



USER'S MANUAL

Mooring Wire Ropes

Handling, Installation and Maintenance of Steel Wire Ropes for Mooring

KATRADIS GROUP OF COMPANIES

MANUFACTURER OF SYNTHETIC, HMPE ROPES & SACRIFICIAL ANODES

PROVIDER OF WIRE ROPES, ANCHORS & CHAINS, VESSEL DECK EQUIPMENT, PORT EQUIPMENT

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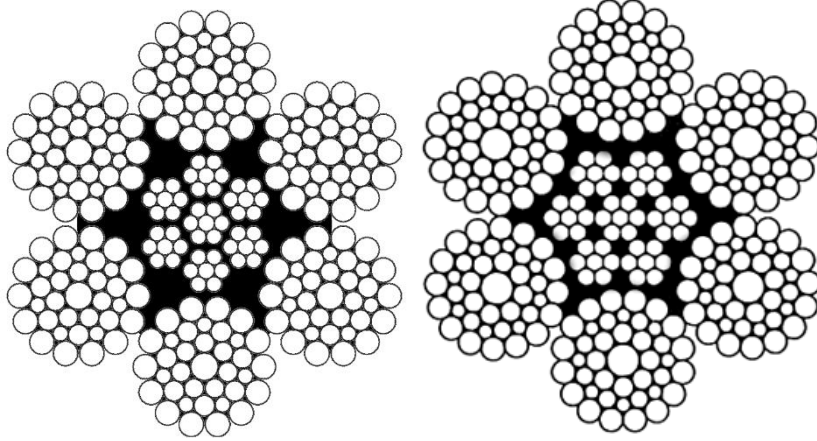
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Mooring Wire Ropes Cross Sections

Acceptable by OCIMF MEG 4 Guidelines



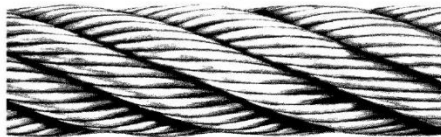
6x36WS+IWRC

6x41WS+IWRC

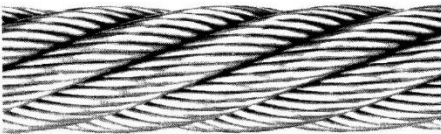
Applicable standard: EN 12385-4 & ISO 4309

Type of lay

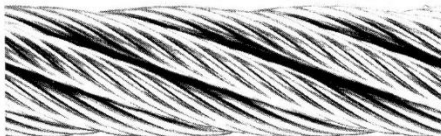
RIGHT
REGULAR
LAY



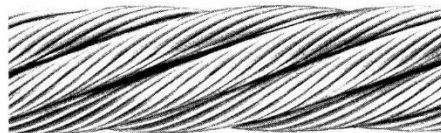
LEFT
REGULAR
LAY



RIGHT
LANG
LAY

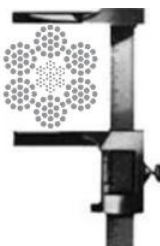


LEFT
LANG
LAY



PROPER MEASUREMENT OF STEEL WIRE ROPE

RIGHT
MEASUREMENT
METHOD



WRONG
MEASUREMENT
METHOD



Installation of wire rope

⚠ Uncoiling and unreeling

Uncoil or unreel wire rope properly in order to preserve its balance and symmetry.

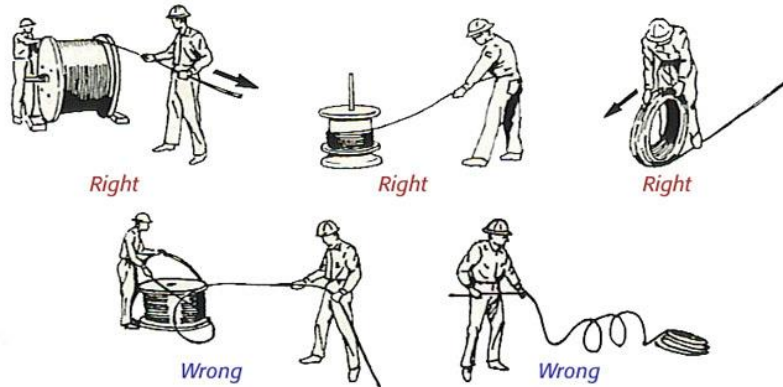
Movement over sharp corners or small radii causes a spiral or cork-screw appearance and will damage the rope.

Hold outer end of the rope on floor or ground. Turn coil on end. Roll coil along the floor letting rope trail behind or mount the coil on a turntable and pull away the free end in a straight line.

