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ISO/TS 14909

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Fibre ropes for offshore stationkeeping — High modulus polyethylene (HMPE)

Cordages en fibres pour le maintien en position des structures marines — Polyéthylène à haut module

Reference number
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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 14909 was prepared by Technical Committee ISO/TC 38, *Textiles*.

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Fibre ropes for offshore stationkeeping — High modulus polyethylene (HMPE)

1 Scope

This Technical Specification specifies the main characteristics and test methods of new high modulus polyethylene (HMPE) fibre ropes used for offshore stationkeeping.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1968, *Fibre ropes and cordage — Vocabulary*

ISO 2060, *Textiles — Yarn from packages — Determination of linear density (mass per unit length) by the skein method*

ISO 2062, *Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 18692:2007, *Fibre ropes for offshore stationkeeping — Polyester*

ASTM D885, *Standard Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic-Base Fibers*

ASTM D1907, *Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method*

ASTM D2256, *Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1968 and in ISO 18692 apply.

NOTE Marine grade fibre and marine finish are not used in HMPE ropes.

4 Materials

4.1 Rope core material

The fibre used in the core of the rope shall be high-tenacity HMPE, with an average tenacity of not less than 2,5 N/tex and in accordance with Annex A. Qualification and testing are given in Annex A.

4.2 Rope cover material

Where polyester yarn is used in the protective cover, its minimum tenacity shall be 0,73 N/tex.

4.3 Other materials

Other materials employed in rope assembly shall be identified in the rope design/manufacturing specification.

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For each material, the following shall be specified, as applicable:

a) base material;

b) size (linear density, mass per unit area, etc.);

c) relevant mechanical properties (tenacity, stiffness, etc.).

5 Requirements — Rope properties

5.1 Minimum breaking strength

The minimum breaking strength (MBS), of the rope (spliced), where tested according to Annex B, shall conform to Table 1.

Table 1 — Minimum breaking strength

Reference number[a]	Minimum breaking strength kN
63	2 500
71	3 200
80	4 000
90	5 000
100	6 300
106	7 100
112	8 000
118	9 000
125	10 000
132	11 200
140	12 500
150	14 000
160	16 000
170	18 000
180	20 000

[a] The reference number corresponds to the approximate outer diameter of the rope, in millimetres (mm). Actual diameters may vary for a given reference number.

5.2 Minimum core tenacity

The minimum tenacity of the rope core shall be 1,3 N/tex, measured in accordance with Annex B. All samples tested shall comply with the minimum value specified in this Technical Specification.

5.3 Creep properties

The rope shall have demonstrated creep properties in accordance with the test method in Annex C.

5.4 Particle ingress protection

If specified, the rope shall be constructed with a protection of the core against the ingress of particles having a size greater than 20 µm (microns) or as agreed between involved parties. Testing of the protection shall be performed in accordance with Annex B.

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6 Requirements — Rope layout and construction

6.1 General

The typical section of a rope shall comprise a rope core, providing intended strength and stiffness, and a cover.

6.2 Type of construction

The rope shall be of one of the following types of construction:

— torque-neutral construction (type TF);

— torque-matched construction (type TM).

The type of rope shall be specified by the purchaser.

NOTE Torque-neutral ropes are intended for use in mooring systems together with chain or torque-neutral spiral strand wire ropes. Torque-matched ropes are intended for use in mooring systems together with six-strand wire ropes or other non-torque-neutral wire ropes. Typical constructions are illustrated in Figures F.3 and F.4.

6.3 Rope core

6.3.1 The total number of yarns in the rope shall be at least the number specified in the rope design specification.

6.3.2 Splices are not allowed in the rope core or in sub-ropes, except for those at the end terminations.

Strands shall be uninterrupted over the length of the rope, with no splice or strand interchange.

NOTE Yarns can be joined, if necessary.

6.4 Protective cover

6.4.1 A protective cover shall be provided around the rope core to protect the rope core from mechanical damages during handling and in service.

The protection shall be water-permeable.

6.4.2 A polyester braided protective cover shall have a minimum thickness, t, with:

— $t = 7{,}0$ mm, for a reference number RN above 100;

— $t = 0{,}07 \times \text{RN}$, but not less than 4 mm, for a reference number RN less than 100.

Strand interchanges, i.e. the overlapping continuation of an interrupted strand with another identical strand following the same path, are permitted if they are properly staggered.

6.4.3 If HMPE or an alternative protective cover is used, it shall demonstrate a level of protection equal to that of a polyester braided cover.

6.4.4 A braided cover shall include coloured strands forming a pattern so that rope twist during installation or in service can be identified. There shall be a minimum of one ‘S’ coloured strand and one ‘Z’ coloured strand to form a cross on the rope.

An alternative protective cover shall be fitted with an axial stripe of contrasting colour, or other means to identify rope twist during installation or in service.

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6.5 Terminations

The terminations shall be made of an eye splice plus abrasion protection materials.

NOTE There can be other terminations, provided they do not jeopardize the rope performance.

The dimensions and arrangement of the eye shall match the diameter and groove shape of the thimble (or other interface piece) to be used for end connections, and shall be the same as for the rope prototype testing.

In the splice area, the integrity and the continuity of rope cover and particle-ingress protection, if fitted, shall be preserved or restored.

The eye and the splice area shall be further covered by an abrasion protection coating, such as polyurethane. Each termination shall be made according to the manufacturing practice as described in the termination specification.

6.6 Length of rope

The bedded-in lengths of the rope sections shall be calculated in accordance with 7.2.2, under 20 % of MBS, unless otherwise agreed on the purchase order or contract.

The calculated length of supplied rope shall be within ±1 % of the specified length.

For each supplied rope, the actual length at the reeling tension or during manufacture shall be reported as an indicative value.

Adequate extra length shall be manufactured in order to prepare the samples for testing, which are considered to be part of the delivery.

7 Rope testing

7.1 Type testing

7.1.1 General

Prototype tests shall demonstrate that ropes declared by the manufacturer as complying with the requirements laid down in this Technical Specification possess the properties specified in this Technical Specification. The purpose of these tests is to verify the design, material and method of manufacture of each size of finished rope, including protective cover and terminations.

All ropes to be prototype-tested shall comply with all the other requirements laid down in this Technical Specification. The tests specified below shall be carried out on a prototype rope for each size of rope, unless otherwise noted in this clause (Clause 7).

Any change in the design, material, method of manufacture, including protective cover and terminations, which can lead to a modification of the properties as defined in Clause 5 shall require that the prototype tests specified in this Technical Specification be carried out on the modified rope.

7.1.2 Sampling

The number of rope samples to be tested is given in Table 2.

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Table 2 — Number of samples for testing

Test	Number of samples
Breaking strength, core tenacity and stiffness	3
Creep	1[a]
Torque properties	1[b]
Linear density	1
Cyclic loading endurance	1[c]

[a] See 7.1.4.

[b] See 7.1.5.

[c] See 7.1.7.

7.1.3 Breaking strength, core tenacity and stiffness tests

7.1.3.1 Three samples shall be tested according to the procedure specified in Annex B, and each shall be capable of meeting the requirements of 5.1 (minimum breaking strength) and of 5.2 (minimum core tenacity).

7.1.3.2 The rope core tenacity and stiffness at end of bedding-in shall be calculated according to the methods defined in Annex B.

7.1.3.3 Measurement of the stiffness at other load levels shall be performed within the same tests.

These measurements are, however, not required where results are available for another qualified rope of the same design, material and method of manufacture, with a reference number of not less than 71 and where the stiffness at end of bedding-in does not differ by more than 10 %.

NOTE 1 These measurements are performed for design purposes only. There are no acceptance criteria on these parameters.

NOTE 2 These measurements can also be performed on a separate rope sample (see Annex B).

7.1.4 Creep properties test

One sample shall be tested for creep properties.

This test needs not be performed where data are available from the previous qualification test of another rope (or a sub-rope of it) with the same design, material and method of manufacture of rope core, and a size not less than reference number 71.

7.1.5 Torque properties tests

Where applicable, torque properties tests shall be performed according to the procedure specified in B.6 of ISO 18692:2007. These tests are, however, not required where results are available for another qualified rope of the same design, material, method of manufacture and termination, with a reference number of not less than 71.

7.1.6 Linear density test

The linear density shall be calculated from the measured mass and elongation according to the method defined in Annex B.

7.1.7 Cyclic loading (endurance) test

7.1.7.1 One sample shall be tested for cyclic loading. However, cyclic loading (endurance) tests performed with one size of qualified rope having the same design, material and method of manufacture including protective cover and terminations, is enough to qualify all sizes with an MBS between 50 % and 200 % of the size tested. The test for cyclic loading (endurance) is not required if such data are available.

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7.1.7.2 The cyclic loading (endurance) test shall be performed according to the procedure specified in B.5. A load range shall be selected by the manufacturer, and the rope shall withstand, without breaking, at least the number of cycles for that load range, as given in Figure B.2.

NOTE The value of the breaking force shows the rope residual strength and it is only for information.

7.1.8 Protective cover thickness

The thickness of the protective cover shall be verified.

The thickness of a braided cover shall be measured as twice the thickness of cover strands under the maximum braiding tension.

7.1.9 Particle ingress protection

See 5.4 and Annex B.

7.2 Testing of current production

7.2.1 Sampling and testing

Where the ropes are already declared by the manufacturer as complying with the requirements laid down in this Technical Specification, the rope tests, including breaking strength and core tenacity, as well as protective cover thickness verification, shall be performed on one sample taken from the manufacturing process for each type and size of rope.

7.2.2 Length measurement

The bedded-in length of each supplied rope section (other than short sections) shall be calculated from the linear density, ρ_l, using Formula (1):

$$L = \frac{(m_\mathrm{T} - m_\mathrm{S}) \cdot 1\,000}{\rho_{l,20}} \qquad (1)$$

where

L is the length of the rope, expressed in metres (m);

m_T is the mass of the total rope length, expressed in kilograms (kg);

m_S is the mass of the materials used to form the eyes and the splices, expressed in kilograms (kg);

$\rho_{l,20}$ is the linear density of the rope, expressed in kilotex, obtained from the prototype test, in accordance with 7.1.6.

The length of short rope sections (i.e. sections of less than 20 m) shall be measured at a load of 2 % of MBS as the length between the centres of termination fittings (i.e. same as L_u on Figure B.1).

8 Report

8.1 Prototype rope

A complete and detailed report of the prototype rope manufacturing shall be supplied, including the fibre manufacturer, the fibre type and finish and all rope characteristics that can influence the mechanical properties, such as design, material specifications, method of manufacture, including protective cover and terminations, with sketches or pictures.

A complete and detailed report of type tests, with sketches or pictures of the test set-up, shall also be provided.

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8.2 Current production

The manufacturing report of supplied ropes shall be provided. A complete and detailed report of rope tests, with sketches and pictures of the test set-up, shall also be provided.

9 Certification

The certificate of approval and control, issued by a Recognized Classification Society (RCS), shall be presented together with the ropes, in order to ensure that testing and fabrication are in accordance with the approved specifications.

The rope manufacturer shall issue a rope declaration or obtain a rope certificate, including at least the following information:

a) reference number;

b) type of construction;

c) linear density;

d) MBS;

e) individual identification number;

f) length at a specified load;

g) length at the reeling handling tension.

NOTE A suggestion for a certificate of conformity can be found in Annex E.

10 Marking, labelling and packaging

10.1 Marking

A tape of at least 3 mm wide printed with a reference identifying the manufacturer shall be incorporated into the rope. The maximum distance between two consecutive markings shall be 0,5 m.

10.2 Labelling

An identification plaque or alternative means shall be installed close to the splice with the following information, as a minimum:

a) purchase identification;

b) individual identification number;

c) reference to this Technical Specification, i.e. ISO/TS 14909;

d) type of construction (TF or TM), in accordance with 6.2;

e) rope MBS;

f) rope length at a specified load, according to 7.2.2.

10.3 Packaging

If the assembly is packed on a spool or a reel, these shall be suitable for the applicable transportation means and of appropriate construction in terms of strength.

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The packaging shall be marked with the manufacturer's trademark and with the lot identification number.

NOTE The ropes can be delivered in steel reels or in containers. Alternative packaging designs can be provided with the prior approval of the purchaser.

