. The grit tends to fall out when the rope is dry and it is flexed.	6.15.1	D-027	No	No	Yes
All ropes	Seawater has dried and left a salt deposit on the inside of the rope. The rope has been used extensively when dry with the salt present.	6.15.2	None	No	Possible	Yes
All ropes	Seawater has dried and left a salt deposit on the inside of the rope. The rope has not been used extensively when dry. Rope can be rinsed thoroughly with fresh water.	6.15.2	None	Yes	No	No
All ropes	Rope has been significantly impregnated with oil or sticky substances. This material attracts and retains dirt and grit. It is not possible to clean the rope.	6.15.3	None	No	No	Yes

APPENDIX D

ROPE TYPES AND FITTINGS

Figure 1
3-Strand Rope

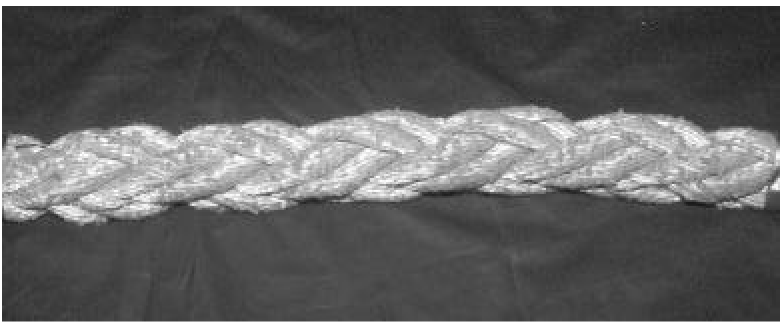

Figure 2
8-Strand Plaited Rope

Figure 3
12-Strand Braided Rope

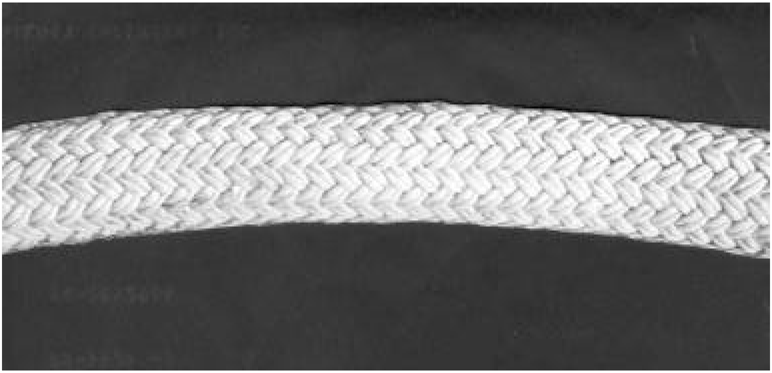

Figure 4
Double Braided Rope

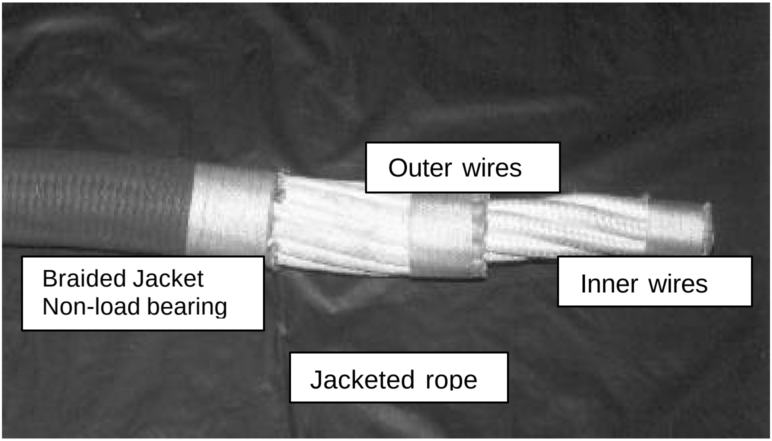

Figure 5
Wire Lay Rope

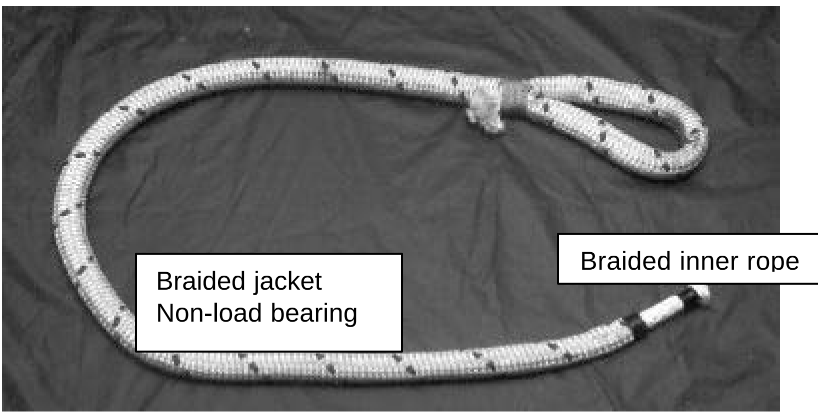

Figure 6
Jacketed Rope

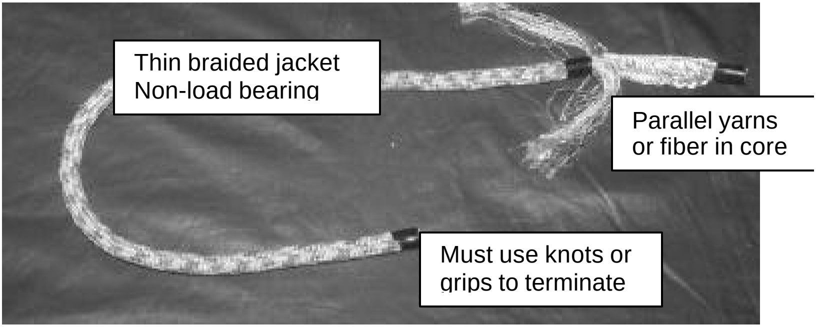