Do not lay the coil on its side and uncoil by pulling rope end, this can disturb the balance of the rope and lead to loops and kinks.

If uncoiling outdoors, do not roll through grit, sand or other abrasive material.

⚠ Figure 1



Pass a suitable bar or pipe through the center holes of the reel, and lift the reel so it is supported by the inserted shaft.

Use a timber brake or some similar device against the reel flange to apply enough tension to the rope to insure snug, uniformly controlled winding and prevent formation of loops at the storage reel.

If uncoiling outdoors, do not roll through grit, sand or other abrasive material.

⚠ Figure 2

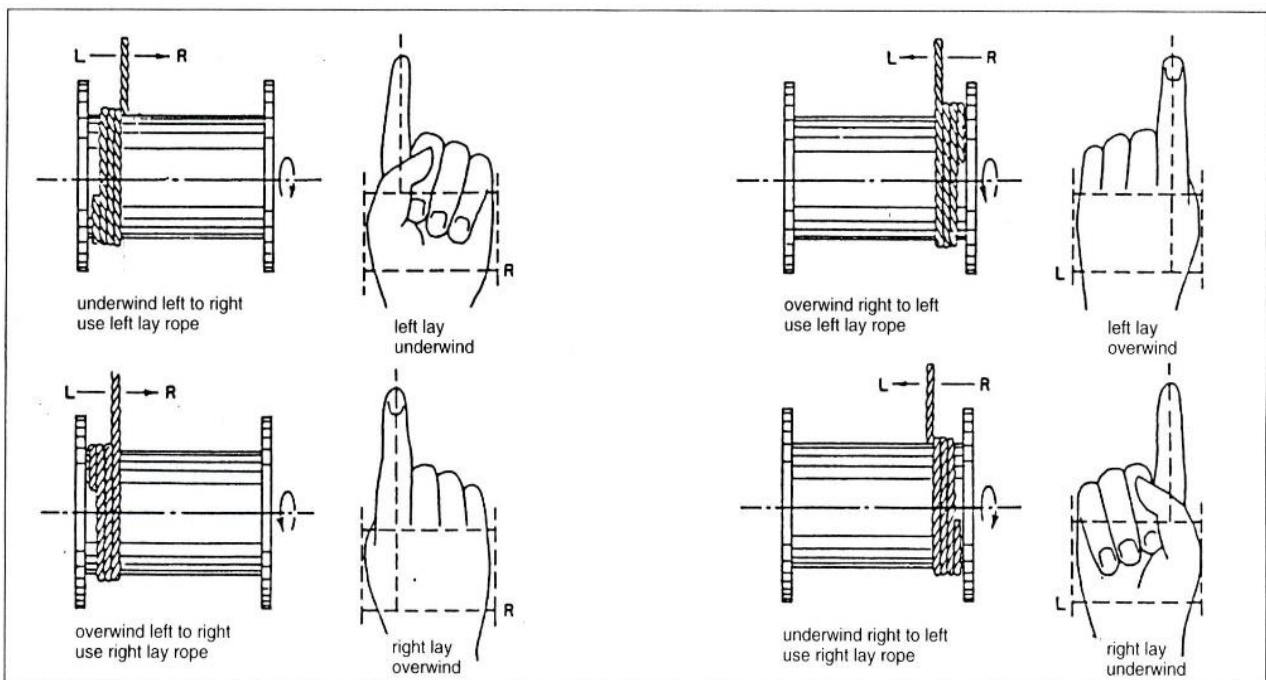
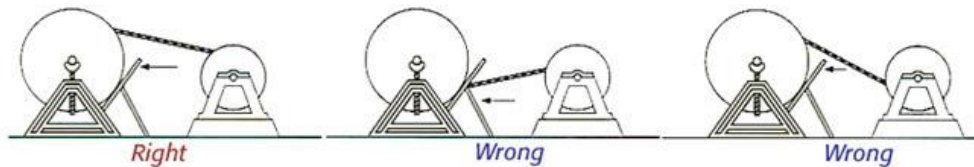


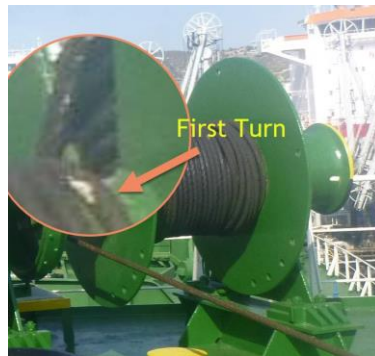
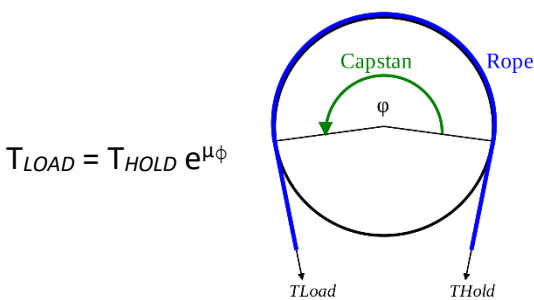
Figure 3: Winding on drum depending on rope lay & drum rotation.