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Annex A
(normative)

Fibre qualification and testing

A.1 General

This annex specifies the requirements for fibre qualification and testing.

A.2 Fibre specification

A.2.1 General information

A fibre specification shall include at least the information defined below:

a) identification and general properties of fibre;

b) detailed specification of physical and mechanical properties.

NOTE General properties of material can be found in the material safety data sheet.

A.2.2 Identification and general properties

The following information shall be provided in the fibre specification:

a) producer of fibres;

b) fibre designation;

c) fibre material (HMPE);

d) number of filaments;

e) nominal size (linear density);

f) average tenacity.

A.2.3 Physical and mechanical properties

The following information shall be provided in the fibre specification, including tolerances on specified properties:

a) linear density;

b) dry breaking strength;

c) dry elongation to break;

d) dry elongation at a specified load level;

e) elongation (%) in a reference condition, i.e. a specified tension (specific stress in newtons per tex) and temperature (°C) and time.

These properties shall be documented by test results in accordance with A.4.

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A.2.4 Creep properties

In addition to data in A.2.3 e) above, the following information extracted from a documented model of fibre creep properties based on test results shall be made available by the fibre manufacturer to the rope manufacturer, covering:

a) creep rate (per cent divided by time unit) and allowable extension (%) (or allowable creep time), under a range of specific stresses (N/tex) and temperatures, to cover those expected in operation,

b) creep rate (per cent divided by time unit) under the tension [and corresponding specific stress (N/tex)] and at the temperature (°C) during rope creep test in accordance with Annex C,

c) creep rate in the conditions of fibre testing during production.

NOTE 1 The “creep rate” in this subclause refers to the creep rate in the so-called “steady state creep” regime (see Annex F and Reference [2]).

NOTE 2 Data of creep properties are used by the rope manufacturer (or by the purchaser) to evaluate the creep allowable life time of the rope (see Annex F).

A.3 Fibre test certificate

For each delivery, the fibre manufacturer shall issue a raw material certificate, including, at least, the following information:

a) fibre designation;

b) merge number/batch identification;

c) size (linear density);

d) dry breaking strength;

e) dry elongation to break;

f) creep test (see A.4.2 below).

For acceptance testing, the properties in a) to f) shall be obtained from testing on a representative number of samples taken from the delivery, not less than once every 5 000 kg (and 10 000 kg for creep test only).

For each property, the number of tests, the mean value and the standard deviation or range shall be reported.

A.4 Fibre testing

A.4.1 Fibre linear density and strength

The fibre linear density shall be tested in accordance with ASTM D1907 and ISO 2060.

The fibre strength and elongation shall be determined based on five samples of basic yarn samples taken and tested. These samples shall be conditioned to equilibrium to a temperature of 21 ± 1 °C and a relative humidity of 60 ± 10 %. After conditioning, the samples shall be loaded to break in accordance with ASTM D885, ASTM D2256, ISO 2062 or a documented equivalent method established by the fibre manufacture and derived from existing standards (see Reference [5]). The testing method to be used shall be identified in the rope design documentation. The same method is then to be used whenever the yarn is tested by the fibre manufacturer. The average yarn breaking strength and elongation shall be determined and recorded.

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A.4.2 Creep — Testing of current production

The creep performance of fibre during fibre production shall be verified by testing for measurement of the elongation (per cent per day) in the reference condition given in the fibre specification, i.e. a specified tension (specific stress in newtons per tex) and temperature (°C) and time.

NOTE As an example, the following conditions can be used:

— tension: 0,8 N/tex;

— temperature: 50 °C;

— time: 5 h.

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Annex B
(normative)

Rope testing

B.1 General

This annex specifies the requirements for full-size testing of rope samples and addresses the following tests:

a) strength and stiffness;

b) linear density;

c) cyclic loading endurance;

d) particle ingress resistance.

NOTE 1 Requirements for testing of torque properties, whenever applicable, can be found in B.6 of ISO 18692:2007.

NOTE 2 For the requirements for creep testing, see Annex C.

B.2 Testing conditions

B.2.1 Rope samples

The rope tests, including strength, cyclic loading endurance and torque measurement shall be performed on samples with terminations that are identical to the supplied ropes. The strength and cyclic loading tests shall be performed with fixed end conditions (without a swivel).

Termination fittings shall be provided, with the same type of material and the same profile and dimensions (radius, groove shape) as the thimbles for the supplied rope.

B.2.2 Ambient conditions

In all tests, the ambient temperature and humidity shall be recorded.

The water used for soaking, wetting and immersing shall be fresh water with no additives.

During the cyclic loading endurance test (see B.5), the rope shall be wetted by a water spray or immersed, and the temperature shall be controlled in order to avoid overheating.

The temperature of the out-flowing water should not exceed 30 °C.

B.2.3 Testing machine

The testing machine shall be of at least class 2 in accordance with ISO 7500-1 and it shall be of such a type that load (or cross-head displacement) can be controlled at all times, during both extension and retraction.

For the breaking test (step 10 in B.3.1), the use of a test machine with a fixed cross-head speed is acceptable, provided time to failure is at least 2 min.

B.2.4 Load and elongation measurements

Load shall be measured by a strain gauge system and continuously recorded during each test.

NOTE In the loading sequences specified below, loads are given as a percentage of the specified MBS of the rope.

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The measurements of the gauge length elongation of the rope core shall be performed with a system of adequate sensitivity for the intended sequences, taking into account the very small elongation of an HMPE rope under such conditions. Extensometer or video image processing may be used.

The cover and the filter shall be cut for fastening of extensometer ends or for marking of core (in case of measurement by video image processing).

B.3 Strength and stiffness test

B.3.1 Test procedure

The following rope test procedure applies to verify the rope MBS, the minimum core specific strength and the stiffness. The test shall be performed according to the following steps:

— step 1: the sample shall be soaked for at least 4 h in fresh water;

— step 2: the sample shall be installed in the test machine;

— step 3: a load of 2 % of MBS shall be applied;

— step 4: the rope shall be marked at each end, at a distance of three times the rope diameter from the last tuck of splices (see Figure B.1);

— step 5: the extensometer shall be installed in a section of the rope undisturbed by the termination, between these marks;

— step 6: a tension of 50 % of the rope MBS shall be applied at a rate of 10 % MBS per minute and held for 30 min;

— step 7: the tension shall be reduced to 10 % of the rope MBS, at a rate of 10 % MBS per minute;

— step 8: a cycling tension between 10 % and 30 % of the rope MBS shall be applied 100 times, without interruption, at a frequency of between 0,03 Hz and 0,1 Hz (bedding-in and measurement of dynamic stiffness after bedding-in);

— step 9: where applicable, a cycling tension between specified limits shall be applied for a specified number of cycles (dynamic or static stiffness measurements; see B.3.5), and without interruption; otherwise, this step is omitted;

— step 10: the sample shall be unloaded, the extensometer removed, and the rope pulled to failure, at a loading rate of approximately 20 % MBS per minute.

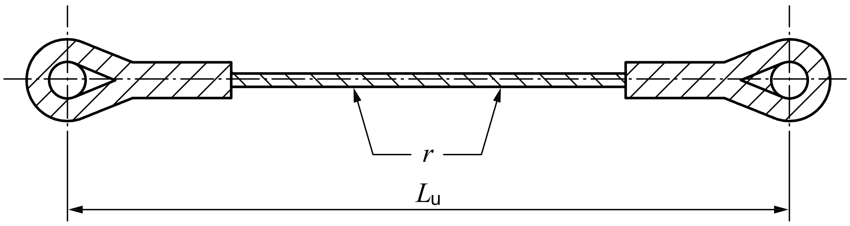

Figure B.1 — Marks, r, on the rope sample

B.3.2 Breaking strength

The tension at break of the rope sample shall be recorded.

All samples tested shall meet the MBS.

If the breaking load of one sample is lower than the MBS, two other samples shall be prepared and tested.

The rope is considered to comply with the breaking strength requirement in this Technical Specification only if the results of both the subsequent two tests meet the MBS.

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B.3.3 Load-elongation measurements

The rope test shall include the measurement of the following:

a) load versus total elongation (stroke), four plots as in the following:

   1) steps 5 to 7;

   2) step 8;

   3) step 9 (whenever performed);

   4) step 10;

b) gauge length (extensometer) elongation (for the prototype rope), three plots as in the following:

   1) load versus elongation encompassing steps 5 to 7;

   2) load versus elongation for the last three full cycles at least, in step 8;

   3) load versus elongation for the last three full cycles at least, in step 9, dynamic stiffness measurement (whenever performed);

c) continuous record of load and elongation versus time, during the three cycles of the quasi-static stiffness measurement (whenever performed).

NOTE The step numbers refer to B.3.1.

B.3.4 Dynamic stiffness at end of bedding-in

The dynamic stiffness at end of bedding-in (step 8 of B.3.1) shall be obtained from the load and gauge length elongation measurements, and shall be calculated according to B.3.6.2.

B.3.5 Quasi-static stiffness and dynamic stiffness

B.3.5.1 The quasi-static stiffness and the dynamic stiffness at other load levels shall be obtained from load and gauge length elongation measurements in step 9 in B.3.1, and calculated according to B.3.6.3 and B.3.6.4.

NOTE Additional measurements of dynamic stiffness can be performed where agreed between the purchaser and the manufacturer (see Annex F).

B.3.5.2 For the measurement of the quasi-static stiffness, the following cycling shall be applied in three full cycles without interruption:

a) slowly load the rope from 10 % of the rope MBS to 30 % of the rope MBS in a period of time between 2 min and 6 min;

b) hold the load at 30 % of the rope MBS for 30 min from the start time of a) above;

c) slowly unload the rope from 30 % of the rope MBS to 10 % of the rope MBS in a period of time between 2 min and 6 min;

d) hold the load at 10 % of the rope MBS for 30 min from the start time of c) above.

This cycling shall be performed during step 9 of B.3.1 above on one sample before the cycling for the dynamic stiffness.

NOTE Other load levels can be considered where agreed between involved parties (see Annex F).

B.3.5.3 For the measurement of the dynamic stiffness, the following cycling shall be applied during step 9 of B.3.1 at a frequency of between 0,03 Hz and 0,1 Hz:

— step 9a: on one sample: 100 cycles between 20 % and 30 % of the rope MBS;

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— step 9b: on a second sample: 200 cycles between 30 % and 40 % of the rope MBS;

— step 9c: on a third sample: 300 cycles between 40 % and 50 % of the rope MBS.

In the case of an interruption within a set of cycling, this set of cycling shall be repeated.

If the interruption leads to unloading of the rope, step 8 shall be performed again before re-running the interrupted set of cycling.

B.3.5.4 Alternatively to the above-mentioned, measurements may be performed as follows.

a) All measurements are performed on the same sample, quasi-static stiffness, then dynamic stiffness, as steps 9a, 9b, and 9c (see B.3.5.3), in ascending order of load. Then, the cycling may be limited to 100 cycles at each level.

b) These measurements are performed on a separate rope sample, in either wet or dry condition according to the following steps:

   1) the sample shall be installed in the test machine;

   2) steps 3 to 8 of B.3.1, including measurement of the dynamic stiffness at the end of bedding-in;

   3) step 9 of B.3.1 with cycling as per B.3.5.2 for the measurement of the quasi-static stiffness;

   4) steps 9a, 9b, 9c of B.3.5.3 with cycling for the measurement of the dynamic stiffness.

B.3.6 Calculation of mechanical properties

B.3.6.1 Core tenacity

The rope core tenacity shall be calculated as given by Formula (B.1):

$$t = \frac{F_{\text{BS}}}{\rho_{l,\text{c0}}} \tag{B.1}$$

where

t is the rope core tenacity, expressed in newtons per tex (N/tex);

F_{BS} is the actual breaking strength of the rope, expressed in newtons (N), obtained in step 10 of B.3.1;

$\rho_{l,\text{c0}}$ is the linear density of the rope core, expressed in tex, at 2 % of MBS, as measured during the linear density test (see B.4).

B.3.6.2 Dynamic stiffness at end of bedding-in

The dynamic stiffness at end of bedding-in is calculated from the load-elongation measurement at end of step 8 of B.3.1.