Figure 7
Climbing (kernmantle) Rope

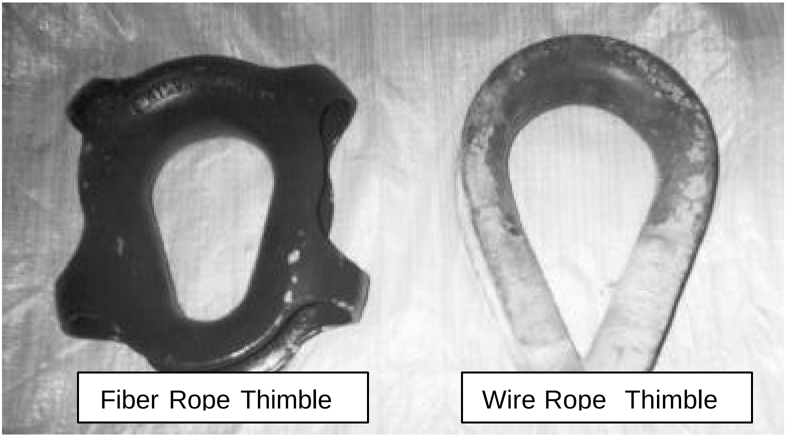

Figure 8
Thimbles

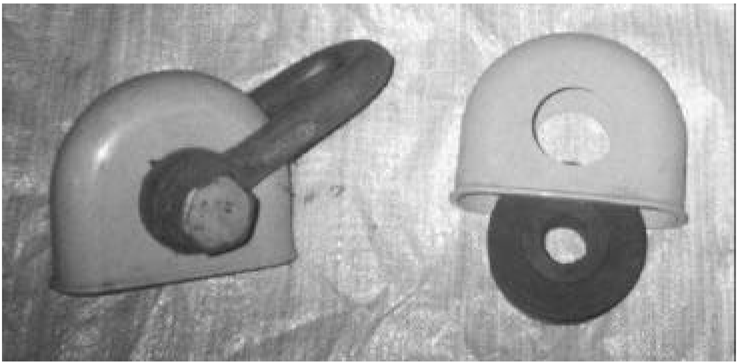

Figure 9
Plastic Thimble for Fiber Rope

APPENDIX D

DAMAGE ILLUSTRATIONS

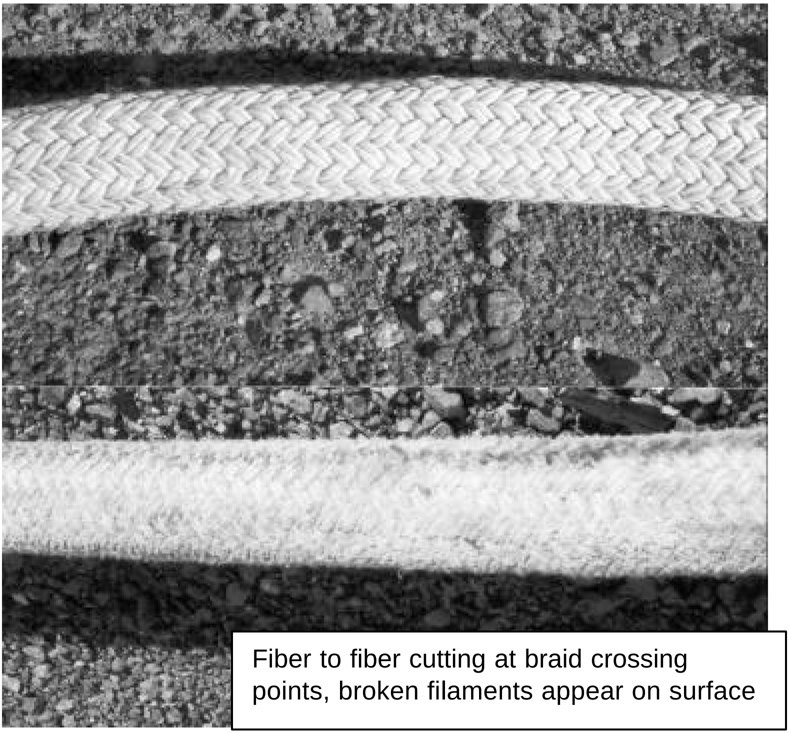

Figure D-001
Fiber Abrasion – Cyclic Tension
Undamaged - Upper Photo

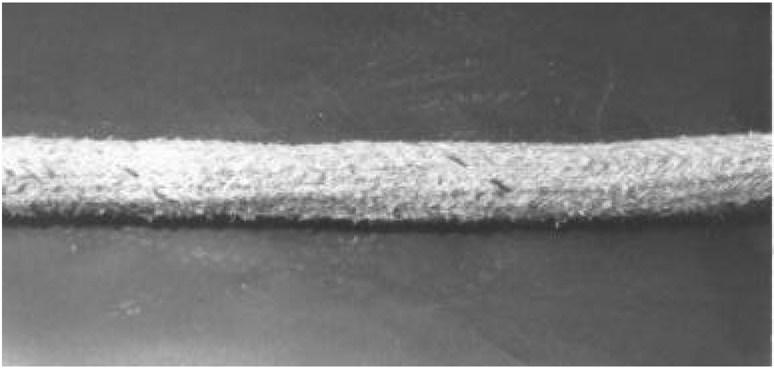

Figure D-002
Fiber Abrasion – Cyclic Tension
(extreme wear)

Figure D-003
Inter-Strand Abrasion
(Exposed internal area reveals wear at strand internal contact points)