⚠ Proper winding of wire rope on the winch

Equally vital and of great importance is the winding of the new wire rope under tension on the ship's storage & tension winch drum. The proper tensioning load should be approx. 2% of the minimum breaking load of the rope. If a tensioning device is not present or is impossible to apply the tensioning load using a special device, please use a wooden board in order to "brake" the pay-off reel. Do not use pressure on the rope itself in order to generate the required tension as structural damage and permanent deformation on the rope might occur. Another solution is to wind the whole length of the rope on the winch, then unwind it until the first layer appears and then apply a tension equal to the 2% of the rope's minimum breaking load so that the required tension level is achieved and then continue to wind the rope on the winch storage drum.

Ideally, 5-6 turns must be on the tension drum of the winch for avoiding slippage and high stresses.

According to our experience and based on studies effected and verified in the past, the tension amplification profile is governed by the Euler – Eytelwein capstan equation.



Considering a friction co-efficient of 0,1, the table shows the approx. tension applied to the first turn of the wire rope depending on the number of turns on the tension drum.

Turn number (T_{HOLD} is imposed)	1	2	3	4	5	6
Tension on First turn as a % of the Mooring Tension applied on the rope during mooring (T_{LOAD})	53.35%	28.46%	15.18%	8.10%	4.32%	2.31%

As shown above, 5 - 6 turns impose the lowest stresses on the rope in the tension drum assisting in the longevity of the rope and safety of the operations.

Tension drum diameter must be at least 16 times the rope diameter for reducing fatigue effects on the rope.

Break in Period

After installing a new rope, it is necessary to run it through its operating cycle several times under light load and at reduced speed. This allows the rope to adjust itself to the working conditions and enable all strands and wires to become seated. Depending on rope type and construction, some rope stretch and a slight reduction in rope diameter will occur as the strands and core are compacted. This way the rope is less liable to be damaged when full load is applied.

The initial stretch (constructional stretch) is a permanent elongation that takes place due to slight lengthening of the rope lay and due to a slight decrease in rope diameter. Constructional stretch generally takes place during the first 10-20 operations, and increases the rope length by between 1/2% for fiber core rope, approx. 1/4% for 6-strand steel core rope, and approaches zero for compacted ropes

Twisting of strands (kinking)

Some rotation may occur in the initial operations. This rotation may result from the cabling of the parts of rope or from the following causes:

- **Torque induced during installation of rope**
- **Torque induced by the operations**
- **Torque induced by the drum**

Removal of kinks: Under no load, turn the rope to the opposite direction until the rope aligns. If any non-linearity is apparent, rope has deformed and must be discarded.

Storage

Wire ropes should be stored under a roof or a weatherproof covering so that moisture cannot reach them. Similarly, acid fumes or any other corrosive atmosphere must be avoided in order to protect the rope from rust. If a reel is to be stored for a long period, it can be covered with a protective cloth. If not covered, the outer layers of rope should be generously coated with rope lubricant.

In case a rope is taken out of service and stored for future use, it should be placed on a reel after it has been thoroughly cleaned and re-lubricated. Used ropes should be given the same storage considerations as new ropes. Every 6 months inspect the ropes for lubrication drying out and re-apply as needed.

Wire rope in storage should be kept away from steam or hot water pipes, heated air ducts, or any other source of heat which can thin out lubricant and cause it to drain out of rope.

