USER'S MANUAL

MOORING STEEL WIRE ROPE

In accordance with provisions and recommendations of:

OCIMF **MEG4**

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1. General

Steel wire ropes are constructed of steel wire strands that are twisted (or laid) into rope form. Products can be made and finished with slightly different processes to improve line quality and performance. Steel wire ropes are used on a wide variety of ship types and sizes. Steel wire ropes have a high strength-to-diameter ratio and excellent resistance to abrasion and other forms of mechanical damage. Steel wire ropes require routine maintenance to prevent corrosion and are significantly heavier than synthetic lines, which can introduce handling challenges for ship personnel. Lines made with Independent Wire Rope Core (IWRC) are strongly recommended over fibre core steel wire ropes. An IWRC steel wire rope has much greater resistance to crushing, higher LDBF for a given diameter and greater strength retention when bent.

2. Material

High quality, high tensile, drawn galvanized wire is recommended for wire mooring lines. Other steel materials and processing methods are used in the manufacture of steel wires, but are not included in this section. If using other materials, consideration should be given to intended use, compatibility with interfacing equipment and maintenance. Other steel materials and processing methods may include high carbon steel, ungalvanized steel, stainless steel, aluminium/zinc coatings and hot dip galvanizing.

3. Construction

6 x 36 or 6 x 41 (6 x 36 class) wire construction is recommended for all general mooring line applications with the wires in each strand of equal lay and the strands of regular (ordinary) right hand lay. Figure 1 shows the recommended wire construction.

