Certification of Fibre Ropes for Deepwater Offshore Services

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GUIDANCE NOTE
NI 432 DTO R01E

17 bis, Place des Reflets – La Défense 2 – 92400 Courbevoie
Postal Address : 92077 Paris La Défense Cedex
Tel. 33 (0) 1 42 91 52 91 – Fax. 33 (0) 1 42 91 53 20
Email : veristarinfo@bureauveritas.com
Web : http://www.veristar.com

MARINE DIVISON
GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine Division (the "Society") is the classification ("Classification") of any ship or vessel or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- prepares and publishes Rules for classification, Guidance Notes and other documents ("Rules");
- issues Certificates, Attestations and Reports following its interventions ("Certificates");
- publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as "Certification".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as "Services". The party and/or its representative requesting the services is hereinafter referred to as the "Client". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.

2.4. - The Client is to give to the Society all access and information necessary for the performance of the requested Services.

ARTICLE 3

3.1. - The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are not a code of construction neither a guide for maintenance or a safety handbook.

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.

3.3. - The Services of the Society are carried out by professional Surveyors according to the Code of Ethics of the Members of the International Association of Classification Societies (IACS).

3.4. - The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- conducts surveys at the place of their construction;
- classes Units and enters their class in its Register;
- surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.

5.2. - The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder, respectively.

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - If the Services of the Society cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee.

The Society bears no liability for indirect or consequential loss such as e.g. loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. hereabove subject to compliance with 2.3. hereabove and Article 8 hereunder.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. - Overdue amounts are increased as of right by interest in accordance with the applicable legislation.

8.3. - The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the classification file consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit ;
- copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society Member of the International Association of Classification Societies (IACS) in case of the Unit's transfer of class;
- the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units are passed on to IACS according to the association working rules;
- the certificates, documents and information relative to the Units classed with the Society may be reviewed during IACS audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France.

12.3. - Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.

ARTICLE 13

13.1. - These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement.

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

CONTENT

1. FOREWORD TO SECOND EDITION

Since the first edition of this Bureau Veritas Guidance Note, published at about the same time as the first installations of operational deepwater fibre rope stationkeeping systems, a number of systems have been installed and operated all over the world. In the mean time, intense R&D activities have brought a better understanding of rope properties, in relation with this or other applications.

This second edition is presenting updated guidelines for certification, reflecting the experience gained in the industry from design and manufacturing, from R&D, and from related certification activities, and the now wider range of applications of fibre ropes in offshore services.

2. GENERAL

2.1 Subject

This Guidance Note defines the procedures and requirements for the certification of fibre ropes intended for use as load-bearing components in the stationkeeping system of a floating offshore unit, or for other offshore deepwater applications, as defined in 2.2 .

(Bureau Veritas Approval and Manufacturing Survey file number : 7676)

Note : "deepwater" is used here as illustrative of the current field of application of ropes in the offshore industry, in systems where the rope is a “critical component” for safety or asset integrity. However, it is not meant as a limitation, neither on the service conditions of ropes nor on the scope of this Guidance Note.

2.2 Field of application/scope

2.2.1 Fibre ropes for Stationkeeping systems

This Guidance Note is applicable to fibre ropes used as elements of anchoring lines, for the stationkeeping of permanent floating offshore platforms or mobile floating offshore units, at their operating site.

The conditions and criteria for use of fibre ropes in a stationkeeping system are defined in Annex 1.

Note 1 : the certification of ropes is to be generally performed as a part of activities for the classification of an offshore unit, and the granting of a **POSA** notation covering the stationkeeping system of that Unit [1] *.

Note 2 : for polyester ropes for offshore stationkeeping, this Guidance Note covers the compliance of ropes to ISO 18692:2007 [4] *, and related rope certification.

**** see references in section 8 .***

2.2.2 Tethers

This Guidance Note is also applicable to fibre ropes used in similar conditions as anchoring lines (i.e. free spanning between terminations) such as tension members (tethers) in subsurface systems. The provisions indicated for stationkeeping lines are generally applicable to such ropes.

2.2.3 Sub-sea lowering and other applications

This Guidance Note is also generally applicable to fibre ropes used for sub-sea lowering lines for a (deepwater) fibre rope handling system, or other offshore “deepwater” applications, subject to adjustments of the technical requirements on rope design and to adequate testing. Some guidance is given.