The dynamic stiffness is calculated as given by Formula (B.2):

$$K_{\text{rb}} = \frac{\dfrac{F_{30} - F_{10}}{F_{\text{MBS}}}}{\dfrac{L_{30} - L_{10}}{L_{10}}} \tag{B.2}$$

where

K_{rb} is the dynamic stiffness after bedding-in;

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$F_{30} - F_{10}$ is the recorded variation of load over the 100th cycle;

F_{MBS} is the specified minimum breaking strength of the rope;

$\frac{L_{30} - L_{10}}{L_{10}}$ is the elongation (strain variation) between F_{10} and F_{30} over the 100th cycle.

NOTE Alternatively, the stiffness can be obtained from the average slope of the load-elongation plot over the last three full cycles.

B.3.6.3 Dynamic stiffness

Where required, the dynamic stiffness is calculated, using Formula (B.3), from load-elongation measurements of step 9a, 9b or 9c of B.3.5.3:

$$K_{rd, X \to Y} = \frac{\frac{F_Y - F_X}{F_{MBS}}}{\frac{L_Y - L_X}{L_X}} \quad \text{(B.3)}$$

where

$K_{rd, X \to Y}$ is the dynamic stiffness under cycling between load X and Y;

$F_Y - F_X$ is the recorded variation of load over the last cycle;

$\frac{L_Y - L_X}{L_X}$ is the elongation between F_X and F_Y over the last cycle.

NOTE Alternatively, the stiffness can be obtained from the average slope of the load-elongation plot over the last three full cycles.

B.3.6.4 Quasi-static stiffness

Whenever required, the quasi-static stiffness is calculated from load-elongation measurements, using Formula (B.4):

$$K_{rs, X \to Y;1h} = \frac{\frac{F_Y - F_X}{F_{MBS}}}{\frac{L_Y - L_X}{L_X}} \quad \text{(B.4)}$$

where

$K_{rs, X \to Y;1h}$ is the quasi-static stiffness under cycling between loads X and Y, over a period of 1 h;

$F_Y - F_X$ is the recorded variation of load over the last cycle;

$\frac{L_Y - L_X}{L_X}$ is the recorded elongation between F_X and F_Y over the last cycle.

NOTE 1 Alternatively, the quasi-static stiffness can be obtained by averaging the results over the last two cycles.

NOTE 2 The quasi-static stiffness for longer cycling periods can be obtained by extrapolation from the records of load and elongation versus time (see Annex F).

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B.4 Linear density

B.4.1 Test procedure

The linear density is calculated from a dry sample of rope with at least 2 m free length (out of splice area, as for the marks, r, in B.3.1) taken from the manufacturing process, according to the following procedure, unless otherwise agreed on in a purchase order or contract:

a) the sample shall be installed in the test machine;

b) a suitable fastening shall be provided in order to ensure no slippage between the cover and the core;

c) the sample shall be submitted to a tension of 2 % of MBS, and a length of about 2 m marked as a reference length, L_{R0};

d) the tension shall be increased to 20 % of the rope MBS, at a rate of 10 % of MBS per minute;

e) a cycling tension between 15 % and 25 % of the rope MBS shall be applied 100 times at a frequency of between 0,03 Hz and 0,1 Hz;

f) after cycling, the tension shall be maintained at 20 % of the rope MBS and the reference length, L_{R20}, shall be measured, immediately after this tension is reached;

g) the tension shall be lowered to 2 % of MBS and the reference length, L_{R2}, shall be measured again, immediately after the 2 % tension is reached;

h) after unloading, the sample shall be cut upon the reference length marks. The cut sections shall be flat and perpendicular to the rope longitudinal axis;

i) the mass of the segment shall be measured and recorded;

j) after removing the cover, the mass of the core segment shall be also measured and recorded.

NOTE The linear density includes the dry mass of the coating applied.

B.4.2 Calculation of linear densities

The linear densities shall be calculated as:

$$\rho_{l,0} = \frac{m_R}{L_{R0}} \qquad \rho_{l,20} = \frac{m_R}{L_{R20}} \qquad \rho_{l,2} = \frac{m_R}{L_{R2}} \qquad \rho_{l,c0} = \frac{m_{RC}}{L_{R0}} \tag{B.5}$$

where

$\rho_{l,0}$ is the linear density of the rope, expressed in kilotex (ktex), as manufactured, under 2 % of MBS;

$\rho_{l,20}$ is the linear density of the rope, expressed in kilotex (ktex), after the rope has been cycled and under 20 % of MBS;

$\rho_{l,2}$ is the linear density of the rope, expressed in kilotex (ktex), under 2 % of MBS after being mechanically worked to the above-mentioned procedure;

$\rho_{l,c0}$ is the linear density of the rope core, expressed in kilotex (ktex), as manufactured, under 2 % of MBS;

m_R is the mass of the reference length, expressed in grams (g);

m_{RC} is the mass of the reference length of rope core, expressed in grams (g);

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L_{R0} is the (length of the) reference length, expressed in metres (m), as manufactured, under 2 % of MBS;

L_{R20} is the (length of the) reference length, expressed in metres (m), after the rope has been cycled and under a tension of 20 % of MBS;

L_{R2} is the (length of the) reference length, expressed in metres (m), under 2 % of MBS after being mechanically worked to the above procedure.

B.5 Cyclic loading endurance test

B.5.1 Planning

A load range, R, of between 40 % and 50 % of MBS shall be selected by the manufacturer.

The corresponding minimum number of cycles shall be obtained from Figure B.2.

The mean load, F_{mean}, during test shall be such that the maximum load, F_{max}, is within 52 % and 55 % of MBS.

NOTE 1 The levels for cycling are then:

$$F_{min} = F_{mean} - \frac{R}{2} \quad \text{(B.6)}$$

and

$$F_{max} = F_{mean} + \frac{R}{2} \quad \text{(B.7)}$$

NOTE 2 The number of cycles, N, in Figure B.2 is given by Formula (B.8):

$$N \cdot R^{5,05} = 166 \quad \text{(B.8)}$$

where

R is the load range divided by the MBS;

N = 17 000 for $R = 0,4$;

N = 5 500 for $R = 0,5$.

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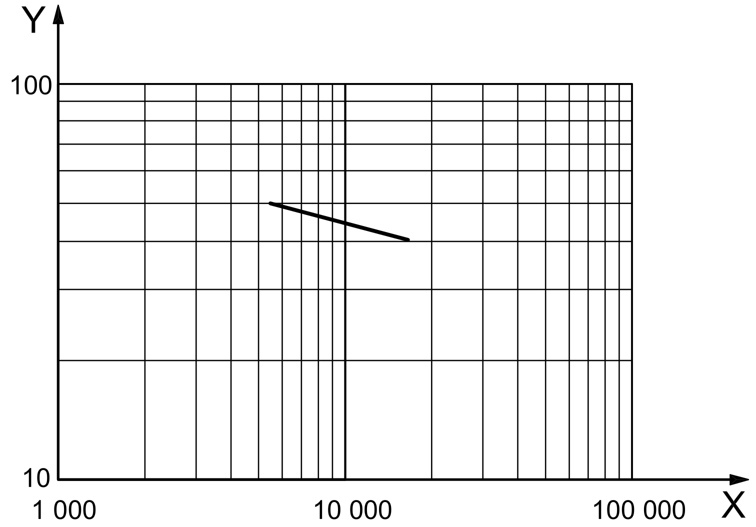

Key

X endurance (number of cycles), N

Y load range, R (% MBS)

Figure B.2 — Minimum requirement for cyclic loading test

B.5.2 Test procedure

The cyclic loading test shall be performed as follows:

a) the sample shall be soaked for at least 4 h in fresh water;

b) the sample shall be installed in the test machine;

c) a load of 2 % of the MBS shall be applied;

d) a tension of 50 % of the rope MBS shall be applied at a rate of about 10 % of MBS per minute and held for 30 min;

e) the tension shall be reduced to 30 % of the rope MBS at a rate of about 10 % of MBS per minute;

Cyclic loading between the selected levels F_{min} and F_{max} shall be applied for at least the specified number of cycles at a frequency of between 0,01 Hz and 0,2 Hz (see B.2.2).

f) unload the sample, and pull the rope to failure at a loading rate of approximately 20 % of MBS per minute.

NOTE The value of the load at breaking shows the residual strength of the rope and is given only for information.

B.6 Particle ingress resistance

One sample shall be tested as follows:

a) a specimen from a new rope with useful length of at least two times the rope diameter shall be selected;

b) the specimen ends shall be sealed with a waterproof compound;

c) the specimen shall be placed into a hyperbaric chamber and it shall be immersed in tap water with a sufficient volume to cover it. It shall be kept for 60 min at atmospheric pressure;

d) an amount of soil shall be added at a proportion of 25 % of water mass;

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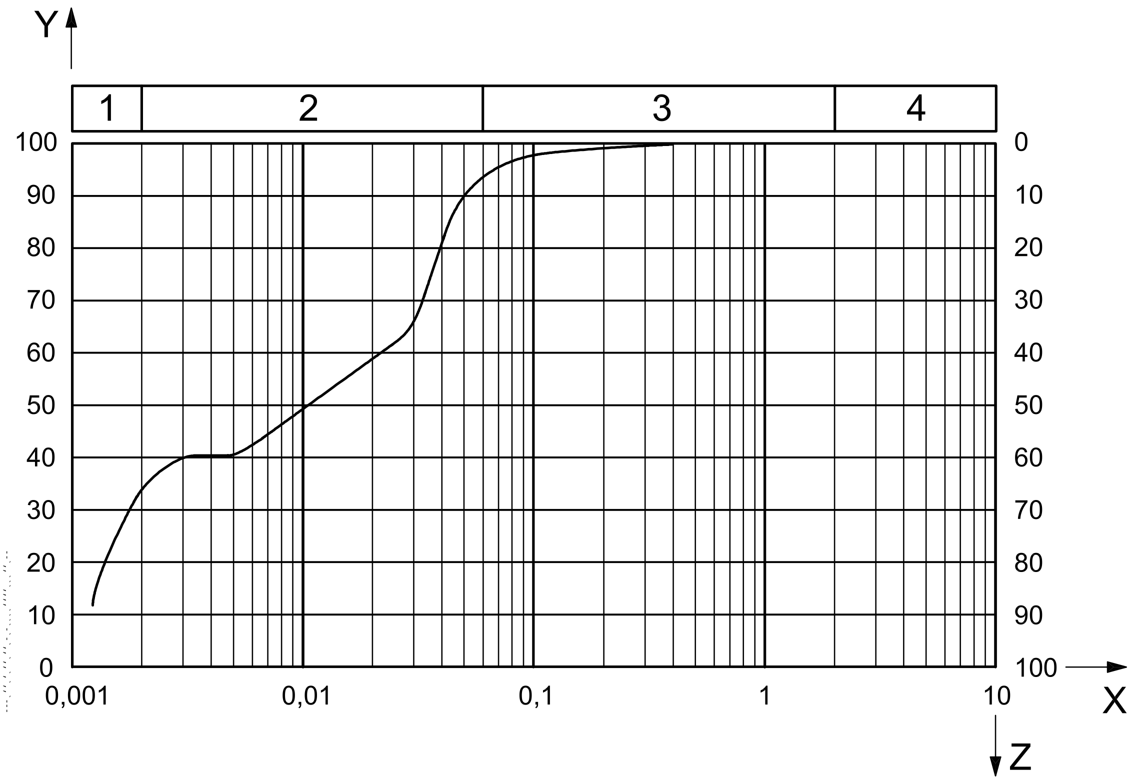
e) a pressure of 10 MPa shall be applied during a period of 72 h. During this period, the soil shall not be allowed to settle and it shall be kept suspended in water;

f) after this period, the pressure shall be removed and the rope core shall be examined by a scanning electron microscope (SEM) to determine the efficiency of the filter in avoiding soil particle ingress with a size equal to, or greater than, the one stipulated.



Key

1 clay ≤ 2 µm
2 silt > 2 µm and ≤ 63 µm
3 sand > 63 µm and ≤ 2 mm
4 gravel > 2 mm and ≤ 63 mm
X particle size (mm)
Y passing percentage (%)
Z retained percentage (%)

Figure B.3 — Grading of soil for particle ingress resistance test

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Annex C
(normative)

Creep properties test

C.1 General

This annex specifies the requirements for creep properties test of HMPE ropes for stationkeeping.