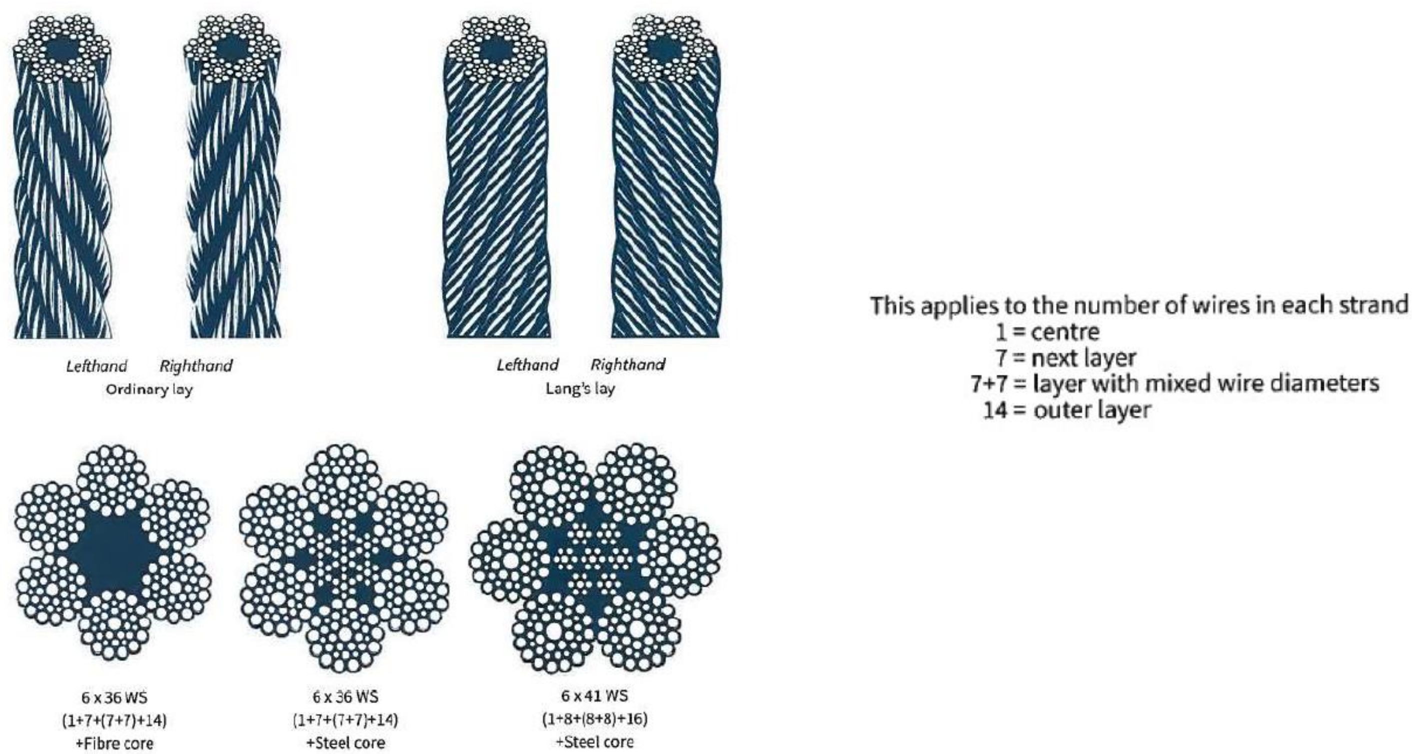


Figure 1

4. Factors influencing performance

The key factors influencing performance of steel wire mooring lines are strength, bend fatigue, tensile fatigue, crushing and deformation, corrosion and abrasion, and temperature. These factors are explained in more detail below, with guidance on how to address each issue provided where feasible.

4.1 Tensile strength of new steel wire mooring lines (i. e. LDBF) should be specified in accordance with the design guidance in section one' his recommended to use wire with minimum tensile strengths ranging from 1,770 to 2,160N/min'. Pre-formed, galvanized drawn wire with these tensile grades is now widely available and is recommended in place of ungalvanized wire grades.

4.2 As with all rope, steel wire will lose strength when bent over a radius. This is a major factor in the design of shipboard equipment for steel wire rope since items such as winch drums and fairleads should have an adequate diameter or surface radius. The recommended minimum values listed in section 5.23 are based on lines using the recommended IWRC. A fibre core rope will lose more strength at a given bend ratio than an IWRC rope. It is therefore recommended that fibre cored steel wire ropes are not used. A minimum bend ratio (D/d) of 15 is recommended.

4.3 Fatigue in wire mooring lines is mainly caused by the wires being bent over a winch drum, sheaves or deck fairleads. A wire constructed with big outer wire strands, e. g. a 6 x 19 construction, will have less resistance to bending fatigue than a wire with smaller wire strands, e. g. a 6 x 36 construction. Abrasion to wire can be caused when it runs over deck fittings or when it rubs against itself when spooled on and off the winch drum.

4.4 A dynamic load (often referred to as a shock load)is a sudden high load that is transferred into a line that has previously been under a low or static load. This can cause a peak load that is higher than the recommended load limit or, in extreme cases, the line's residual break load, which can cause the line to fail. Repeated dynamic loading can cause significant strength loss in the line. This can be difficult to detect in normal conditions and can lead the line to fail some time later, even when operating below the maximum load limits. Dynamic loads exceeding the WLL should always be recorded and advice should be sought from the line manufacturer on whether they can continue to be used.

4.5 Crushing damage to wire can be caused by high pressure on winches with more than one layer of line or by the wire being bent on deck fittings at high load. Wire should be installed on the winch drum with back tension according to the manufacturer's guidelines and should be uniformly spooled. his recommended that IWRC ropes are used instead of fibre core ropes because they have a higher crush resistance.

4.6 Corrosion on steel wire mooring lines will increase the rate of fatigue of the line and should be avoided. More details on proper line maintenance and corrosion prevention is provided in section 6.3.

4.7 For most applications, steel wires can usually be used in temperatures as low as -40'C and as high as 90'C, although wire lubricants and terminations such as sockets and ferrules may have limitations on use at extreme temperatures. Further advice should be obtained from the line manufacturer.

5. Specifications and procurement

There are currently no international standards for the specification of steel wire ropes specifically for use as ship mooring lines. 6 x 36 class wire is suitable for most mooring line applications. Purchasers should consult with suppliers to make sure the lines meet their required performance criteria and that testing is appropriate for the intended use. Steel wire rope products are covered by many national and international standards. The following standards concern steel wire ropes that use the recommended materials and constructions noted above.

- American Federal Specification (FS) RR-W-410-F Wire Rope and Strand. (6 x 37 with IWRC extra improved plow steel).
- BS EN 12385-4+AISteelWire Ropes. Safety. Stranded Ropes for General Lifting Applications.
- BS EN 10264-2 Steel Wire Grid Wire Products. Steel Wire for Ropes. Cold Drawn Non-o110ySteel Wire Ropes for General Applications.
- BS EN 13411-8 Terminations for Steel Wire Ropes Safety. Swage Terminals and Swaging.

When ordering steel wire ropes it is good practice to give as much application and background information as possible. It is recommended that replacement lines match the performance of the existing lines and are compatible with the mooring design. While not all performance indicators will be relevant (e.g. temperature), this will help users assure product suitability by confirming strength, stiffness, angled endurance, etc.