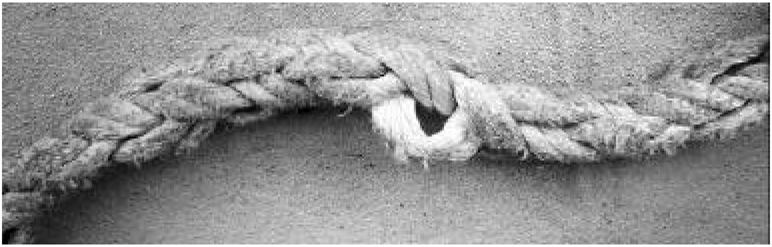

Figure D-004
Matted Internal Yarns
(Exposed stands reveal internal matting)

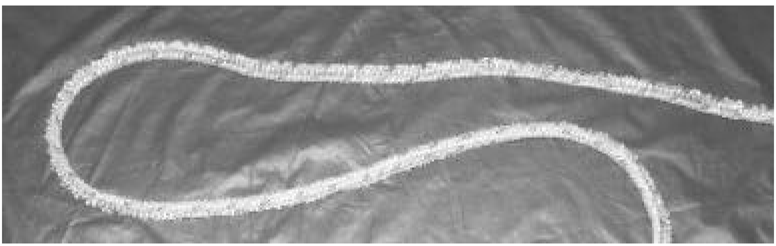

Figure D-005
Uniform Surface Abrasion
(Tree limb bull line)