2.2.4 Limits of scope

This Guidance Note may be referred to when agreed by involved parties.

However, this Guidance Note is in principle not intended to cover the certification of synthetic fibre ropes for other marine applications, such as :

- SPM hawsers,
- towing line, mooring lines (ship to terminal, ship to ship) , etc…

Note 1 : the document enclosed in Annex 4 is however applicable to fibre qualification for such applications.

Note 2 : the type approval and inspections of SPM hawsers is normally performed with reference to the OCIMF « Guidelines for Hawsers » [5] .

(Bureau Veritas Approval and Manufacturing Survey file number : 6602)

Note 3 : the type approval (if requested) and the Inspections of ropes for other services is performed based on applicable Rules, with reference to recognised product standards (such as ISO standards or Cordage Institute documents) .

(Bureau Veritas Approval and Manufacturing Survey file number : 6602)

2.2.5 Termination fittings

Termination fittings, such as thimbles or similar device are covered in this Guidance Note only for their interface properties with rope and for testing (see sections 5.3 and Annex 3).

Shackles or other connecting devices are not covered by this Guidance Note.

Note : for classification, or when requested, reference is to be made to the relevant provisions of "Rules for Classification of mooring systems" [1].

2.3 Conditions

2.3.1 References

The certification activities are performed with reference to :

- this Guidance Note,
- other publications of Bureau Veritas, as applicable,
- ISO 18692, [4] when relevant.

Reference will be also made to specific requirements of Purchaser's specification, where applicable.

2.3.2 State of the Art

The certification scheme and related requirements in this Guidance Note are based on the present State of the Art in using fibre ropes for the above defined applications (see also 4.1.1 for materials).

The Society reserves the right to modify the content of this scheme or associated requirements, or to call for specific requirements for a particular product or usage or service condition.

2.3.3 General conditions

The certification activities defined in this Guidance Note are carried out within the framework of the General Conditions applicable to the interventions of Bureau Veritas Marine Division.

2.4 Definitions

The definitions in 2.4.1 to 2.4.3 apply in this Guidance Note.

Further definitions may be found in ISO 18692:2007 [4] and, for general vocabulary, in ISO 1968:2004 : "Fibre ropes and cordage -- Vocabulary".

2.4.1 **Minimum Breaking Strength (MBS)** of a rope : the specified minimum for the tension at break of a rope, when tested following the procedure defined in this Guidance Note.

Note : the MBS is thus defined as that of the spliced (terminated) rope.

2.4.2 **Rope model** : a set of ropes having, over a range of sizes, common characteristics including fibre and other materials, construction and method of manufacture for the rope core, the cover, and the terminations, and dimensional characteristics such that a rope in one size can be considered as homothetic to a rope of another size.

Note 1: a rope model generally corresponds to a product in a Manufacturer's catalogue, provided same fibre(s) and other materials are used.

Note 2 : two ropes of the same model have, in principle, the same number of elements (strands, sub-ropes, …) and all dimensions (diameters, lay length, …) in same proportion or, for a parallel construction, can be made of a different number of identical sub-ropes.

Note 3 : the acceptance, for the purpose of rope approval, of several ropes being of "the same model" is subject to the prior agreement of the Society (see 3.1.2 and 7.1.3).

2.4.3 **Rope size** : a nominal dimension (e.g. diameter, or circumference) of the cross section of a rope, or a reference number (in ISO rope standards), or the resulting MBS of that rope.

Note : in this Guidance Note, the MBS is generally used to indicate size.

3. PROCESS OF CERTIFICATION

3.1 General

3.1.1 The certification of ropes intended for a given project involves the following steps be carried out :

1) Qualification of the fibre material, resulting in a Type Approval of the fibre, usually with the fibre Manufacturer (see section 4),
2) Qualification of the rope based on the design, manufacturing, and testing of a **full size** prototype of the specified rope, and resulting in a "Rope Approval". This Rope Approval will be valid for the manufacturing of ropes that are identical, **in model (see 2.4.2, i.e. including fibre(s)) and in size** to the rope that has been prototype tested,
3) Manufacturing in conformity to prototype and testing of ropes for supply.

Note : for further manufacturing, the qualification does not need to be repeated when the ropes are identical to a rope already holding a "Rope Approval", i.e. no change is made to materials, design, nor manufacturing process.