6. Usage and care

The following gives general guidance on steel wire rope usage and care in service. More detailed information can be found in EN 12385-3, ISO 4309 and in the Wire Rope Technical Board's Wire Rope User's Manual. Further advice should also be obtained from the line manufacturer

6.1 A clean, well-ventilated, dry, under cover location such as a rope locker is preferred. If outdoor storage is unavoidable, the rope should be covered with waterproof material to protect it from the sun and weather. The rope should be stored in a location where it is not likely to be affected by salt water contact, steam, chemical fumes or other corrosive agents, and protected in such a manner that it will not be exposed to any accidental damage. During long periods of storage, the reel or winch should be rotated periodically, particularly in warm environments, to prevent lubricant from leaking out of the mooring line and/or migrating to other areas of the mooring line. It should be ensured that the rope does not make any direct contact with the deck and that there is a flow of air under the reel. Consideration should be given to supporting a reel on a simple. A-frame or cradle securely located in the rope locker or on deck. Ropes in storage should be examined periodically and, when necessary, a suitable dressing that is compatible with the manufacturing lubricant should be applied. The rope supplier should be contacted for guidance on the type of dressings available and the methods of application. After the dressing has been applied, the rope should be re-wrapped unless otherwise specified by the manufacturer. Steel wire ropes installed on winches should be covered with water proof tarpaulins or other suitable coverings when not in use.

6.2 The procedure for installing the steel wire rope should be planned in accordance with manufacturer's recommendations and should be carried out in accordance with a detailed plan under the supervision of a competent person or persons' To avoid accidents, ropes should be offloaded with care. The rope reels or coils should not be dropped and care should be taken to prevent the rope being damaged during handling. The steel wire rope should be checked to verify that it is not damaged when unloaded and when transported to the storage compound or site. A turntable or similar rig should always be used for installing new mooring wires to avoid twists and kinks developing if the temporary storage drum is not rotated while running the wire off. The relevant certificate should be obtained before installing and putting a rope into service, ensuring the marking on the rope or its package is verified and matched to the certificate. The rope diameter shoutd be checked and terminations examined to ensure they are compatible with the equipment to which they are to be fitted. More detailed guidance on installation should be obtained from the line manufacturer. Design requirements for drum length are included in ISO 3730. The minimum number of turns needed on the tension section of the drum may vary depending on the type of mooring line. Ship designers are recommended to allow for at least ten turns to accommodate varying mooring line types. As a general guideline allow for the following: A minimum of ten turns for steel wire rope mooring lines.

6.3 The entire length of line should be inspected at routine intervals by a competent person, with attention paid to those sections that are proven by experience to be the main areas of deterioration. These include wear zone areas, eyes, splices and sections of the line prone to be on the top layers of the winch while under load during mooring operations. Steel wire ropes in service may suffer corrosion damage. Corrosion affects the residual strength of a wire but it can also affect the wire ductility and other mechanical characteristics and may shorten the service life. It is recommended that steel wire ropes should have corrosion protection provided by both galvanizing individual wires and the application of an appropriate lubricant, which should be reapplied as required through the service life of the wire. Steel wire rope itself is not affected by UV, although in some instances lubricants that may be used could be affected by UV. Advice should be obtained from the rope manufacturer.

6.4 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:

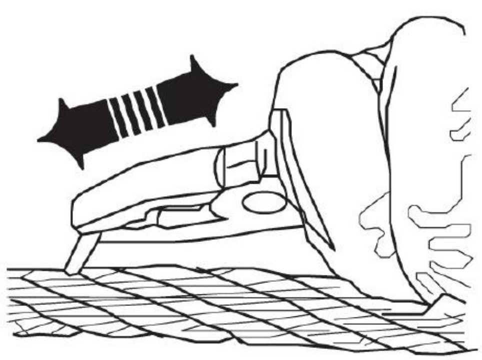
- Winch anchor point and the section of wire close to it.
- Sections of rope in wear zones, particularly sections that run regularly through deck fairleads and around pedestal rollers.
- The eye, especially at the bend of the eye and its termination.
- Cross-overs on winch drum.
- Terminations, particularly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

Table 1 gives a summary of the criteria for inspection and discard of steel wire ropes in ISO 4309.