NOTE The objective of this test is to calibrate long-term rope creep rates with data and model of fibre creep (see Annex F).

C.2 Test conditions

C.2.1 Rope samples

The creep tests shall be performed on one sample of the rope to be qualified. For parallel construction ropes, this test can be performed on a sub-rope.

Terminations of samples shall be adequate with respect to intended test sequence.

C.2.2 Ambient conditions

The creep test shall be performed under controlled temperature conditions, and the temperature shall be kept as constant as possible over test duration, within a range of 5 °C.

The ambient temperature and humidity shall be recorded.

C.2.3 Testing machine and measurement

The testing machine and the measurement system shall be in accordance with the provisions of B.2.3 and B.2.4 in Annex B.

C.3 Testing

C.3.1 Planning of test

A testing temperature not exceeding 25 °C shall be selected.

A tension, T, not exceeding 55 % of MBS shall be selected.

C.3.2 Test procedure

The creep test shall be performed according to the following steps:

a) the test piece shall be installed in the test machine;

b) a load of 2 % of MBS shall be applied;

c) the extensometer shall be installed in a section of the rope undisturbed by the termination;

d) a tension of 50 % of the rope MBS shall be applied at a rate of 10 % MBS per minute and held for 30 min;

e) the tension shall be reduced to 20 % of the rope MBS, at a rate of 10 % MBS per minute;

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f) a cycling tension between 10 % and 30 % of the rope MBS shall be applied 300 times at a frequency of between 0,03 Hz and 0,1 Hz;

g) the sample shall be loaded at the preselected tension, T%, for a minimum period of 7 days (see F.2.4 in Annex F) at the preselected temperature, and the gauge length shall be measured over this duration;

h) the sample shall be unloaded.

C.3.3 Load and elongation measurements

The rope test shall include the measurement of:

a) gauge length elongation (three plots):

   1) load versus elongation encompassing load steps 3 to 5;

   2) load versus elongation for the 100th cycle, step 6;

   3) load and elongation versus time, over the complete duration of step 7 (continuous measurement, sampling rate: once per hour, minimum);

b) load versus overall elongation (stroke), two plots as the following:

   1) load steps 3 to 5;

   2) the last cycle of load step 6;

c) overall elongation (stroke) versus time over the complete duration of step 7.

C.3.4 Creep properties

The creep rate (per cent divided by time unit) is to be obtained by fitting of the elongation versus time (in natural scale) over the end of the test (e.g. the second half of step 7).

The specific stress, S_c, during creep test is calculated using Formula (C.1):

$$S_c = \frac{\tau \cdot F_{MBS}}{\rho l,_{c0}} \tag{C.1}$$

where

τ	is the tension (in per cent of MBS);
F_{MBS}	is the specified minimum breaking strength of the rope, expressed in newtons (N);
$\rho_{l,c0}$	is the linear density of the rope core, as manufactured, under 2 % of MBS obtained from the linear density test (see B.4) or, where the test is performed on a sub-rope, the linear density of the sub-rope, expressed in kilotex.

The following data shall be recorded:

— type of sample and linear density;

— applied tension, τ, and specific stress, S_c;

— temperature during step 7;

— creep rate.

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Annex D
(informative)

Guidance for rope handling care

NOTE This annex is extracted from ISO 18692:2007.

D.1 General considerations

Whenever fibre ropes for offshore stationkeeping are being handled, avoid the following:

a) contact between rope and sharp edges (attention to vessel's drum area and stern roller);

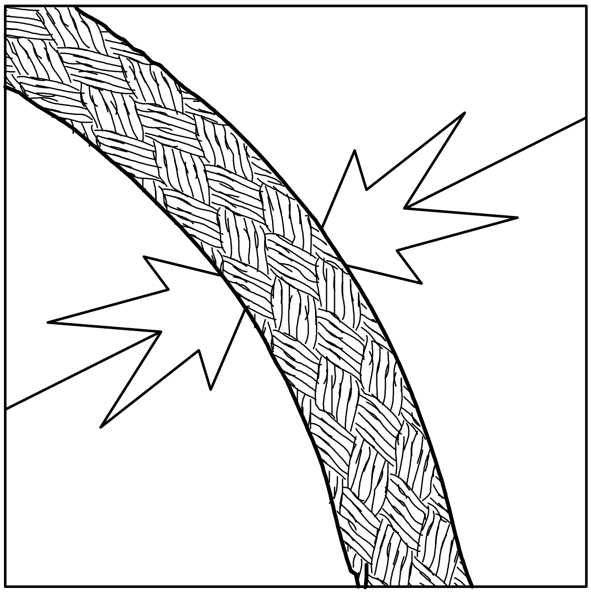

Figure D.1

b) excessive abrasion between rope and rough surfaces (attention to vessel's deck and stern roller);

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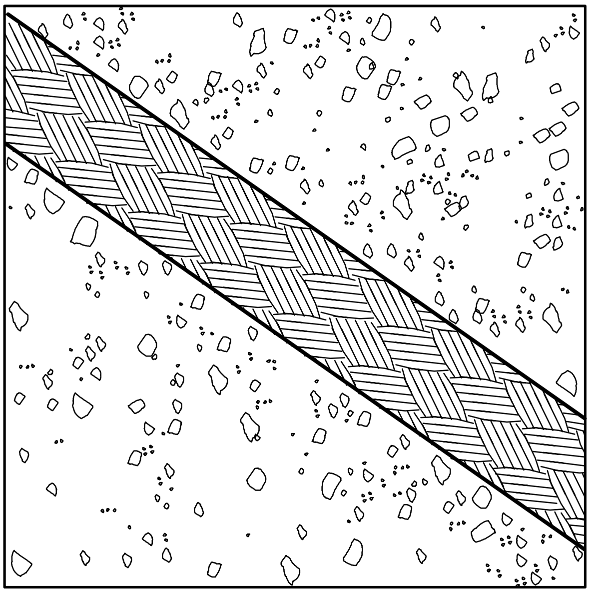

Figure D.2

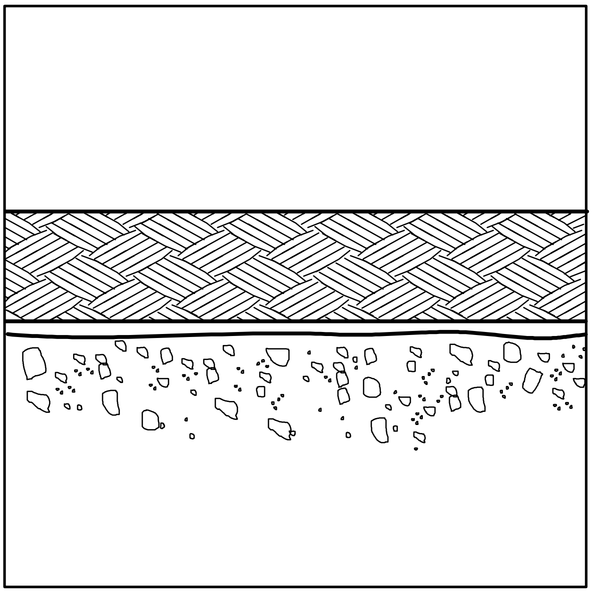

Figure D.3

c) working or handling with sharp tools (knives, blades, steel cables);

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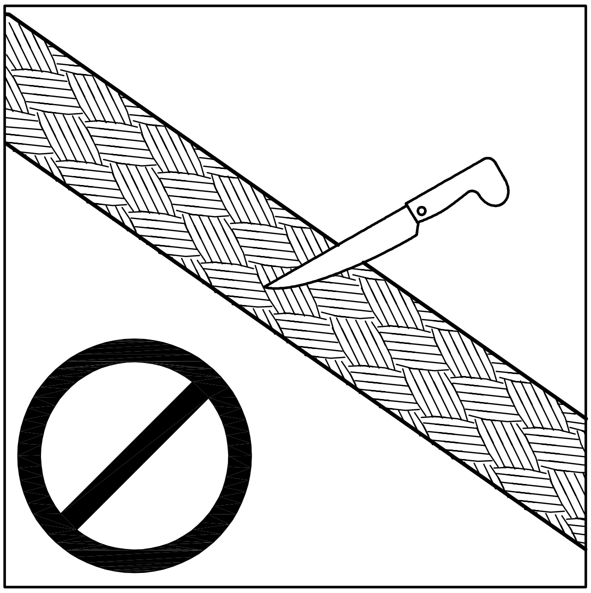

Figure D.4

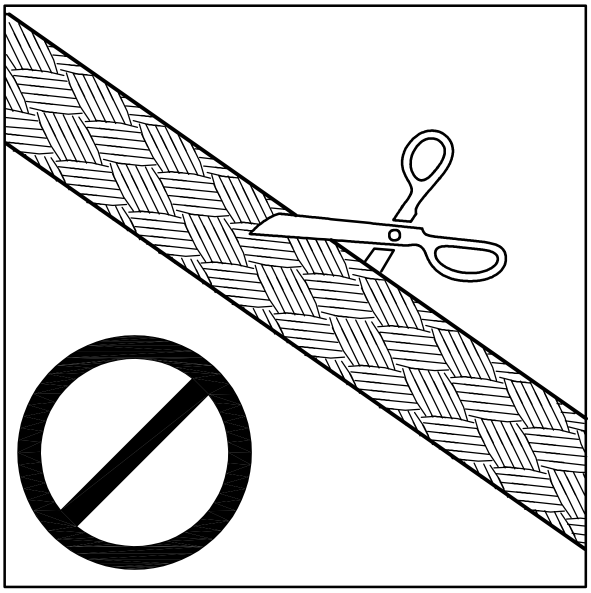

Figure D.5

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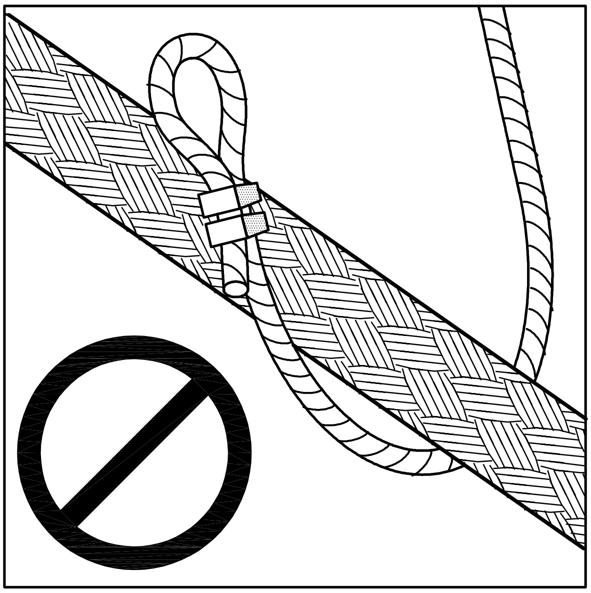

Figure D.6

d) excessive dirt in the rope and work area (oil, mud, scraps);

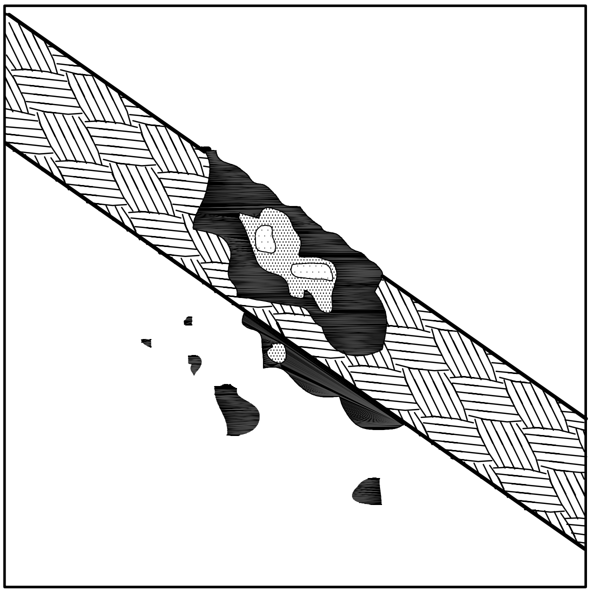

Figure D.7

e) excessive twist or bending in the rope;