Improper storage & incomplete maintenance, that will result in a shortened service lifetime, includes, among others, the following:

- Salty/humid environment
- Corrosive/Acid/Dusty environment (chemical fumes, gritty / sandy environment and the like)
- High or low temperatures that will affect the lubricant inside the rope (so every 3 months ropes must be turned upside down)
- Lubrication (type of lubricant): Very important that a proper lubricant is used (specialized for wire ropes, with high drop point).
- Waviness of the rope (that must be straightened before rope is put in operation, eg, with a 10% of the MBL / LDBF of the wire rope applied overnight)
- Improper handling
- Inadequate ventilation
- Lack of intermediate inspection of the stored ropes every 3 months

Before taken into use, the rope must be visually inspected along its full length for broken wires, waviness, lack of lubricant (if high temperatures were prevailing during storage), corrosion signs (pitting, oxidation). For additional safety, you can have a piece of the rope tested to destruction (breaking load test), however this will reduce the original rope length by the specimen's length and leave one end of the rope without pressed eye splice.

Unreeling & uncoiling must be effected correctly as per provided instructions.

Important remarks:

- Always follow the rule: First in - First out for the spare ropes in your possession, meaning that ropes must be used in the order of delivery on board. By this, you make sure that older delivered ropes are being put into service first and not after being stored for many years. This is accomplished by marking the reel / coil with a suitable date / number etc and by following the delivery logs / records.
- Apply a coat of lubricant on the top layer of the rope in the reel every 3 months
- Removed ropes awaiting further use, should be thoroughly cleaned, inspected, lubricated and stored under the same conditions as new ropes.
- Re-lubrication (during usage), must be effected by means of a pressure lubricator

After 2 years (of proper) storage & maintenance, it is advisable to rewind the stored ropes to another reel, with core diameter bigger than the current (eg from 15x to 20x). This should be repeated every 1-2 years afterwards. Maintenance must continue as advised above for as long the rope remains under storage. No significant / measurable loss is effected per year of storage (less than 1% per year).

Expiry date of the steel wire ropes under storage: Inspection will determine, according to the discard criteria & OCIMF's MEG4 discard limit at 25% strength loss of sdMBL, if rope can be put in service after a period of storage.

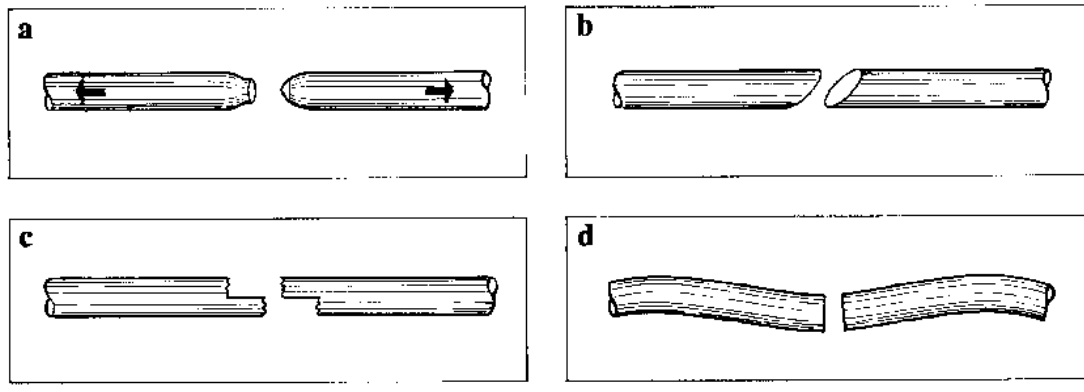
Wire rope inspection

Note : Please read the “Operator Handbook for steel wire mooring ropes about Inspection & discard as per OCIMF MEG 4 Guidelines”

⚠ Deformations/ Defects

A wire broken under a tensile load that exceeds its strength is recognized by the "cup and cone" configuration at the fracture point (a). The necking down of the wire at this point shows that failure occurred while the wire retained its ductility. Shear-tensile fracture (b) occurs in wire subjected to a combination of transverse and axial loads. Fatigue breaks are usually characterized by squared-off ends perpendicular to the wire either straight across or Z-shaped (c&d).

Figure 1



If special rope damage is found, the cause has to be determined and eliminated before a new rope is installed. If in doubt, discard rope or consult our company for further assistance.

Specific inspection procedures and frequency should be defined and documented as part of the operator's LMP.

Only qualified and experienced personnel, taking the appropriate safety precautions and wearing the appropriate protective clothing, should be responsible for inspecting wire in service.

The main causes of deterioration of wire are excessive wear, broken wires or strands, distortion and corrosion. Areas that should be regularly inspected as part of the LMP include:

- Winch anchor point and the section of wire close to it.
- Sections of rope in wear zones, particularly sections that run regularly through deck fairleads and around pedestal rollers.
- The eye, especially at the bend of the eye and its termination.
- Cross-overs on winch drum.
- Terminations, particularly the Talurit type, to identify any looseness, cracks, distortion or corrosion.