	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
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%

Table 1: Summary of criteria for inspection and discard of steel wire ropes in ISO4309

In order to avoid any localized deterioration, which might otherwise originate from a broken wire protruding excessively from the rope and overlying others when that portion travels through a sheave, it may be removed by gripping the protruding end(s) and bending the wire backwards and forwards (see below Figure), until it eventually breaks (invariably in the valley position between the strands). When a broken wire is removed from the rope as part of a maintenance exercise, its location should be recorded for the information of the rope inspector. If such action is taken, this shall be counted as a broken wire and taken into account when assessing the condition of the rope in relation to the discard criteria for broken wires.



Removal of protruding wire

7. Inspection guidelines

This is a guideline provided by PIKASOMA. Users can set and manage their own standards according to the facility operating environment and climate conditions.

7.1 At least the intended working section of rope for that particular day shall be observed with the objective of detecting any general deterioration or mechanical damage. The rope shall also be checked to ensure that it is sitting correctly on the drum and over the sheave(roller) and has not been displaced from its normal operating position. Any appreciable change in condition shall be reported and the rope examined by a competent person in accordance with 7.2 If, at any time, the rigging arrangement is modified, such as when the equipment has been moved to a new site and re-rigged, the rope shall be subjected to a visual inspection as described in this subclause. The driver/operator of the equipment may be appointed to carry out daily checks to the extent that the driver/operator is sufficiently trained and considered competent to carry out this action.

7.2 Periodic inspections shall be carried out by a competent person. The information gained from a periodic inspection is to be used to assist in deciding whether a mooring rope.
a) can safely remain in service and by which latest time it shall undergo its next periodic inspection, or
b) needs to be withdrawn immediately or within a specified timeframe.
Through an appropriate assessment method, i.e. by visual means and/or measurement, or with an MRT, the severity of deterioration shall be assessed and expressed either as a percentage (e.g. 20 %, 40 %, 60 %, 80 % or 100 %) of the particular individual discard criteria or in words (e.g. “Slight”, “Medium”, “High”, “Very high” or “Discard”). Any damage that might have occurred to the rope prior to it being run in and entering service shall be assessed by a competent person and observations shall be recorded. A list of the more common modes of deterioration and whether each can be readily quantified (i.e. by counting or measuring) or needs to be subjectively assessed (i.e. by visual means) by the competent person is given in Table 2.

Mode of deterioration	Assessment method
Number of visible broken wires (including those which are randomly distributed, localized groupings, valley wire breaks and those that are at, or in the vicinity of, the termination)	By counting
Loss of metallic area caused by broken wires	Visual, MRT
Decrease in rope diameter (resulting from external wear/abrasion, internal wear and core deterioration)	By measurement
Loss of metallic area caused by mechanism other than broken wires e.g. corrosion, wear, etc.	Visual, MRT
Fracture of strand(s)	Visual
Corrosion (external, internal and fretting)	Visual, MRT
Deformation	Visual and by measurement (wave only)
Mechanical damage	Visual
Heat damage (including electric arcing)	Visual

Table 2: Modes of deterioration and assessment methods

The frequency of the periodic inspection shall be determined by the competent person, who shall take account of at least the following:

a) the statutory requirements covering the application in the country of use;
b) the type of crane and the environmental conditions in which it operates;
c) the classification group of the mechanism;
d) the results of previous inspection(s);
e) experience gained from inspecting ropes on comparable cranes;

f) the length of time the rope has been in service;
g) the frequency of use;
h) the crane manufacturer's recommendations.

NOTE 1 The competent person can find it prudent to initiate or recommend more frequent periodic inspections than those required by legislation. This decision can be influenced by the type and frequency of operation. Also, depending on the condition of the rope at any time and/or whether there is any change in circumstances, such as an incident or change in operating conditions, the competent person can deem it necessary to reduce or recommend the reduction of the interval between periodic inspections.

NOTE 2 Generally, ropes develop broken wires at a greater rate later in the life of the rope than in its early stages.

Each rope shall be inspected along its entire length. However, in the case of a long length, and at the discretion of the competent person, only the working length plus at least five wraps on the drum may be inspected. In such a case, and where a greater working length is subsequently foreseen after the previous inspection and prior to the next one, that additional length should also be inspected before the additional length of rope is used.
Particular care shall nevertheless be taken at the following critical areas and locations:
a) drum anchorage;
b) any section at, and in the vicinity of, a rope termination;
c) any section that travels through one or more sheaves(roller);
d) any section that travels through a safe load indicator which incorporates sheaves(roller);
e) any section that travels through the hook block;
f) in the case of cranes performing a repetitive operation, any part of the rope that lies over a sheave (roller) while the crane is in a loaded condition;
g) that part of the rope which lies over a compensating sheave(roller);
h) any section that travels through a spooling device;
i) those sections that spool on the drum, particularly crossover zones that are associated with multi-layer spooling;
j) any section that is subjected to abrasion by external features (e.g. hatch combings);
k) any part of rope that is exposed to heat.