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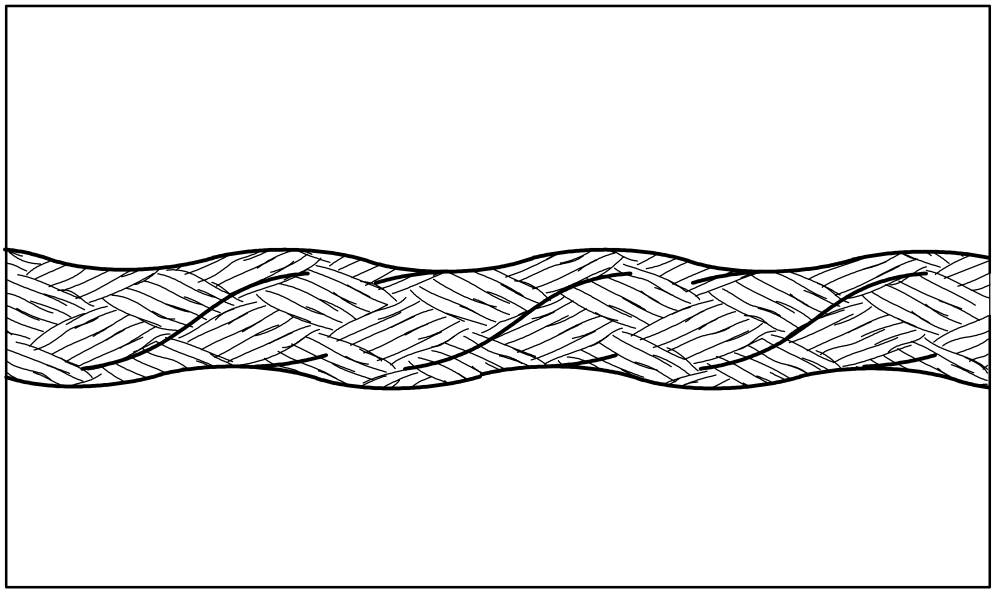

Figure D.8

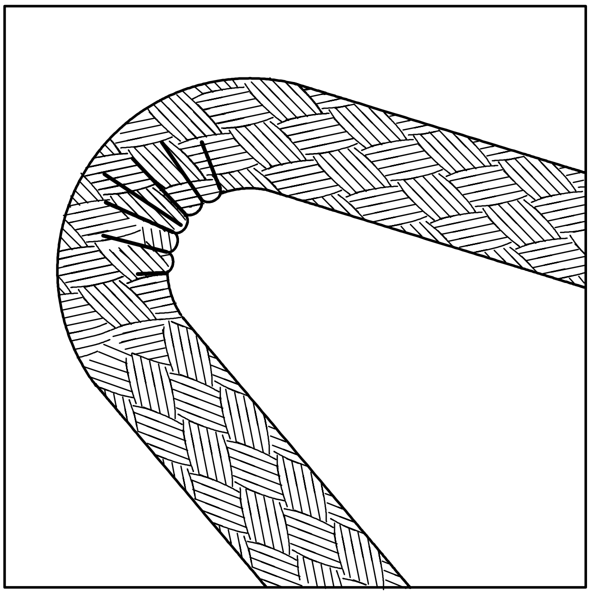

Figure D.9

f) contact with chemicals and prolonged exposure to sunlight.

D.2 Presentation of rope on reels

Fibre ropes for offshore stationkeeping are normally supplied wound on to steel reels.

Protective packaging material is wound around the main body of the rope to provide protection during transportation.

Packaging material should be carefully removed without cutting or damaging the rope. Strapping around the packaging may be under high tension and can snap back when cut, so extra care should be taken.

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Insert segments are likely to be provided in packing crates of considerable dimension. Crates may be handled with a forklift truck of suitable dimension and working load, provided the fork positions enable safe lifting. Alternatively, the crates may be lifted by a slinging arrangement, provided the slings are connected to the underside of the crate and are positioned to enable equal load distribution and safe lifting. Lifting slings, which risk damaging the crate, thereby exposing the segments packed inside, are not permitted.

D.3 Reel lifting and handling

Where using a crane, reels should be lifted using a specified lifting arrangement.

Whenever lifting reels, the initial load application and final set-down should be conducted as slowly and gently as possible to prevent the imposition of undue acceleration and deceleration forces.

Reels should not be rolled on the floor where loaded with rope. Whenever empty, reels should not be rolled unless it is absolutely essential, and only on flat clear ground and where methods to fully control rolling are applied.

Reels should not be twisted or moved sideways while standing on the ground. Forklift trucks should not be used to lift reels in either the full or empty condition.

Where reel cradles are provided, the reel should not be disconnected from the cradle until just prior to installation into the rope spooling mechanism. The use of the cradle prevents reel rolling, minimizes instability and ensures correct reel orientation whenever in storage.

D.4 Reel storage and maintenance

The ropes should be stored on reels on flat ground in reel cradles, where supplied, or else suitably chocked to prevent any unexpected movement. They should not be stacked on top of each other. The reels should be covered if stored outside to avoid prolonged exposure to sunlight, prevent plant growth on the ropes and prevent abrasive particles from being deposited in the cover. These measures ensure that the rope cover is maintained in as good a condition as possible.

Steel spools and other fittings should not be connected to the rope whenever stored on a reel to avoid chafing of the rope cover.

D.5 Installation

D.5.1 Deployment overboard

a) Where a new rope is in contact with the vessel's deck and stern roller, spraying water directly on the rope helps to avoid damage caused by external abrasion and reduce rope internal abrasion between fibres.

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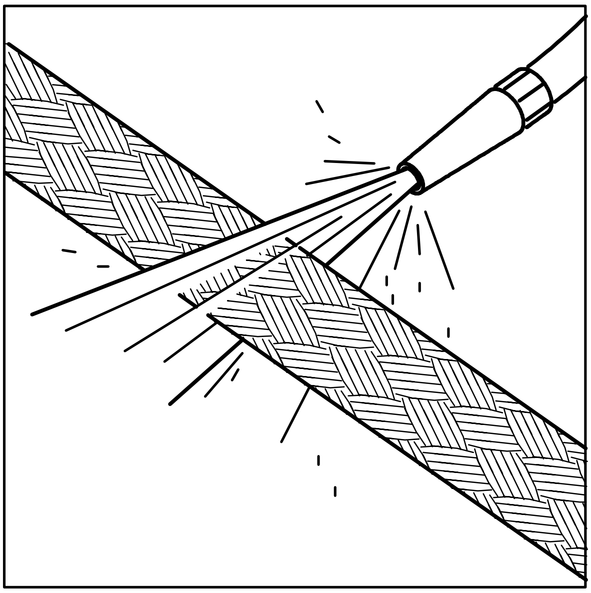

Figure D.10

b) Whenever installing the thimble, avoid excessive opening of the rope eye, which can damage or crack the polyurethane coating.

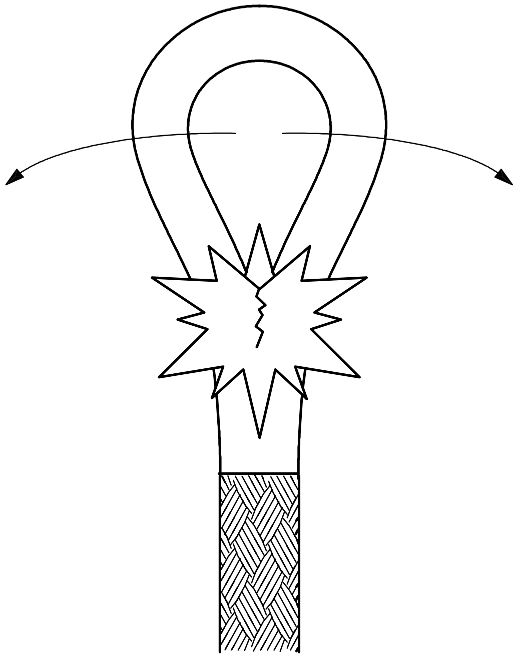

Figure D.11

c) Avoid proximity with works involving fire, corrosive chemical products, or excessive heat. If unavoidable, protect the rope.

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Figure D.12

d) Avoid contact of the rope with the seabed.

D.5.2 Line tensions and re-reeling

The maximum line tension during deployment should be calculated and designed not to exceed 10 % of MBS. The deployment of heavy anchors and long lengths of chain may be required. It is recommended that the rope not support the complete mass of these and that they be either pre-deployed or a second line be used. In the latter case, care should be taken to avoid the second line causing damage to the rope both during the deployment and after disconnection. This second work line should ideally be a torque-balanced fibre rope.

The standard reels on which ropes are normally transported cannot withstand line tensions over a few tonnes. It is recommended that the ropes be transferred to a winch drum on an anchor-handling vessel or to a purpose-built deployment reel. The lines can then be deployed directly from the winch or from the deployment reel via a dedicated deployment winch. Any temporary connection to the eye during re-reeling should be made using a fibre rope or webbing sling. The load in any connecting rope should be kept to a minimum to avoid cutting into the bearing point of the eye.

To reduce the chances of burying on a drum and possible damage caused to the cover by relative movement of the rope against the layer below, the deployment tension should be designed to be as low as possible. Applying tension during re-reeling on to a winch or storage drum helps avoid burying, along with a good traverse mechanism. As a guide, lines re-reeled at low tension and deployed with a line tension below 5 % of MBS do not experience problems with burying.

D.5.3 Equipment condition

All surfaces with which the rope can come into contact should be smooth and free of sharp edges. Relative movement between the rope and any equipment that it can come into contact with during deployment should be avoided. Special care should be taken to avoid contact between the polyurethane eyes of the rope and metal parts such as winch frameworks.

D.5.4 Rollers and rope bending

Occasional bending and running over rollers is allowable during deployment. The rope should not be repeatedly cycled around rollers for prolonged periods of time. The rope should also not be left curled for prolonged periods around bends under dynamic loading conditions.

Drums, sheaves and rollers should rotate freely.

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The minimum storage *D*/*d* proportion is given by the barrel diameter of the transport reels. Insert lengths may utilize a lesser *D*/*d* proportion whenever packed in the original shipment.

D.5.5 Pre-tensioning and hook-up

In order to test the anchors and to remove initial constructional stretch from the tethers, a tensioning programme may be used. It may also be necessary to re-tension the lines from time to time during the early life of the mooring system and after its first storm loading in order to remove further constructional extension from the rope. Line tensions should continue to be monitored and retensioning should be completed where necessary.

Where applying high tensions to the rope during deployment or hook-up, the rope and terminations should be clear of any bends or obstructions. The rope should be completely outboard of the deployment vessel and fully submerged in the seawater.

D.6 Identifying damage

D.6.1 Damage to the rope cover

Small external damages, such as dirt and minor abrasion, are very common. The objective of the rope cover and filter is to protect the inner cores. The cover and filter are not considered for calculations of rope performance regarding, for example, breaking strength and stiffness.

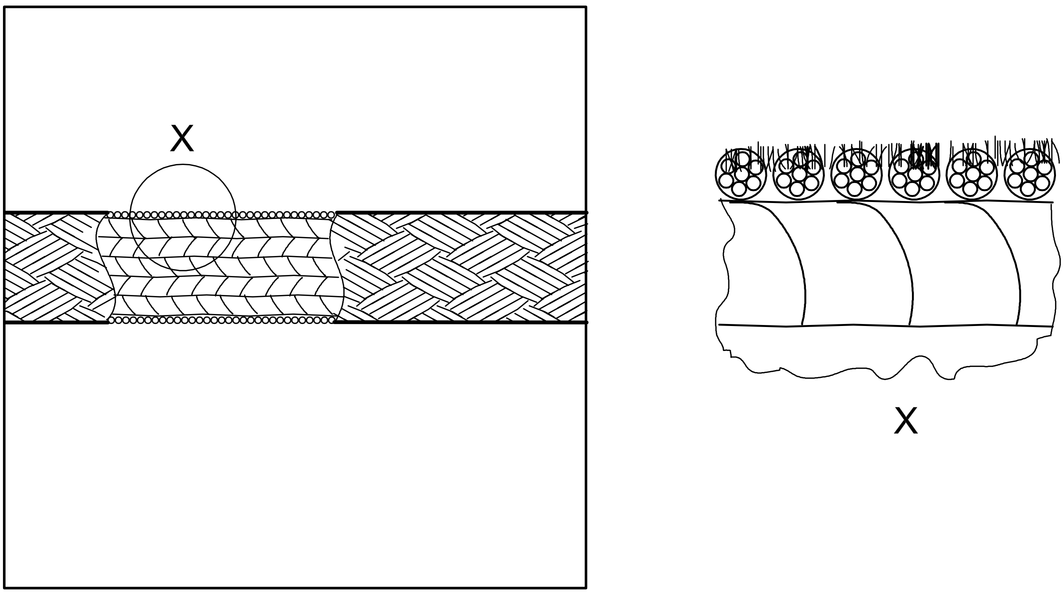

Figure D.13

External damage can be visually identified as the following.

a) Excess dirt, which does not represent major damage. The objective of the cover is to protect the rope cores. In this case, wash the area with fresh water.