Rope inspection summary

Any wire rope that has broken wires, deformed strands, variations in diameter or any change from its normal appearance must be considered for replacement. It is always better to replace a rope when there is any doubt concerning its condition or its ability to perform the required task. The cost of wire rope replacement is quite insignificant when considered in terms of human injuries, the cost of down time, or the cost of replacing broken structures.

Wire rope inspection includes examination of basic items such as:

Rope diameter reduction | Rope lay | External wear | Internal wear | Peening | Scrubbing | Corrosion | Broken wires

 **Some wire rope sections can break up without any visible warning.**

Sections where this occurs are usually found at end terminations,. Because of the "working" that takes place at those sections, neither appreciable external wear nor crown breaks will appear. Under such conditions the core fails thereby allowing adjacent strand nicking. When this happens, valley breaks are likely to appear and the rope should be removed.


If preventive maintenance is performed diligently, rope life can be prolonged.

Cutting off an appropriate length of rope at the end termination before the core degrades, and valley breaks appear, minimizes degradation.

 **Use and care of wire rope**

What follows is a brief outline of the basic information required to safely use wire rope

- Wire rope will fail if **WORN OUT, OVERLOADED, MISUSED, DAMAGED, OR IMPROPERLY MAINTAINED**.
- In service, wire rope loses strength and work capability. Abuse and misuse increase the rate of loss.
- The Line Design Breaking Force or **MINIMUM BREAKING STRENGTH** of wire rope applies **ONLY** to a **NEW, UNUSED** rope.
- The Minimum Breaking Strength should be considered the straight line pull with both rope ends fixed to prevent rotation, which will **ACTUALLY BREAK** a new, **UNUSED**, rope. The Minimum Breaking Strength of a rope should **NEVER BE USED AS ITS WORKING LOAD**.
- To determine the working load of a wire rope, the **MINIMUM** or **NOMINAL** Breaking Strength **MUST BE REDUCED** by a **DESIGN FACTOR** (formerly called Safety Factor). The Design Factor according to the MEG 4 Guidelines is 1,82, which is the 55% of the Minimum Ship Design Breaking Load.
- **WIRE ROPE WEAR OUT**. The strength of a wire rope slightly increases after the break in period, but will decrease over time. When approaching the finite fatigue life span the breaking strength will sharply decrease. Never evaluate the remaining fatigue life of a wire rope by testing a portion of a rope to destruction only. An in-depth rope inspection must be part of such evaluations.
- **NEVER** overload wire rope. This means **NEVER** use the rope where the load applied is greater than the working load.
- **NEVER 'SHOCK LOAD'** a wire rope. A sudden application of force or load can cause both visible external damage (e.g. bird caging) and internal damage. There is no practical way to estimate the force applied by shock loading a rope. The sudden release of a load can also damage a wire rope.
- Lubricant is applied to the wires and strands of a wire rope when manufactured. This lubricant is depleted when the rope is in service and should be replaced periodically.
- Regular, periodic **INSPECTIONS** of the wire rope, and keeping of **PERMANENT RECORDS SIGNED BY A QUALIFIED PERSON**, are required by OCIMF, **OSHA** and other regulatory bodies for almost every rope installation. The purpose of inspection is to determine whether or not a wire rope may continue to be safely used on that application. Inspection criteria, including number and location of broken wires, wear and elongation, have been established by **DIN, ISO, CEN, OSHA, ANSI, ASME** and other organizations.

 **If in doubt, replace the rope.**

- When a wire rope has been removed from service because it is no longer suitable, IT **MUST NOT BE RE-USED IN ANOTHER APPLICATION**.
- Every wire rope user should be aware of the fact that each type of fitting attached to a wire rope has a specific efficiency rating which can reduce the working load of a rope system (like the mooring system), and this must be given due consideration in determining the capacity of a wire rope system.
- Some conditions that can lead to problems in a wire rope system include:
 - Broken wires mean a loss of strength. Kinks permanently damage a wire rope.
 - Environmental factors such as corrosive conditions and heat can damage a wire rope.
 - Lack of lubrication can significantly shorten the useful service life of a wire rope.
 - Contact with electrical wire and the resulting arcing will damage a wire rope.