The rope shall be inspected in the vicinity of the termination, particularly where it enters the termination, as this location is vulnerable to the onset of wire breaks due to vibration and other dynamic effects and, depending on the state of the environment, corrosion. Some probing with a spike may be carried out to establish if there is looseness in any of the wires, suggesting the existence of a broken wire within the termination. The termination itself should also be inspected for any excessive amounts of distortion and wear.
Additionally, ferrules used in the securing of eyes or loops shall be visually inspected for any cracks in the material and for evidence of any possible slippage between the ferrule and the rope. Detachable terminations such as symmetrical wedge sockets shall be inspected for evidence of any broken wires in the vicinity of the entry of the rope into the termination and checked to see that the termination has been correctly assembled. Eye splices shall be checked to see that the serving is only over the tapered section of the splice, thus allowing the remainder of the splice to be visually inspected for broken wires.

After each periodic inspection, the competent person shall provide a rope inspection, and state the maximum time interval that is not to be exceeded before the next periodic inspection takes place. Preferably, a running record should be maintained.

7.3 If an incident has occurred that might have caused damage to a rope and/or its termination, the rope and/or its termination shall be inspected as for a periodic inspection (see 7.2), prior to recommencement of work or as required by the competent person.

7.4 If the application has been out of operation for more than three months, the rope(s) shall undergo a periodic inspection, as described in 7.2, prior to recommencement of work.

8. Recommended service life

Due to the characteristics of steel wire rope, there is a great difference in service life due to product use environment and maintenance. It is recommended that the user determine the appropriate service life. When determining the service life, it is referred the residual breaking force data introduced in the following MEG4. Figure 5.9 shows how testing and inspection data can be used to determine service life. It is recommended that all mooring lines are retired when their residual strength has reached 75% of ship design MBL. ('Discard' or 'Cross-over' recommended if less than 75% of ship design MBL)