Figure D-006
Extensive External Abrasion

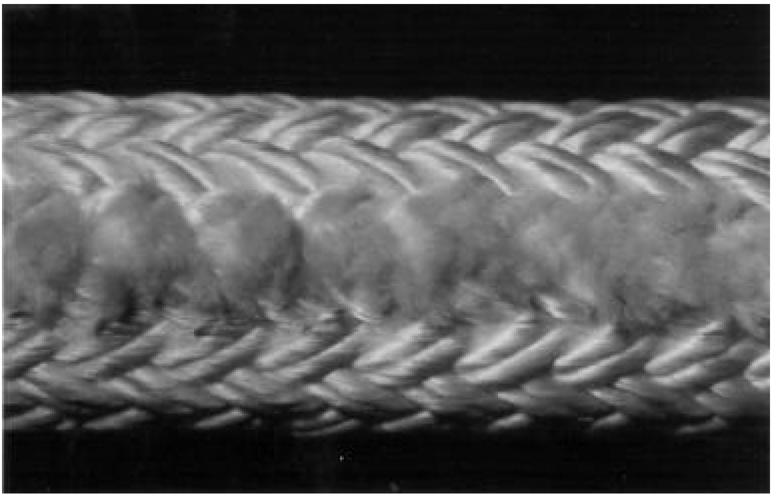

Figure D-007
Localized External Abrasion

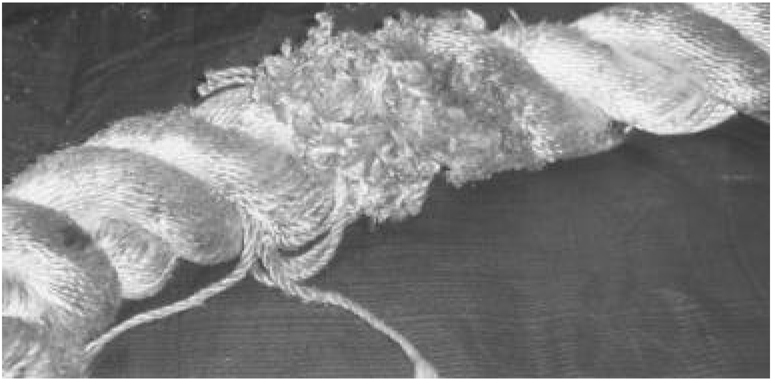

Figure D-008
Localized External Abrasion

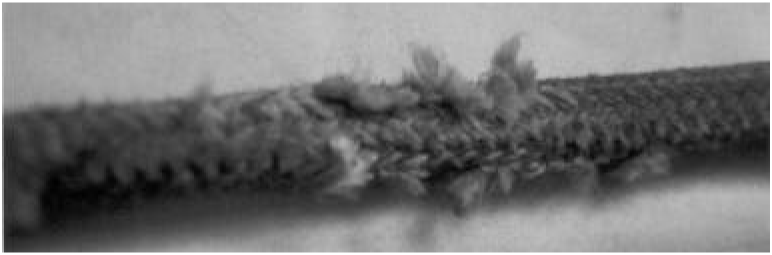

Figure D-009
Localized Jacket Wear

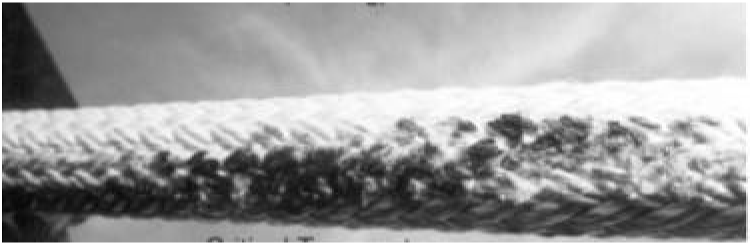

Figure D-010
Burn and Melting from External Abrasion

Figure D-011
Cutting

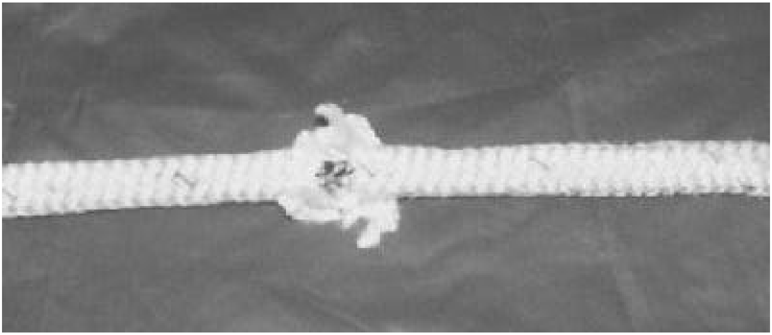

Figure D-012
Cut in Jacket Exposing Core

Figure D-013
Pulled Strand in 8 Strand Rope

Figure D-014
Pulled Strand in Worn Double Braid
(note color difference due to external dirt)