Areas that should be given operator's attention include the following:

Winch anchor point and the section of wire close to it

Sections of rope in wear zones, particularly sections that run regularly through deck fairleads and around pedestal rollers

The eye splice, especially at the bend (bow) of the eye and its termination

Cross-overs on winch drum

Terminations, particularly the aluminium Talurit ferrule, to identify any looseness, cracks, distortion or corrosion

Discard criteria for wire ropes - when to replace wire rope based on various deformations (number of broken wires, diameter reduction etc) as per ISO 4309 standard & OCIMF's MEG 4 Guidelines

	Inspection Criteria	Discard Criteria
Visible wire breaks	Number in length of 6d or 30d	Discard if over 4 in length 6d or 8 over 30d (RHOL & LHOL ropes)
Wire breaks at termination	Evidence of broken wires	Remake termination or discard rope
Fracture of strand	Strand fracture	Discard if present
Reduction of rope diameter	Percentage reduction	Discard if diameter decreased by 10%
Abrasion of outer wires	Degree of deterioration (%)	Discard if over 7%

Rope lay length: Approx equiv to 6 x d (d is the nominal rope diameter)

Fracture of strands: If a complete strand fracture occurs, the rope must be immediately discarded (ISO 4309 §6.4).

Mooring Wires Connection

a) Connection with Mooring Link



b) Connection with Mooring Shackle



⚠ Bear in mind that Cow Hitch or any other knot based solution to connect a mooring wire with synthetic tails is **not safe and is **not recommended**.**

The maintenance of steel wire ropes

Wire rope cleaning and lubrication best practice

The information in this guide has been gained from working with wire rope, OEMs and extensive field experience with customers using mooring wire ropes.

a) Cleaning

Prior to lubrication, effective cleaning of wire ropes can enhance the performance, corrosion resistance and ultimately the life of wire ropes. Both dynamic and standing ropes will naturally attract dirt over time. By removing old lubricant and cleaning back to the bare metal, lubricant will naturally penetrate deeper into the rope. Lubricating over a dirty wire rope can force dirt into the rope and act as an abrasive. Adhesion of the lubricant to the rope will also improve as the new lubricant will have more of an affinity to the rope than to a layer of old grease. When new grease is applied over an old heavily lubricated rope, it may reduce its adhesive performance. It is important to understand that if a new wire rope is fitted, it may come with a heavy build lubricant applied from the manufacturer. When stored in hot climates over time, wax based build lubricants can harden with a glass-like finish. This will prevent any service lubricant being able to penetrate or adhere to the rope effectively. This should be noted when fitted and monitored in service. Initial inspection periods should determine the re-lubrication at a suitable time when the build lubricant has loosened. The use of solvents for cleaning wire ropes should be avoided and can be harmful to operators and aquatic environments. Jet washing and steam cleaning should also be avoided as the forceful ingress of water can be difficult to displace and increase the likelihood of internal corrosion. Effective cleaning of wire ropes is a difficult task. However, there are various ways to make this easier. The rope and its accessibility will determine the best way to carry this out. Ropes that are difficult to access may be cleaned the mechanically with a stiff nylon brush. High pressure lubricant applicators often have cleaning rings or scrapers that clean the rope prior to applying lubricant. These tend to be the quickest and easiest method of cleaning and lubricating in one pass. If corrosion is present it should not be mechanically abraded to remove it, for example with a wire brush. Although this would remove the surface corrosion, it may also remove any remaining galvanic protective layer. The bare metal is then more susceptible to flash corrosion.

b) Fluid or Grease?

A solvated fluid wire rope lubricant has a natural tendency to displace water. For that reason it is excellent for the lubrication of wet wire ropes. For marine applications such as tug boat wires, this can be beneficial to chase off water internal to the core of the wire rope. Fluids can easily be applied using a spray type system, often incorporating compressed air. For smaller applications such as hoists wires, backpack sprayers (that are resistant to oils and solvents) can be used to easily apply the lubricant. A benefit of a fluid is that it will exhibit greater penetration into the wire rope than a standard grease. Penetration is essential for a lubricant to coat the internal strands to prevent wear and internal corrosion. A drawback of a fluid is that the lubricant life span is lower so application frequency is greater compared to a grease.

c) Environmentally Considerate Lubricants

For wire ropes in marine environments, it is important that an environmentally considerate product is selected. These are developed to be high performance, biodegradable, non-toxic to marine environments and non-bio accumulative. The use of products containing mineral oils should be avoided as these can be very harmful to the environment, marine life and operators applying them. Failure to comply can result in heavy fines being issued the Environmental Protection Agency (EPA).

d) Compatibility

The recommended wire rope lubricant products for the mooring wire rope HYPERMAX 6S are the **ROCOL**. They are fully compatible with other brand wire rope lubricants. However, applying **ROCOL** wire rope lubricants over excessive amounts of previously used or build lubricant may restrict the performance. The product **Wireshield** of **ROCOL** is the unique grease with pseudoplastic rheology. This unique technology aids penetration of the lubricant into strands of wire rope, ensuring deeper protection for long time.