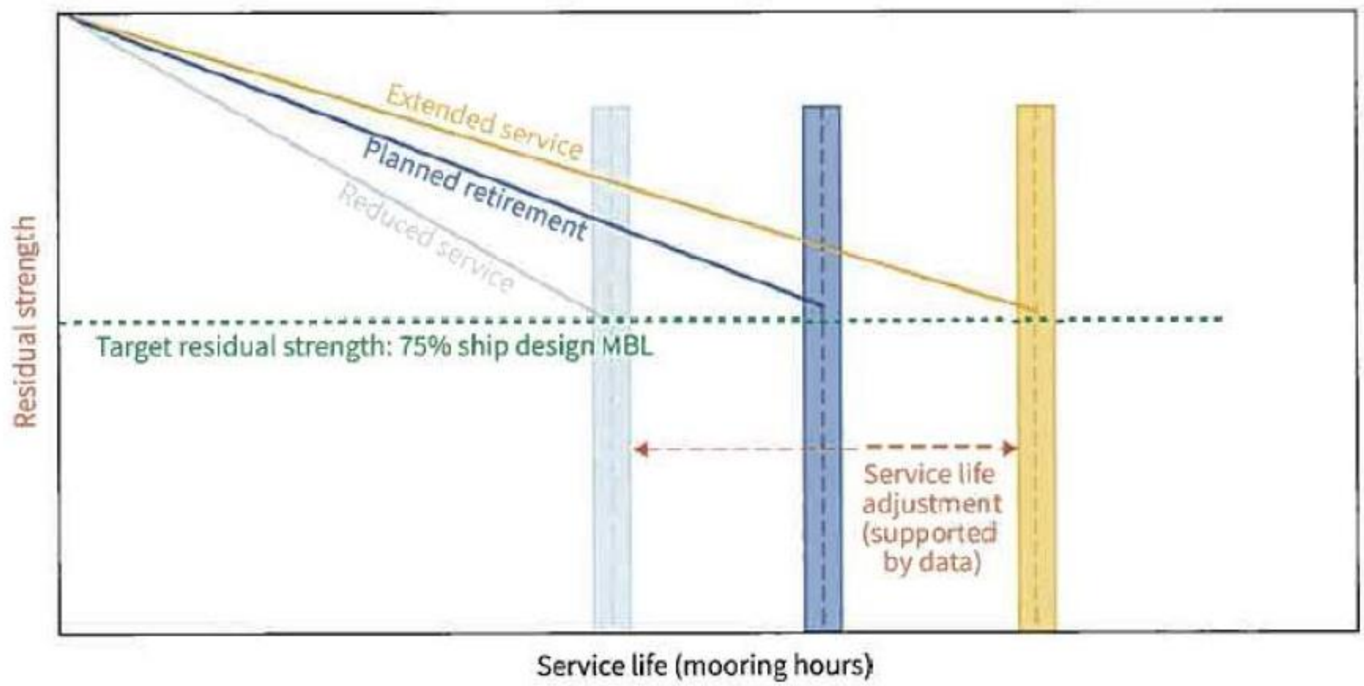


Figure 5.9: *Mooring line service life management*

Following the historical data from related industries, the average service life time is about 5 years. However, it is recommended that the user set the appropriate service life directly because there are differences in usage environment and maintenance method.

Annex A. Wire rope damage

We recommend replacing the wire rope or accessory if the following damage occurs.


(1)

(2)

(3)

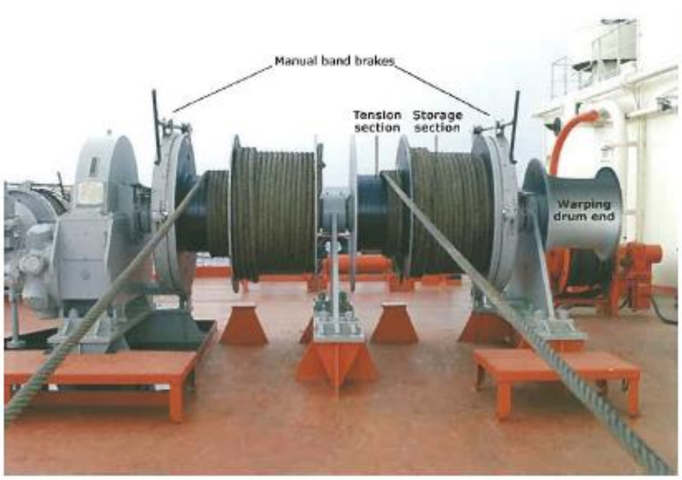
(4)

(5)

(1) Fair-lead Roller (Surface Damage can occur)
(2) Guide Roller (Surface damage can occur)
(3) Damage can be caused by excess friction during pay off on the pass line
(4) Wire Rope damage due to poor winding on the drum
(5) Wire Rope Corrosion

Annex B. Winch Drum

Design requirements for drum length are included in ISO 3730. The minimum number of turns needed on the tension section of the drum may vary depending on the type of mooring line. Ship designers are recommended to allow for at least ten turns to accommodate varying mooring line types.
As a general guideline allow for the following:
A minimum of ten turns for steel wire rope and HMSF mooring lines.
A minimum of five to six turns for conventional fibre mooring lines. Drums that are too wide or too small may not spool correctly.



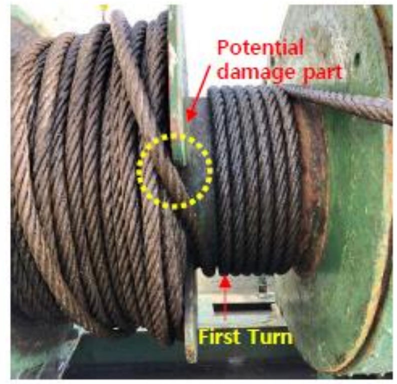
When using a split drum, the number of turns for the tension section is not mentioned in MEG4. (The previous page can be interpreted as a provision for drum width) A minimum turn number of at least 6 turns is recommended for the tension section to minimize potential damage to the wire rope.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics
Physics 8.01 IC-W03D1-4 Table Problem
Capstan Solution

$$T_B = T_A e^{-\mu_s \theta_{BA}}$$

The simulation calculation values from the above formula are shown in the following table.

Turn number	First turn rope tension
1 turn	53.5% of Mooring Tension
2 turns	28.5% of Mooring Tension
3 turns	15.2% of Mooring Tension
4 turns	8.1% of Mooring Tension
5 turns	4.3% of Mooring Tension
6 turns	2.3% of Mooring Tension



*** This table data is calculated value and may be different from the actual value.**