3.1.2 During qualification, account is taken, subject to agreement by the Society at time of the review of rope design and manufacturing specifications, of test results from previously qualified ropes of the same model, holding a "Rope Approval" by the Society (see 7.1.3).

Note : in practice, the rope for a given project is most often not a unique product, but one size in a rope model proposed by the Manufacturer, with other size(s) of the same rope model having been already qualified.

3.2 Certification activities

3.2.1 Certification activities generally include the following :

1) For rope qualification :
- review of design and manufacturing documents,
- review of fibre certification status (see section 4),
- visits during the manufacturing of a prototype rope and the preparation of rope samples for testing,
- witnessing of prototype testing,
- review of manufacturing and testing reports;

- issuance of a Certificate of Rope Approval (Type Approval Certificate) upon satisfactory completion of the procedure,
- assessment of manufacturing facilities and issuance of a recognition certificate upon satisfactory completion of the procedure (BV mode II survey) [2].

2) For the production of ropes in accordance with the rope approval :
- attendance to tests and examinations as agreed for individual supplies,
- visits during manufacturing of ropes,
- visits during rope testing (where applicable);

- issuance of a certificate of inspection for the individual supply upon satisfactory completion of the procedure.

3) During both steps :
- inspection at suppliers works, as needed.

3.3 Documentation to be submitted

3.3.1 The Manufacturer shall submit the following documentation, in due time :

1) For rope qualification :
   - Manufacturer's brochures and catalogues of products (for information),
   - Quality Management system certificates,
   - Rope Approval data sheet, (see 3.3.2),
   - data of intended material (type, Supplier, and grade),
   - plans for prototype testing with, for any request of test dispensation, reference to previously obtained Rope Approval(s) for the same model of rope (see 7.1),
   - detailed planning for design activities, prototype manufacturing, prototype testing, and subsequent rope manufacturing,
   - Manufacturer's design and manufacturing specifications, and related Inspection and Test Plans (as per 3.3.4),
   - plans and specifications for the purchase of thimbles and fittings (if any),
   - list of Quality control procedures,
   - testing reports (when available).

2) For the production of ropes in accordance with the Rope Approval :
   - Rope Supply data sheet, (see 3.3.3),
   - Inspection and Test Plans,
   - testing reports (where applicable and when available).

3.3.2 Rope Approval data sheet

A Rope Approval data sheet is to provide a general description of the rope to be qualified, including :

- identification of product (rope model),
- type of service,
- material (with fibre designation),
- type of construction, including type of torque behaviour,
- type of protective cover and particle ingress protection,
- type of terminations,
- specified MBS,
- reference assembly and interface drawings.

The format as given in A2-1 may be used.

3.3.3 Rope Supply data sheet

A Rope Supply data sheet is to provide a general description of the intended supply, including :

- identification of product (rope model),
- type of service and other information on rope service conditions, as provided by Purchaser,
- specified MBS,
- reference Rope Approval, with a Statement of Compliance by the Manufacturer,
- material (with fibre designation),
- type of construction, including type of torque behaviour,
- protective cover and particle ingress protection information,
- type of terminations,
- assembly and interface drawings,
- achieved “dynamic stiffness at end of bedding-in” *“Krebi”* (see 7.2.4),
- diameter and weight information,

- scope of supply (for information and interface with classification activities),
- number and length of finished ropes in the supply.

The format as given in A2-2 may be used.

3.3.4 Design and Manufacturing Specifications

The detailed design and manufacturing specifications are to include :

- specifications of materials,
- details of rope construction,
- details of terminations,
- specification of thimbles,
- manufacturing specifications, including production sheets, and relevant procedures,
- Quality Control procedures, Inspection Plans, and report forms.

Note : as per Bureau Veritas General Conditions, these detailed design and manufacturing documents are kept as confidential, unless otherwise agreed between involved parties,

3.3.5 Manufacturing records

Full fabrication files are to be made available to Surveyor, at factory.

This is to include, as a minimum :

- Material certificates,
- Production sheets,
- Records of controls and inspections,
- Testing records.

4. FIBRE

4.1 Fibre for rope core

4.1.1 The following fibre material are currently used (or considered) for the rope core (i.e. the load-bearing part of the rope - see 5.1.4), and form the basis of this Guidance Note :

- Polyester (high tenacity, marine grade),
- High Modulus Polyethylene (HMPE),
- Aramids and LCP.