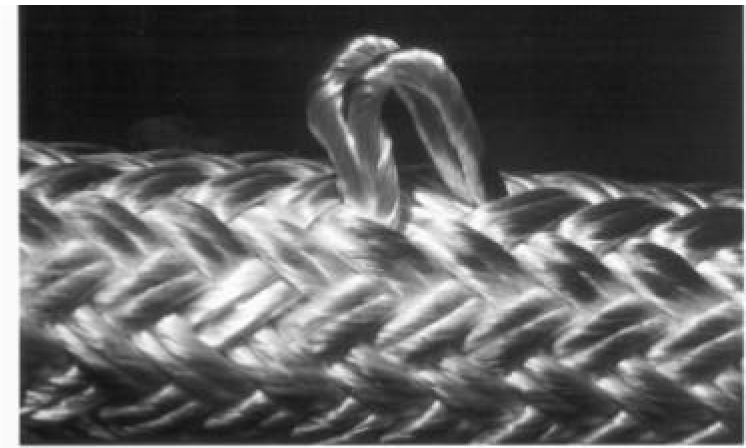

Figure D-015
Pulled Strand in New Double Braid

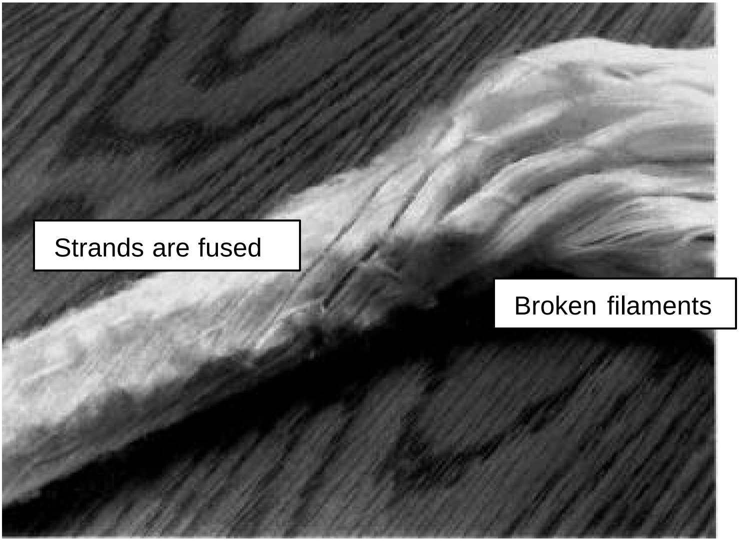

Figure D-016
External & Internal Damage – Running Over Pulley

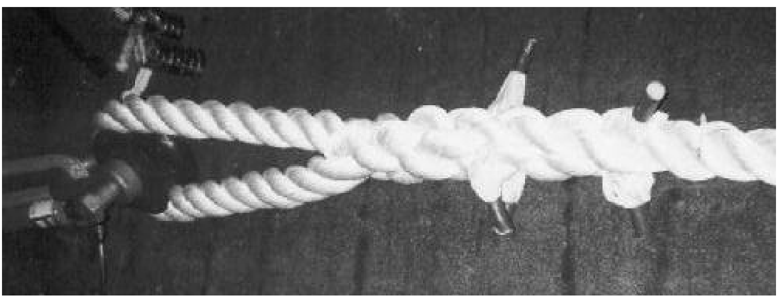

Figure D-017
Properly Made 3-Strand Eye Splice
(correctly made – shown for reference)