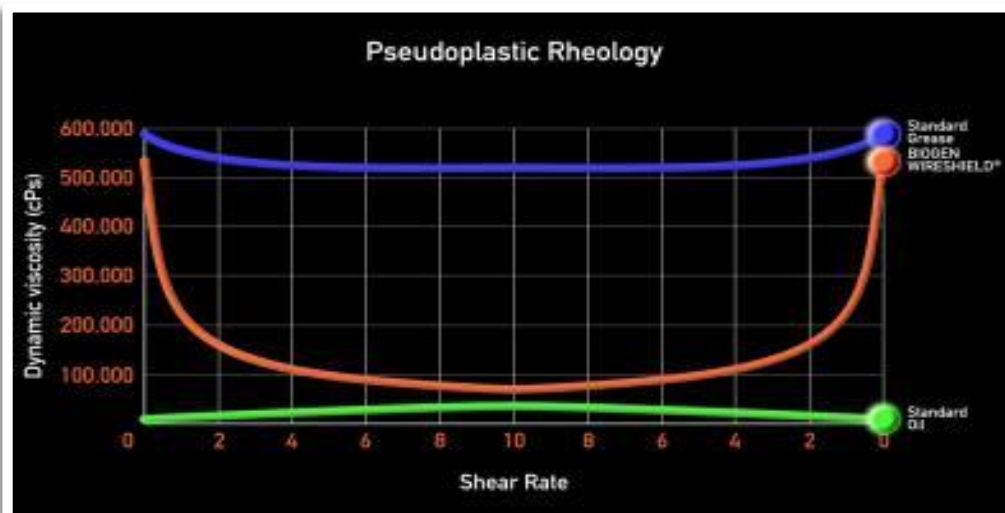


Figure 1.1 — Pseudoplastic rheology –Wireshield

e) Lubricant Application

An application method should be selected that is suitable for the wire rope and the asset it is fitted to. Katradis and **ROCOL** recommend the use of a wire rope pressure applicator. These have the benefits of effectively cleaning the wire rope with a helical grooved cleaning ring, prior to the lubricant application. They also apply the grease with pressure, promoting penetration and leaving a thin and even lubricating film. If not using a pressure applicator, wire ropes can be cleaned using a stiff bristled brush if required. Solvents and cleaning fluids should not be used for cleaning. **ROCOL** wire rope products can also be applied by hand. This can be either swaging or brushing and care should be taken to get good coverage of the rope. When applied by hand, wire rope lubricants should be worked into the surface of the wire rope to aid coverage and penetration. Over application should be avoided to prevent excessive usage, build-up of grease on sheaves and prevent fling.

f) Lubricant consumption

Lubricant consumption can be vary widely depending on many factors such as age of the rope, size and construction, lubricant choice, application method, temperature of application, environmental factors (wet/hot/cold weather or sunlight UV exposure),load cycles, rope speeds, water depth/pressure etc. There are various calculators (available on request) that will give a guide to the amount of lubricant required for the size/length of asset you have. As a good starting point a grease will give approximate rope coverage, based on a 25mm diameter rope, of 50 meters per kg.

g) Re-lubrication Periods

Re-lubrication periods can vary widely according to the same factors mentioned in the above lubrication consumption. Depending on the operation or location of the asset it will dictate when it is possible to lubricate. A general rule of thumb would be every 6 months. If the rope is in constant operation or extreme environments, this can be significantly shortened. Conversely, it could be lengthened if the rope is subject to less harsh environments.

Concluding, the Key features of wire rope lubricants are as below:

- Corrosion Protection.
- Wide operating temperature ranges -50° up to $+180^{\circ}$ C, with drop point at least 100° C (as per IP 396)
- Ability to penetrate rope strands.
- High resistance to water wash-off.
- Low propensity for fling-off.
- Environmentally considerate formulations.