Other fibre materials and yarns made of several materials (dual fibre yarns) will be given special consideration by the Society, based on their particular properties and intended application.

4.1.2 The fibre is to be qualified and Type Approved by the Society with respect to the provisions of this Guidance Note, following the requirements and procedures of the document "Type Approval of fibres and yarns" [6], enclosed in Annex 4.

Compliance with this document is to include the specific provisions applicable to “deepwater mooring lines or other specific offshore applications” (marked "DW").

Fabricated yarns are to be Type Approved on the same basis.

Note : the Type Approval is to be obtained by the fibre Manufacturer. In case of fabricated or re-processed fibre, the Type Approval is to be obtained by the rope Manufacturer.

4.1.3 Fibre for the rope core of polyester ropes is to be high tenacity fibres, with a tenacity not lower than 0.78 N/Tex .

4.1.4 Polyester fibres, and other fibres, where relevant, are to be marine grade fibres, i.e. fibres provided with a marine finish having documented efficiency and persistence, as per Annex 4.

4.1.5 Fibres and fabricated yarns are to be delivered with a work’s certificate stating compliance with the Type Approval (such as type 3.1 as per EN10204:2004), as detailed in the document referred to in 4.1.2 . When the product is for internal use, same information is to be given in a test report.

4.2 Fibre for braided rope cover

4.2.1 Fibre for a braided rope cover (see 5.1.5) is to have documented properties, in accordance with the document "Type Approval of fibres and yarns" [6], enclosed in Annex 4 and the general provisions for "marine application" therein.

A Type Approval should be obtained by manufacturer.

Fibre is to be delivered with a work’s certificate stating compliance with the type approval.

4.2.2 Polyester fibre used for a braided cover is to have a minimum tenacity of 0.73 N/tex.

Note : using other material with better resistance to cutting and abrasion than polyester is recommended (see 5.1.5).

5. ROPE DESIGN AND MANUFACTURING

5.1 Rope Design

5.1.1 General

The rope design is to be identified in all details, including materials, arrangement, method of manufacture, as well as numerical data (sizes, numbers, dimensions such as twist or lay-length , etc…) for the proposed rope size.

5.1.2 Rope Construction

The constructions of rope core and of rope cover are to be identified in all details.

The mass and dimensional characteristics of the rope are to be also defined.

(see summary data sheet in A2-3)

Note : for ropes for stationkeeping, the diameter or the particulars of a specific (non-circular) cross section are given for information. The diameter is however an important parameter for some applications (e.g. sub-sea lowering lines).

Polyester ropes for stationkeeping, and other ropes unless otherwise specified, are to comprise a rope core, as the load-bearing part of the rope, and a protective cover.

For sub-sea lowering lines or other specific applications, an open construction, without cover, is to be used.

5.1.3 Materials

All materials entering in rope manufacturing are to be identified and shall not be changed subsequently.

Fibres for rope core and for rope cover are to be in accordance with the provisions of section 3.

Additional materials entering in the manufacturing of rope (e.g. filter, lubricant,…) and terminations (lining, coating, …) are to have identified nature and properties, including, as applicable :

- base material,
- type of construction/preparation,
- brand name / reference to a specification,
- dimensional properties (thickness, linear density, …),
- strength and performance (e.g. filtering capability), with reference to standards appropriate for the product.

Note : the final acceptance of fibres and other materials for a given rope is, in any case, pending the full size testing of prototype ropes.

5.1.4 Rope core

The rope core is to be of suitable construction to provide intended strength and stiffness, meeting the performances specified in section 7, and other relevant properties of the rope.

The construction of rope core is to be such that the rope has a defined torque behaviour, as suitable for the intended application, being in principle one of the following :

- Torque-neutral construction : i.e. a construction such that rope ends do not exert a torque, or tend to rotate, when the rope is tensioned,

Note 1 : some constructions are inherently torque-neutral.

- Torque-matched construction : i.e. a construction such that, over a certain range of tension, the rope develops a similar torque to, and thus can balance that of a given steel wire rope.

Note 2 : the type and size of matched steel rope are to be specified.

Note 3 : see A1-2.2 for application to stationkeeping lines. For lowering/lifting lines working in single fall, an inherently torque-neutral construction must be used.

5.1.5 Protective cover

A protective cover, when required, is to protect rope core from mechanical damages during handling and in service.