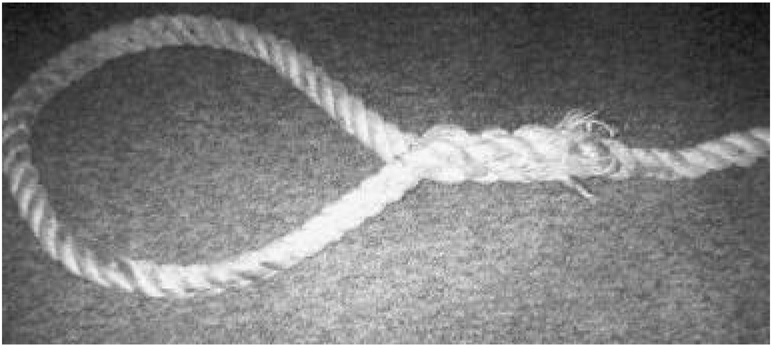

Figure D-018
3-Strand Splice of Poor Quality

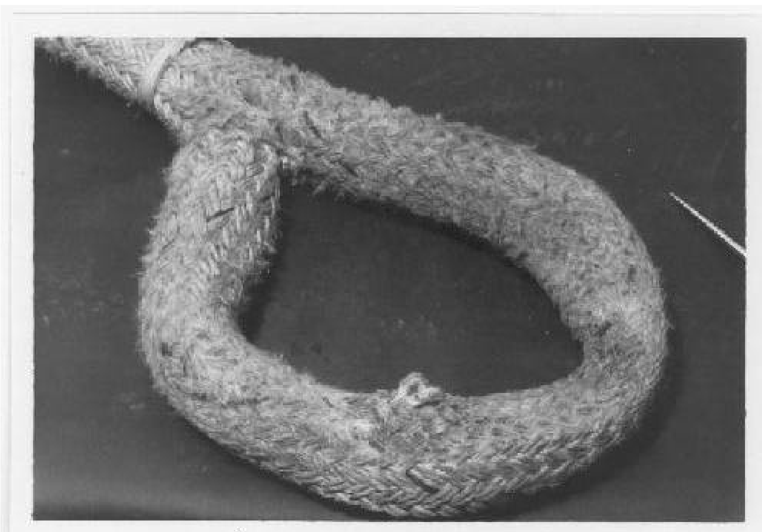

Figure D-019
Wear in Double Braid Eye Splice

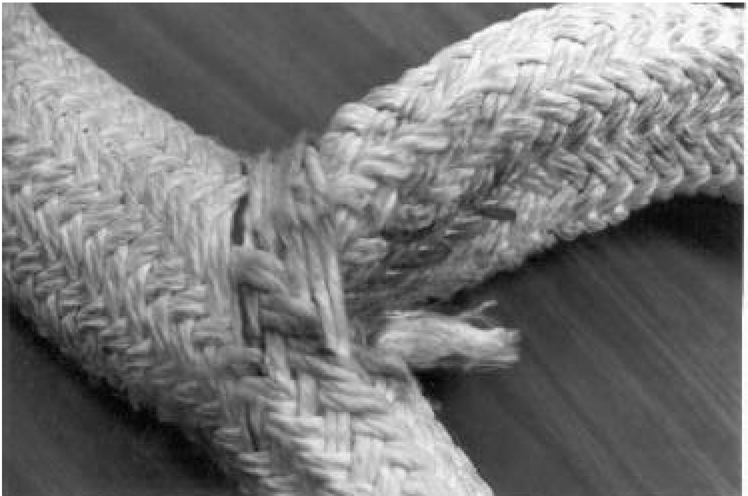

Figure D-020
Tearing at Leg Junction of Eye Splice

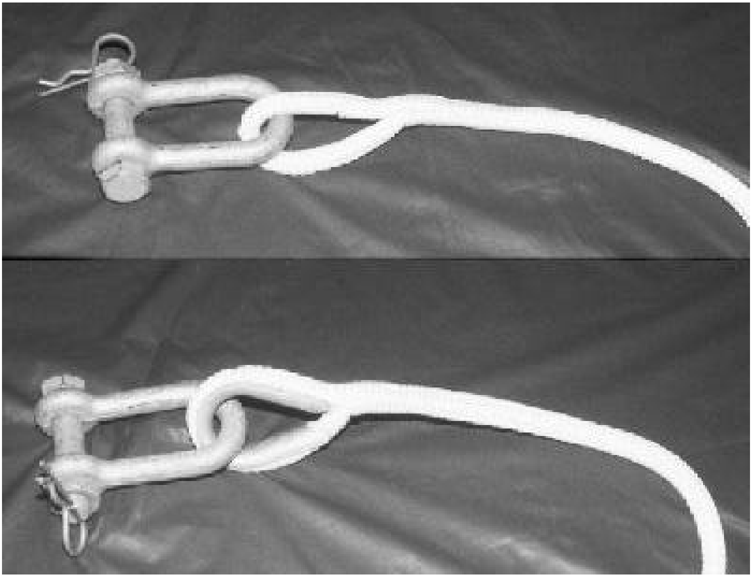

Figure D-021
Rope with Thimble (lower**) and Without (**upper**)**

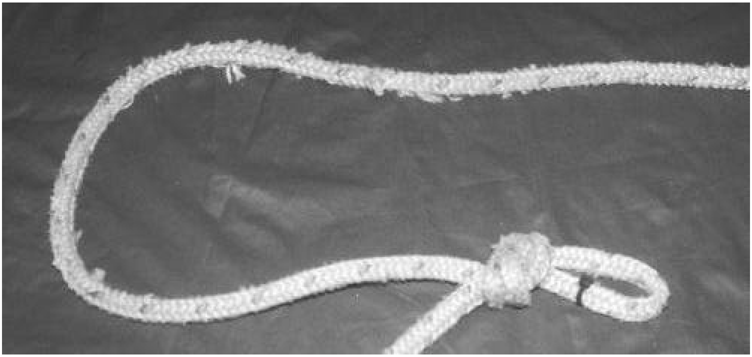