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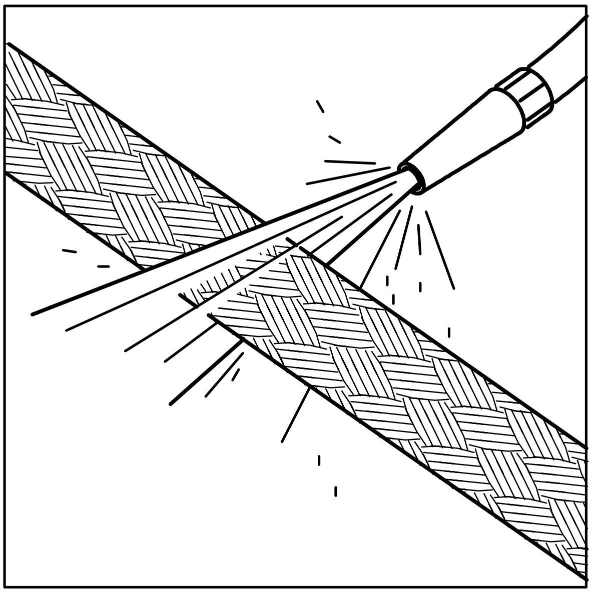

Figure D.14

b) Cuts in the rope cover exposing the cores. In this case, if the exposed area of the core does not show any sign of cuts or dirt, cover the area with small diameter cords in a spiral array and secure them with reinforced adhesive tape; otherwise, the rope should be rejected.

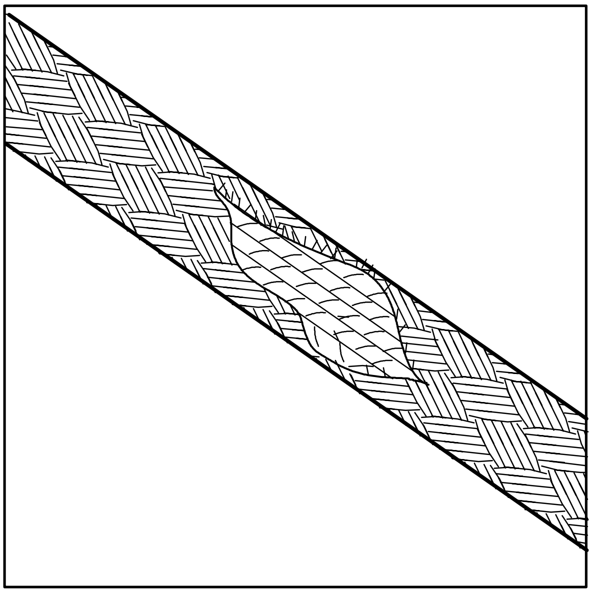

Figure D.15

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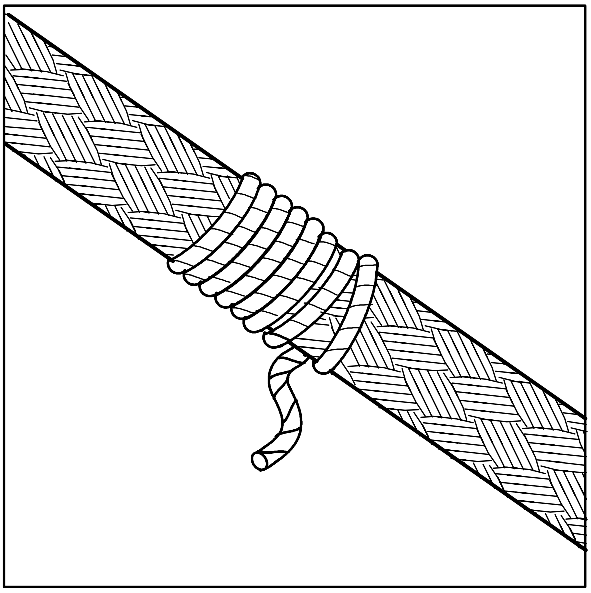

Figure D.16

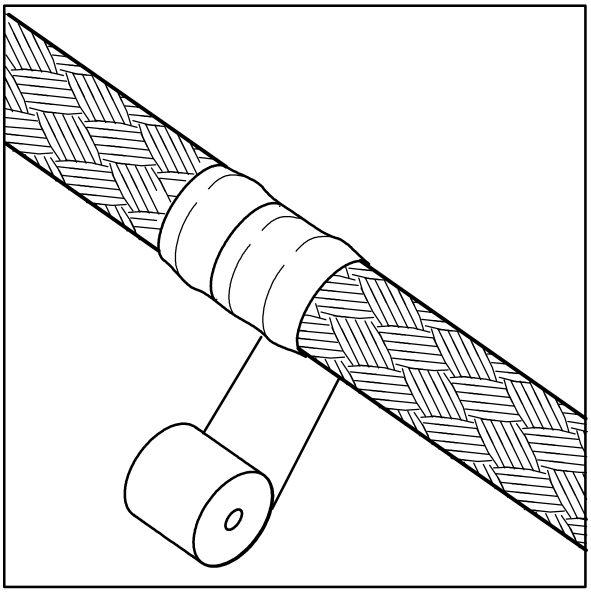

Figure D.17

c) Threadbare cover caused by abrasion, without a cut. In this case, cover the area with reinforced adhesive tape.

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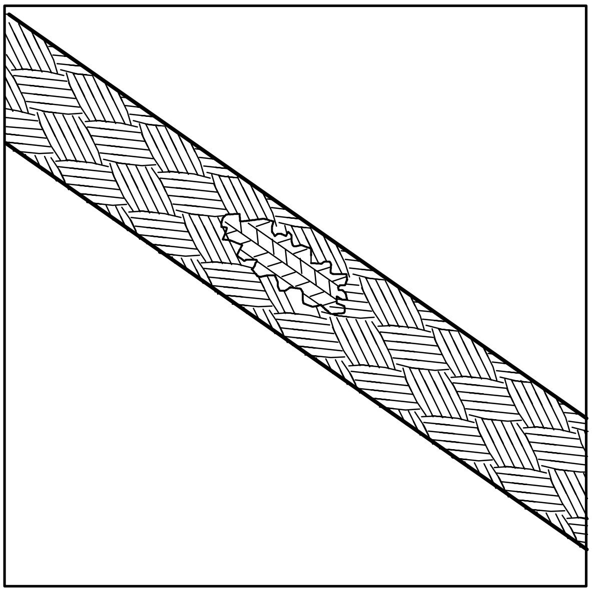

Figure D.18

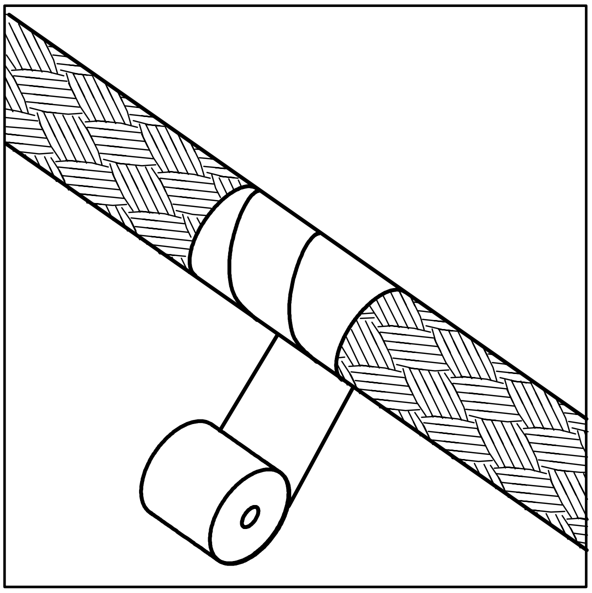

Figure D.19

D.6.2 Damage to the rope core

Ropes with damaged cores should be rejected.

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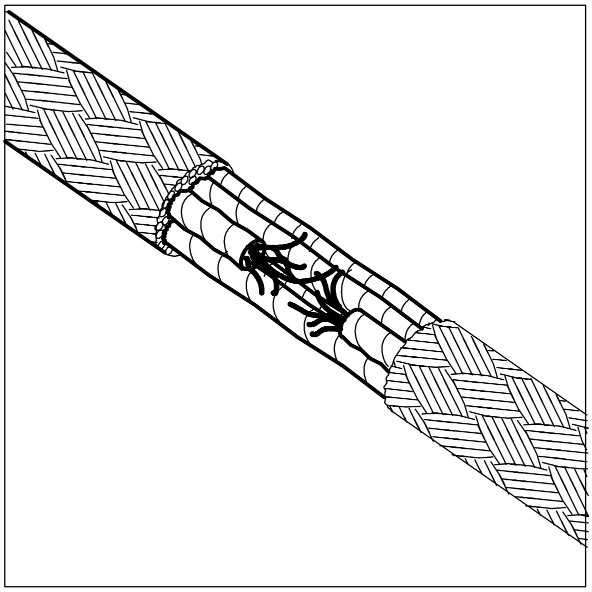

Figure D.20

It should be noted that only major internal damage can be identified visually. Excessive nonlinearity in the rope surface may represent internal damage.

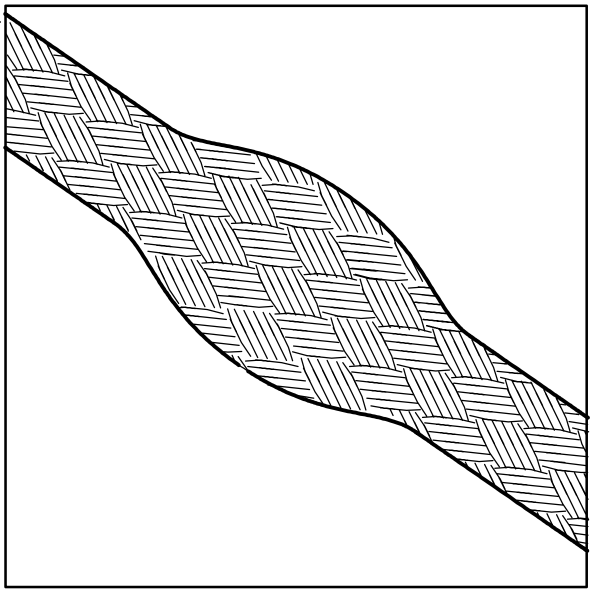

Figure D.21

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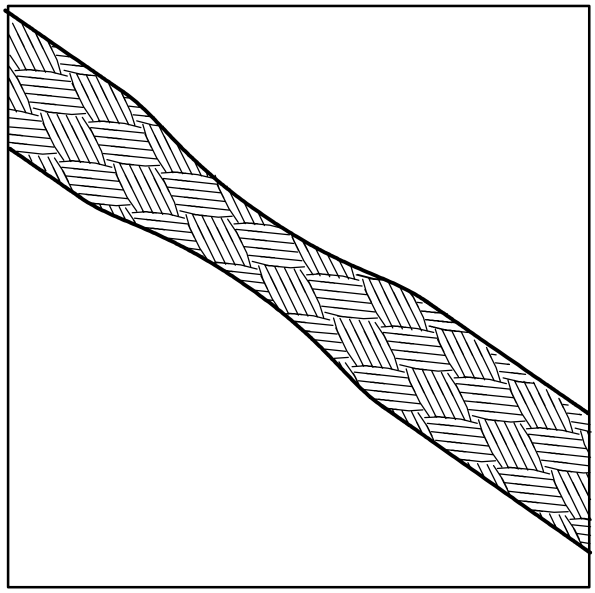

Figure D.22

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Annex E
(informative)

Certificate of conformity — High modulus polyethylene (HMPE) ropes for offshore stationkeeping

	Certificate number: ____________
Purchaser	
Purchaser order number :	
Production order :	
ROPE IDENTIFICATION	
Designation :	
Reference document :	**ISO/TS 14909**
Material :	High modulus polyethylene (HMPE)
Reference number :	
Type of construction :	Torque-neutral (type TF) – Torque-matched (type TM) *
Linear density (ktex) :	
Minimum breaking strength (kN) :	
RCS/Type approval certificate number :	
:	

* specify

Item	**Rope individual identifica-tion number**	**Nominal length (at …% MBS)** (m)	**Actual length (at …% MBS)** (m)	**Rope length at reeling handling tension** (m)	**Rope net mass** (kg) **	**Packaging number**
1						
2						
3						
…						

** including termination and fitting

Place: ***Date:***

____

Quality Control Supervisor

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Annex F
(informative)

Commentary

NOTE Reference is made to the corresponding clauses of this Technical Specification and its annexes.