The cover is to be permeable, to permit flooding of void spaces within the rope when immersed.

Note 1 : in case of a parallel construction, the cover also has the function of holding rope core elements (sub-ropes) together.

A braided cover is typically used. The braided cover is to have a thickness not less than 7 mm when made of polyester yarns (see 4.2.2) or, if another material is used, a thickness providing at least an equivalent level of protection.

Note 2 : an improved protection with respect to risk of cutting (the most frequent cause of rope failure) or abrasion can be achieved by using material (fibre or mixed fibres) with better resistance to cutting and/or abrasion than polyester.

Note 3 : for sizes lower than 3100 kN, the minimum cover thickness may be taken as :
t (mm) = 0.125*SQRT(MBS) (with MBS in kN) , but not less than 4 mm.

Coloured strands in a suitable pattern are to be provided within the braiding, as a mean to verify that the rope has not been twisted, during handling or in service.

Note 4 : although this pattern is not intended as a colour coding, a distinctive pattern is current practice.

5.1.6 Particle ingress protection

For covered ropes, a particle ingress protection is to provide a secondary barrier to avoid penetration of dust or soil or other particles into the rope cover. (see A1-4)

Note 1 : this secondary barrier may be provided as an under-layer to the braided cover or other suitable arrangement. A properly selected non-woven filtering material may be used.

The filtering capability of material may be assessed by standard filtering tests, prior to the qualification test below.

The particle ingress protection is to be able to prevent the ingress of particles with a size above a limit not exceeding 20 microns.

Note 2 : a lower limit is easily achievable and may be specified. See also A1-2.4.

The arrangement and method of placement of the protective cover are to be specified (see also 5.3.3). The efficiency of the particle ingress protection is to be verified by testing in accordance with 7.4.2 .

5.2 Rope Manufacturing

5.2.1 Manufacturing specifications shall define each step of the manufacturing process, and associated setting of parameters.

Any particular aspect of manufacturing process is to be duly identified and covered by specifications and procedures.

The Society reserves the right to require specific documentation on any aspect of proposed practice.

5.2.2 Strands (i.e. rope or sub-rope strands), sub-ropes and rope core are to be manufactured in a single length over each supplied rope, with no interruption, nor interchange, nor splice.

Note : a longer length is normally made of several segments. The case of very long single length in large size, if needed (i.e. a rope with a length above say 1500 m and a weight exceeding say 24 t), would be specially considered, subject to adequate validation tests.

5.2.3 The method for joining yarns and the staggering of joins are to be defined.

5.2.4 If a lubricant or other additive is added during some stage of manufacturing, the methods of preparation and application are to be specified, and to be traceable to a specification of the product.

5.2.5 A cover braiding may include properly staggered strand interchanges.

5.3 Terminations

5.3.1 Ropes are normally provided with spliced terminations, to suit a thimble or similar device.

Manufacturing specifications and procedures are to define dimensions of eye, splicing method, splice arrangement, and each step of the manufacturing process.

5.3.2 The type of material (type of steel, or other material), diameter, and groove geometry of thimble are to be defined, and the manufacturing of termination is to suit that geometry.

For parallel construction ropes, the arrangement and matching of sub-rope splices are to be defined.

Note : to avoid that a damage (e.g. by cutting) of one sub-rope jeopardise the residual strength of the rope, one to one splicing should be used.

For short rope length, the relative orientation between the splices at each end is to be also defined, and kept identical between samples for prototype testing, for production testing, and for supplied items with a length less than 70 m (e.g. inserts).

5.3.3 The cover and particle ingress protection are to be restored over the splice area, to ensure continuity of protection.

An additional lining is to be provided in the bearing area of eye onto thimble.

Eye and splice are to be further protected by a polyurethane coating.

Note : coating may be omitted for test samples

5.3.4 Other termination systems would be given special consideration, when supported by extensive investigations of strength and durability.

5.4 Length of finished rope

5.4.1 The length of finished ropes is defined as a bedded-in length at a specified tension.

The bedded-in length L_{T0} (in m) of supplied ropes at a tension T_0 is obtained as :

$$L_{T0} = M / LD_{T0}$$

where M (kg) is the net mass of rope, obtained by weighing, and corrected for ancillary weights and the additional mass of material in terminations,

and LD_{T0} is the linear density (mass per unit length, MTex) of the rope in a bedded-in condition at a tension T_0 (in % of MBS), obtained from the "linear-density test" specified in 7.3.1 , following the procedure in A3-3.3.