Figure D-022
Knot in Non-Spliceable Rope

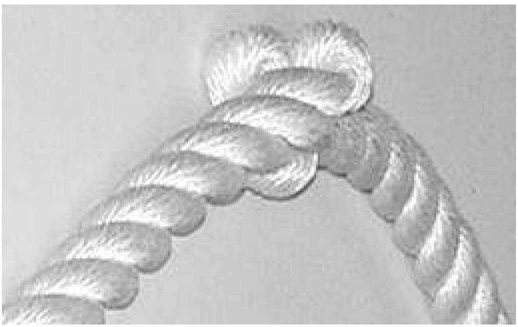

Figure D-023
Hockle

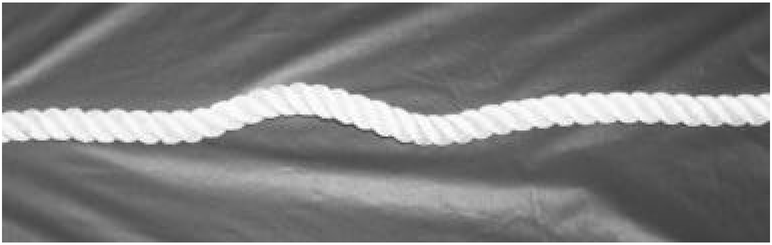

Figure D-024
Corkscrew Due to Twist

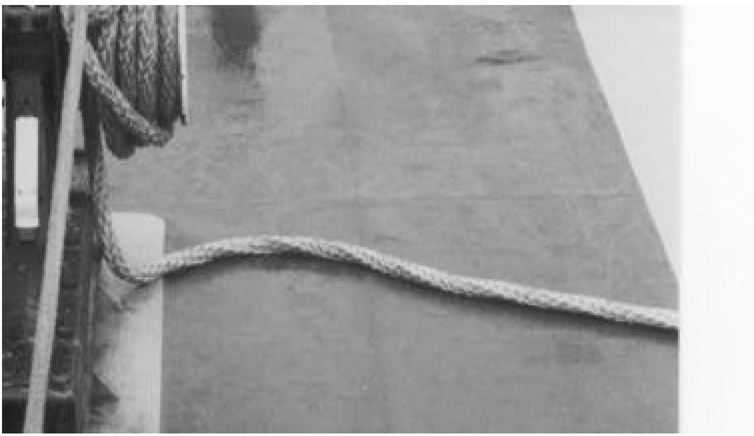

Figure 25
Twist in 12-Stand Braid

Figure D-026
UV (Sunlight) Degradation of Polypropylene Rope

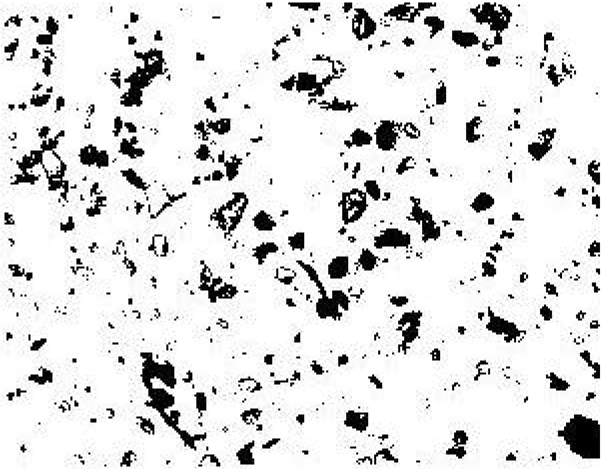

Figure D-027
Dirt and Grit
(revealed by low level magnification)