F.1 Clause 1 — Scope

This Technical Specification covers HMPE fibre ropes intended for use as components of anchoring lines forming the stationkeeping system of permanent or mobile offshore floating structures, or for use in a similar application.

The design of stationkeeping systems of offshore floating structures, and the criteria for the application of fibre ropes in such systems, are covered in ISO 19901-7 (Reference [1]).

In such systems, fibre ropes are typically permanently immersed and freely spanning between end terminations. Contact with the seabed is avoided and may normally happen only in an accidental situation (e.g. during the handling of lines for installation).

In this Technical Specification for HMPE ropes, and in this commentary, reference is made to ISO 18692.

Further information on HMPE fibres can be found in ISO 9554 (Reference [4]).

F.2 Clause 5.3 — Creep properties

F.2.1 Creep of HMPE fibres

Under a constant load, HMPE fibres can show an irreversible deformation (creep) behaviour, which is strongly dependent upon load and temperature. Figures F.1 and F.2 (see Reference [2]) shows a typical creep curve of HMPE, where the elongation of a fibre is plotted as a function of time. Three regimes can be clearly distinguished, characterized by a different behaviour of the creep rate (see Reference [2] for further details):

Regime I: “primary creep”: in this regime, amorphous realignment takes place. Initially, the creep rate is high, but quickly decreases with time, until a plateau level is reached. The elongation is mostly reversible.

Regime II: “steady-state creep”: in this regime, sliding of molecular chains takes place. The elongation is what is defined as plastic creep, which is irreversible.

Regime III: “tertiary creep”: in this regime, molecular chains start to break. High strains can start to cause necking in the filaments and can increase the local stress, which further accelerates the strain until breakage.

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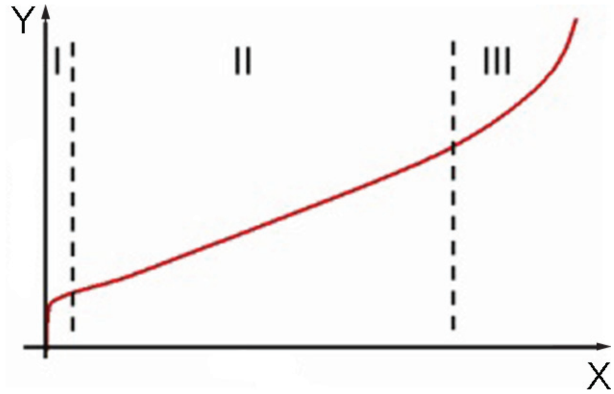
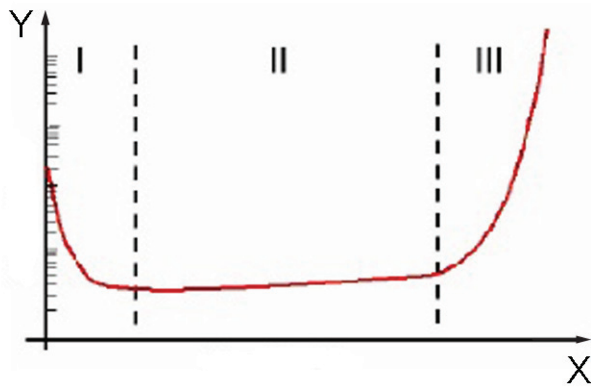


Key
Y elongation (%)
X time (s)

Figure F.1 — Typical HMPE creep curve



Key
Y creep rate (1/s)
X elongation (%)

Figure F.2 — Typical HMPE creep rate curve

In this Technical Specification, “creep” and creep rate refer to the “steady-state creep” of regime II. Creep is strongly dependent on load, time and temperature.

The transition of creep regime II and III, indicated by acceleration in the creep process, may be used to mark the end of life.

The levelling off of creep rates in creep regime I is marking the end of this regime. Thus, for extrapolations over longer times, creep tests should at least be carried out up to the plateau in the creep rate.

F.2.2 Prediction of rope creep

For HMPE ropes used as components in a stationkeeping system, creep performance (a topic specific to HMPE) should be evaluated (see ISO 19901-7:2005, 14.4 and A.14.4) including:

— a prediction of the expected creep per year, thus of the expected life time of rope under the operating conditions, for the most critical area of the rope, i.e. the area which is subjected to the highest ambient temperature and highest tension (generally, the uppermost area of the rope);

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— where needed, a prediction of the cumulative creep elongation of the whole line, over the design service life of the rope, for the mooring system in the intact condition.

An evaluation method is outlined in ISO 19901-7:2005, A.14.4. It takes into account that the line is under a variable tension over time. Data of rope creep performance are to be obtained from qualification tests, but getting such information from full-size rope test is neither practicable nor necessary, as creep estimation models can support the creep performance requirements and limit the need for full-size testing.

F.2.3 Fibre creep model

Based on the data of fibre creep tests over a wide range of parameters, the fibre manufacturer should establish a documented model of yarn creep performance.

From this model, creep data (creep rate, allowable creep elongation and time) can be obtained to cover:

— rope operating conditions;

— conditions for rope creep tests;

— fibre production control.

F.2.4 Rope creep test

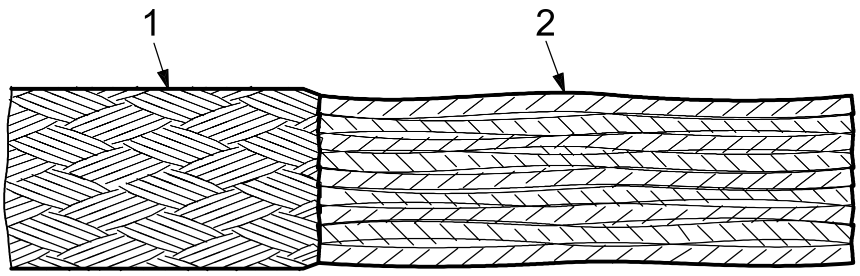
The objective of the rope creep test is to calibrate long-term rope creep rates with data and model of fibre creep.

The selected test conditions (mean load, temperature and duration of the test) should be such that the test is covering regime II of the creep behaviour (see F.2.1 above). The model of fibre creep may be used to support the indication of being in region II of the creep behaviour.

Comparing rope creep rate with fibre creep rate under the same conditions can provide information about the ratio, between fibre and rope, of creep rates at the same specific stress (N/tex) and temperature.

F.3 Subclause 6.2 — Type of construction

Typical constructions of ropes are illustrated in Figures F.3 and F.4.



Key

1 cover

2 sub-ropes

Figure F.3 — Typical torque-neutral parallel construction rope with cover and sub-ropes (type TF)

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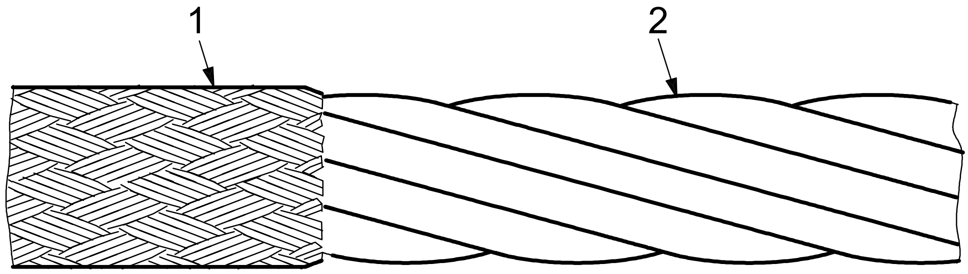

Key

1 cover

2 rope core

Figure F.4 — Typical torque-matched wire rope construction rope with cover (type TM)

Depending on the rope construction, the rope may be torque-neutral or designed to accommodate a given torque (torque-matched construction). Torque-matched fibre ropes are intended for use in series with wire ropes. These constructions are specifically designed to reduce torsional fatigue in the wire rope.

F.4 Subclause 6.6 — Length of rope

The length of rope is defined as the installed length at a typical mean tension, as simulated by the loading and the bedding-in sequence of the typical elongation and linear density test defined in B.4 (see F.8 below).

F.5 Subclauses 7.1.3 and B.3.2 — Breaking strength

The purpose of the test is to verify the breaking strength of the rope against the specified MBS. The testing of three samples provides a margin that is quantifiable. Adjusting the breaking strength upward or downward from the test results is not to be considered.

The test sequence includes an initial loading and a bedding-in sequence. Further load-elongation measurements that may be performed in between are not deemed to significantly affect the condition of the rope with respect to the break test.

F.6 Subclause 7.1.3 and Clause B.3 — Dynamic stiffness at end of bedding-in and quasi-static stiffness

The load-elongation properties of fibre ropes under cyclic loading have been investigated in several research and development projects, and models have been proposed to quantify the dependence of stiffness on testing parameters (see for example Reference [3]).

Depending on the construction particulars, a rope of a given strength can exhibit a wide range of stiffness under given conditions: the dynamic stiffness at the end of the standard bedding-in sequence has been found to provide a pertinent indication of the degree of stiffness of a given rope. Then, only a limited amount of testing performed on one rope size only is necessary to verify the rope behaviour and adjust models, if needed (see F.9 below).

F.7 Subclause 7.1.6 and Clause B.5 — Cyclic loading endurance test

The endurance of polyester ropes at moderate load ranges, typical of mooring system response, has been quantified by systematic cyclic loading tests on small-size ropes (see E.7 of ISO 18692:2007), and found to be far above that of a steel wire rope. Limited data of similar tests on HMPE ropes indicates that, for endurance, HMPE ropes outperform polyester.

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As testing a rope to failure is not practically achievable, the purpose of cyclic loading endurance testing in B.5 is, therefore, to establish that a particular rope can be expected to have the same endurance as demonstrated by testing projects, and does not present risks of premature failure due to inadequate design or manufacturing.

F.8 Subclauses 7.2.2 and B.4.2 — Length measurement and calculation of linear densities

The objective of the linear density test is to provide data to determine/verify the as-installed length of supplied rope segments. For this purpose, the linear density of the rope after a typical installation sequence is determined.

Other methods of measuring the length of a rope can be used in conjunction with the method specified in this Technical Specification, but can require a suitable calibration to ensure an accuracy consistent with specified length tolerances.

F.9 Subclause B.3.5 — Quasi-static stiffness and dynamic stiffness

The axial stiffness of a rope is defined in this Technical Specification as the ratio of rope load to strain variations between the lower (trough) and upper (peak) stresses imposed during testing, normalized by the rope minimum breaking strength:

$$K_\mathrm{r} = \frac{\Delta F}{F_\mathrm{MBS}} \div \frac{\Delta l}{l} \qquad \text{(F.1)}$$

The reduced stiffness, K_r, is dimensionless (%/%).

For additional background, see E.9 of ISO 18692:2007.

The quasi-static stiffness, i.e. the stiffness under quasi-static cycling, is defined as a secant stiffness between the end points of successive half-cycles. The results of a 1 h cycling can be extrapolated to more representative durations, e.g. 24 h or 7 days, as noted in Reference [3]. For the longer durations, the effect of rope creep over such duration (averaged over *in situ* rope length) should be accounted for in addition.

The dynamic stiffness is representative of the near-linear behaviour observed under cycling at frequencies which are typical of vessel slow drift motions and wave actions. A load range smaller than 10 % can be desirable in some cases, but can lead to difficulties in the measurement of small elongations.