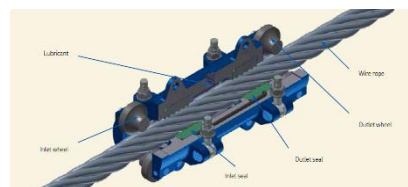


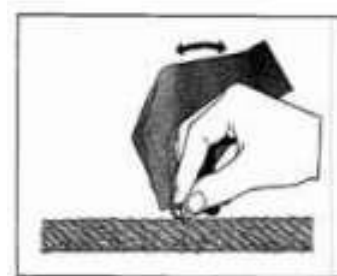
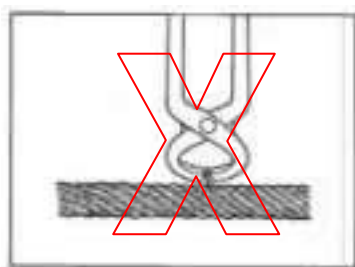
Figure 1.2: Wire rope Pressure Lubricator System



Removing broken wires

If, during an inspection, ends of broken wires are detected, which might cross adjacent wires and destroy them when running over sheaves, these broken wire ends must be removed.

Under no circumstances should the broken wire ends be pinched off with a pair of nippers (see figure below). The best method is to move the wire ends backwards and forwards until they break deep in the valley between two outer strands (see figure below). With thicker wires a tool should be moved backwards and forwards on the surface of the rope, thus bending the wires until they break.



Diagnostic guide to common wire rope degradation

Mode	Symptoms	Possible causes
Fatigue	Wire break is transverse-either straight across or Z shape. Broken ends will appear grainy.	Check for rope bent around too small a radius; vibration or whipping; wobbly sheaves; rollers too small; reverse bends; bent shafts; tight grooves; corrosion; small drums & sheaves; incorrect rope construction; improper installation; poor end terminations. (In the absence of other modes of degradation, all rope will eventually fail in fatigue.)
Tension	Wire break reveals a mixture of cup and cone fracture and shear breaks.	Check for overloads; sticky, grabby clutches; jerky conditions; loose bearing on drum; fast starts, fast stops, broken sheave flange; wrong rope size & grade; poor end terminations. Check for too great a strain on rope after factors of degradation have weakened it.
Abrasion	Wire break mainly displays outer wires worn smooth to knife edge thinness. Wire broken by abrasion in combination with another factor will show a combination break.	Check for change in rope or sheave size; change in load; overburden change; frozen or stuck sheaves; soft rollers, sheaves or drums; excessive fleet angle; misalignment of sheaves; kinks; improperly attached fittings; grit & sand; objects imbedded in rope; improper grooving.
Abrasion Plus Fatigue	Reduced cross-section is broken off square thereby producing a chisel shape.	A long-term condition normal to the operating process.
Abrasion Plus Tension	Reduced cross-section is necked down as in a cup and cone configuration. Tensile break produces a chisel shape.	A long-term condition normal to the operating process.
Cut or Gouged Or Rough Wire	Wire ends are pinched down, mashed and/or cut in a rough diagonal shear-like manner.	Check on all above conditions for mechanical abuse, or either abnormal or accidental forces during installation.
Torsion or Twisting	Wire ends show evidence of twist and/or cork-screw effect.	Check on all above conditions for mechanical abuse, or either abnormal or accidental forces during installation.
Mashing	Wires are flattened and spread at broken ends.	Check on all above conditions for mechanical abuse, or either abnormal or accidental forces during installation. (This is a common occurrence on the drum.)

Determination of NORMAL / EXTREME Operating Conditions

Generally, mooring lines operate in various weather conditions, types of ports (sheltered or exposed – open sea), mooring arrangements and loading conditions. Such factors highly affect the service life of mooring lines and should be taken into consideration when evaluating their condition and performance.

Below, there is a table for determining the normal or extreme operating conditions

Determination of NORMAL / EXTREME Operating Conditions	
NORMAL OPERATING CONDITIONS	Operating temperatures up to 90°C
	Mooring at sheltered port
	Low wind forces (1-4 beaufort)
	Typical mooring layout
	Absence of swell
EXTREME OPERATING CONDITIONS	Operating temperatures exceeding 150°C (aluminium ferrule limitation)
	Mooring at exposed terminal
	Ship-to-Ship operations
	High wind forces (over 5 beaufort)
	Presence of swell
	SPM, CBM or Multi Buoy Mooring layout

DISCLAIMER

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Visual Illustrations

The images of damages and deformations included in this manual are intended solely for illustrative purposes, serving as general guidelines to help users recognize common forms of wear, tear, and damage. Actual damages or deterioration in equipment may differ substantially in appearance, extent, and causation.

These images are not intended to be the sole basis for assessing the safety or condition of any equipment. For a thorough evaluation and recommendations regarding repair or replacement, users are advised to consult a qualified professional or contact Katradis Marine Ropes Industry S.A.



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