Note 1 : unless otherwise specified, T_0 is taken as 20% of MBS and the load sequence in A3-3.3 is used. If a different tension or a different bedding-in/pre-stretching sequence is used, these conditions are to be indicated in the rope supply data sheet (see also 7.3.1 and A1-5.3).

Note 2 : taking LD_0 (see A3-3.3) in the above formula, a “length at reference tension” L_0 can be obtained (see also A1-5.3).

Note 3 : if another method than weighting is used to determine rope length, the Manufacturer will have to document the relation between the length of finished rope in the specified conditions and the length measurements performed during production.

5.4.2 The length of short ropes (such as rope samples or inserts) may be taken as the length measured at a reference tension of 2% of the rope MBS.

5.4.3 The length of finished ropes is to be within 1% of the specified length.

5.5 Marking

5.5.1 A name plate is to be affixed at a convenient location at one end of each rope (be it a test sample of a part of the supply) with, as a minimum, the following indications durably marked :

- Manufacturer identification,
- order and part number,
- rope MBS
- date (month, year) of production.

The name plate is stamped with Bureau Veritas markings, at time of final inspection.

6. QUALITY CONTROL ACTIVITIES

6.1 General

6.1.1 Inspection and testing activities are to be conducted by the Manufacturer, with the objectives of ensuring that:

- the prototype rope is conform to specifications, with any change made during the course of approval, in parameters that could affect quality of finished product, being duly reflected by modification of the specifications and procedures,
- produced ropes are in conformity with approved prototype.

6.1.2 A Quality plan, covering all steps of manufacturing and inspection, is to be prepared by the Manufacturer and submitted to the Society for review, together with corresponding procedures.

Note 1 : the qualification of operators, particularly those employed in rope splicing, is to be addressed within quality procedures.

Quality control checklists and report forms are to be prepared by the Manufacturer, following those in OCIMF Guidelines [5] (duly modified to account for rope construction), or an equivalent practice.

Note 2 : a Quality plan usually covers a rope model and is reviewed accordingly, taking into account, if applicable, the reviews made for similar models.

6.2 Rope samples

6.2.1 Rope samples are to be taken from the production, at following rates :

- during manufacturing of prototype rope, once in every length of continuous production,
- during manufacturing of ropes for delivery, once in the first length of continuous production, then at an agreed rate, not less than once every 70 t.

6.2.2 For each sample, a piece of rope is to be taken out, then set under a reference tension of 2% of MBS, so that a sample with a length of about 2m (at the reference tension) can be marked, than cut.

Note : if, for large size ropes, the above tension cannot be achieved, a lower target may be set, not less than 100 kN, that is to be duly specified in inspection and test records (see also note 4 in A3-3.3).

6.2.3 Measurements are to be taken, at the reference tension, of :

- rope outside diameter,
- length and weight of rope sample,
- weight of rope core of the sample,
- cover thickness.

The linear density of rope and of rope core are to be calculated from the weight of sample and its length at the reference tension.

Note : the rope diameter is generally given for information, and may be measured by a PI tape. Where diameter is deemed an important parameter, the effective maximum outside diameter should be measured with a calliper.

6.2.4 Samples are to be opened and inspected for conformity to design (number of components at each level, pitch or lay length of cover, sub-ropes and strands).

6.2.5 Yarn re-testing and recalculation of rope strength are not required at this stage, and if performed as part of the Manufacturer's Quality Control procedures, are not to be used to advocate another breaking strength than the Minimum Break Strength given in rope specifications.

Note : such testing however provides useful information for later reference (see A1-4.3)

6.3 Rope Testing

6.3.1 For rope approval, testing of prototype ropes is to be performed in accordance with the provisions in section 7 .

6.3.2 When a rope has been previously qualified, a breaking test is to be performed on one rope sample taken from the on-going manufacturing, for verification.

The breaking test is to be performed following the same procedure as for prototype rope (see 7.2 and Annex 3) and the result (the tension Tb at rope breaking) is to be above the specified MBS.

Besides, the rope core tenacity is to be not less than specified for prototype in 7.2.3.

Note 1 : a measurement of the end of bedding-in stiffness is normally not required in the present test, not dispensing however from the bedding-in sequence, before testing to break.

Note 2 : test is not required for the production immediately following rope qualification tests.