F.10 Clause B.6 — Particle ingress protection

The intent of the particle ingress protection is to prevent risks of damaging the rope core, in the case of accidental contacts with the seabed; see ISO 19901-7.

F.11 Clauses B.3 to B.5

Testing sequences specified in B.3 to B.5 are shown for illustration in Figures F.5 to F.9.

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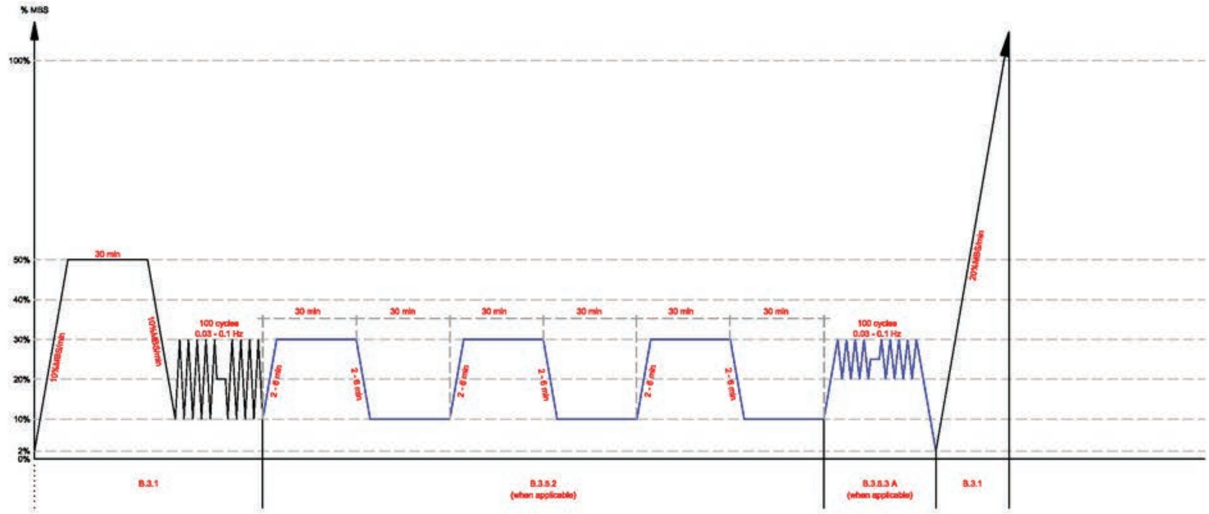

Figure F.5 — Quasi-static stiffness, dynamic stiffness and breaking test sequence, B.3, sample a

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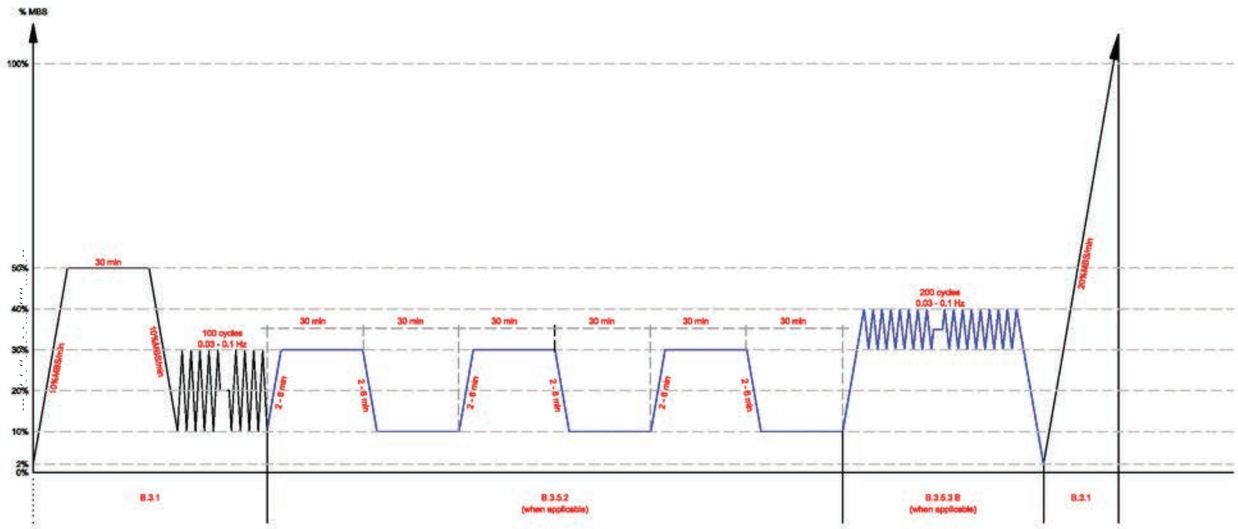

Figure F.6 —Quasi-static stiffness, dynamic stiffness and breaking test sequence, B.3, sample b

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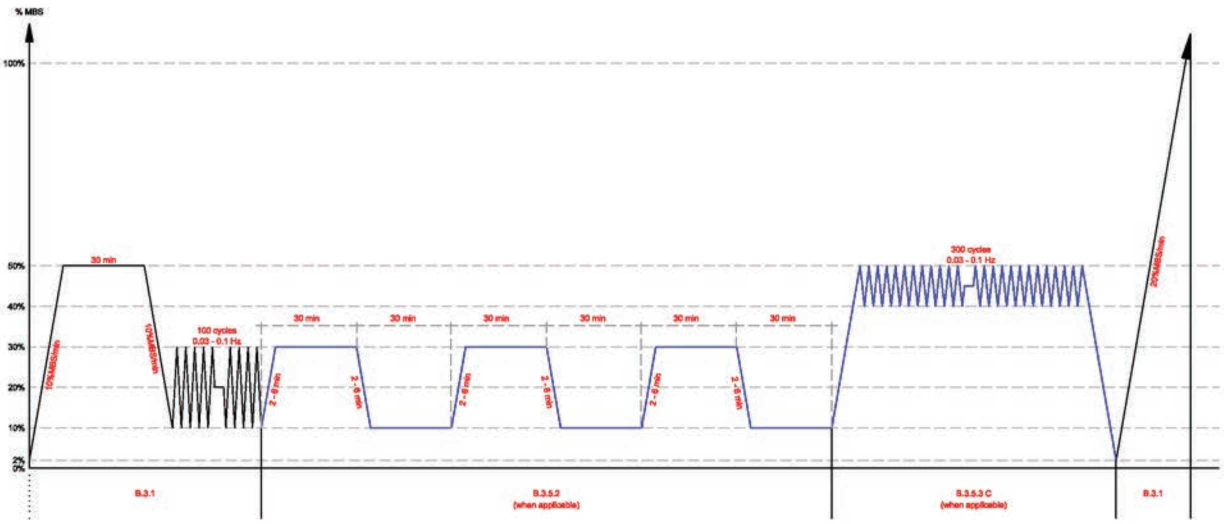
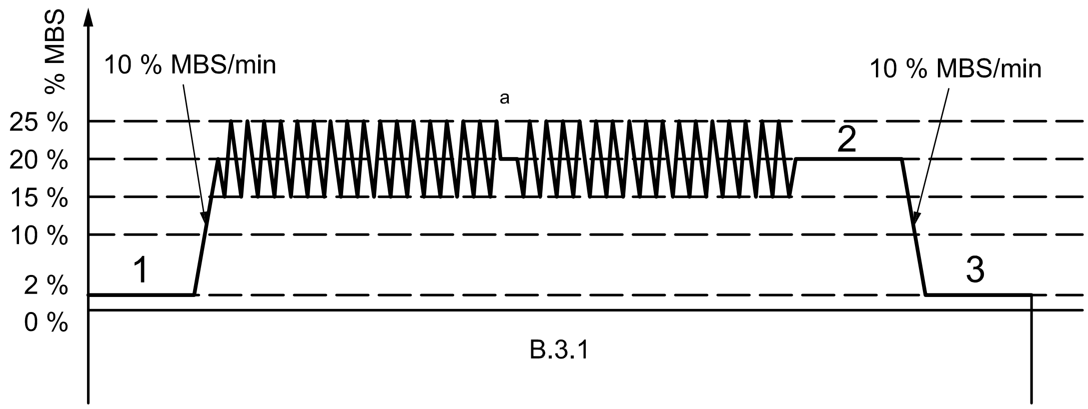


Figure F.7 —Quasi-static stiffness, dynamic stiffness and breaking test sequence, B.3, sample c



Key

1 mark 1, L_{R0} (2 m)

2 mark 2, L_{R20}

3 mark 3, L_{R2}

[a] 100 cycles; between 0,03 Hz and 0,1 Hz.

Figure F.8 —Linear density test sequence, B.4

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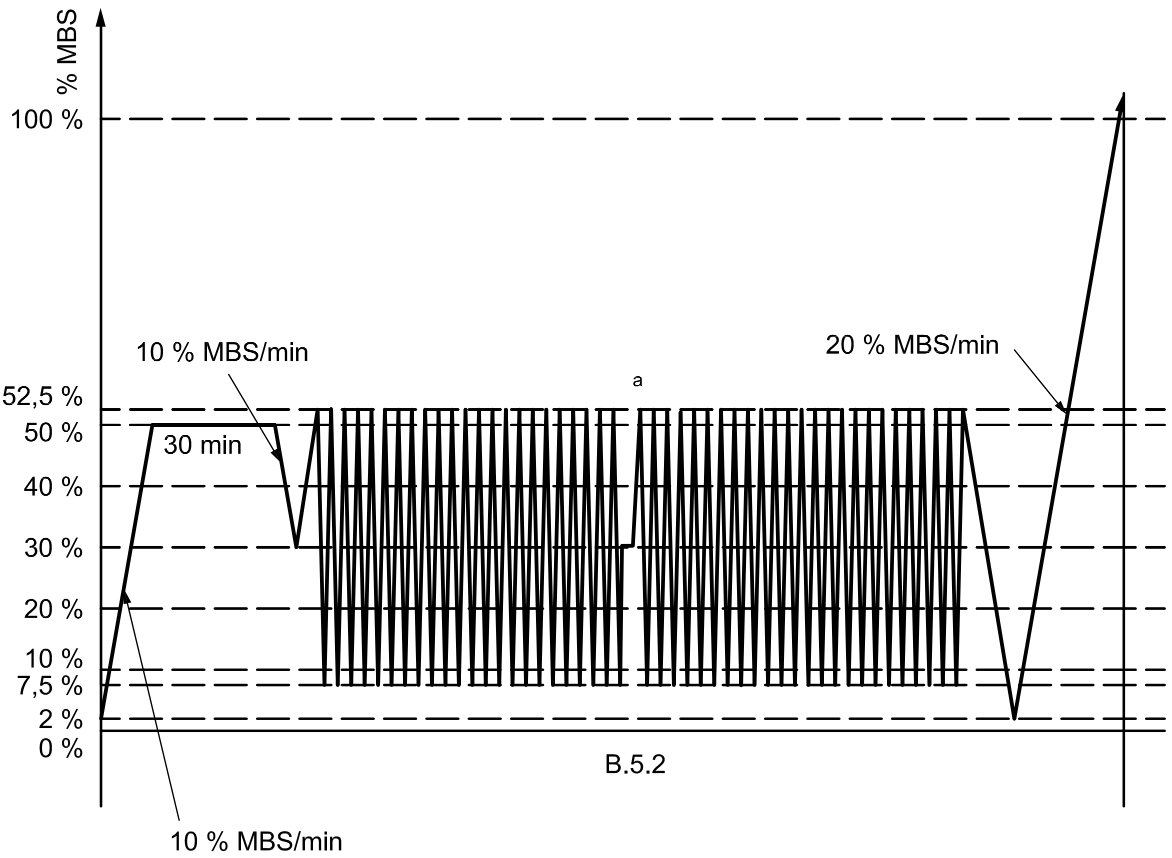

a 9 362 cycles; between 0,01 Hz and 0,1 Hz.

Figure F.9 —Cyclic loading endurance test sequence, B.5 (example with a cycling range, R, of 45 %)

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[4] ISO 9554, *Fibre ropes — General specifications*

[5] *Test method — Tensile properties — DSM Dyneema Ref. DTM YA 001 of 4.02.2009*

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