7. ROPE PROTOTYPE TESTING

7.1 General

7.1.1 Testing of a prototype rope is to be performed, with the objectives of verifying the breaking strength and other properties of the proposed rope.

7.1.2 Tests for the breaking strength and those for other properties, unless otherwise specified below, are to be performed on full size samples of the prototype rope. Tests qualifies proposed rope and other ropes that are identical, i.e. of the same model (see 2.4.1) and size as tested.

7.1.3 When data is available from the previous qualification tests of another rope (or other ropes) of the same model but a different size, to which a "Rope Approval" has been granted by the Society, some of the tests need not be performed. This is however subject to prior agreement by the Society, based on a review of all characteristics, including construction parameters of both ropes, and to the conditions specified below for each test.

Note : the Society may also give consideration, if relevant, to some tests performed for a different but similar model, provided it can be established as an evidence that results are not affected by the differences.

7.1.4 A plan for prototype testing is to be prepared and submitted to the Society, for review and agreement, at the time of the request for rope approval.

For ropes for stationkeeping, and other ropes unless otherwise specified, the testing is to include, as a minimum, the tests defined in 7.2 to 7.4, as applicable, taking into account the accepted results of earlier tests (see 7.1.3).

(see 7.5 for sub-sea lowering lines and other applications)

7.1.5 A provision is to be made of spare rope for eventual retesting, in addition to the number of samples for the required tests.

7.1.6 Rope samples for break test and cyclic loading endurance tests is to be provided with the specified thimbles, or mounted on equivalent fittings (see A3-2.2).

Note : for a roller thimble, such testing with rope qualifies the thimble, provided the diameter of the pin hole is not exceeding 1.3 that of the final thimble. For thimble qualification in other cases, see 4 and 5 in section 4 of [1] .

7.1.7 Tests are to be performed on a testing machine with adequate capacity, stroke, and control and recording systems, for the test sequences defined in Annex 3, and having documented calibration.

7.1.8 When tests have been performed, a complete and detailed report of testing issued by the testing laboratory is to be provided for review. This report is to include identification of rope samples, all details of sample characteristics and mounting, with sketches and pictures, and the records of load-elongation measurements (see A3-2.3).

7.2 Breaking test

7.2.1 For prototype testing, a breaking test (i.e. loading up to the actual breaking of rope) is to be performed, on three samples, following the procedure in Annex 3.

7.2.2 Strength

When all three results (the tension Tb at rope breaking) are above the specified MBS, the rope is deemed to have that MBS.

If one of the results is below the specified MBS, the result can be discarded only if the cause is identified, so that remedial action can be taken. Then, two additional tests may be performed and, for the rope being deemed to have the specified MBS, shall both break at a tension above that MBS.

Note 1 : a test failure may be due to a malfunction of the test machine, or may be due to the rope. In the later case, changes to rope design may need to be made that, if substantial, could lead to a complete re-run of all tests be required.

Note 2 : adjusting the breaking strength, upward or downward, form test results is not permitted : see A1-3.1.

7.2.3 Tenacity

The rope core tenacity T (N/Tex) is to be obtained from each test as :

$$T = Tb / LDC_0$$

where Tb (kN) is the tension at rope breaking, and LDC_0 (kTex) is the linear density of rope core at the reference tension of 2% of MBS. (see 7.3.1 and A3-3.3, or 6.2.3 when applicable)

For polyester ropes for stationkeeping, the rope core tenacity is to be not less than 0.5 N/Tex, for all tests.

7.2.4 End-of bedding-in axial stiffness

The dynamic stiffness at end of bedding-in *"Krebi"* (see A3-3.1) is obtained during each test.

For polyester ropes for stationkeeping, *Krebi* is to be between 18 and 28.

Note 1 : measurement of Krebi is for comparison (see A1-5.6) . *Krebi* is not meant to be a stiffness for utilisation in design.

Another range may be specified. See however A1-3.3.

Note 2 : for other materials and applications, and if a specific range is not defined, *Krebi* is to be measured for information.

7.3 Load-elongation measurements and response in torsion

7.3.1 Rope length

A "linear-density test" is to be performed at time of prototype testing, on one sample, following the procedure in Annex 3. This test provides load-elongation data, then the linear density LD_{T0} of the rope in a bedded-in condition under tension T_0, from which the bedded-in length L_{T0} of supplied ropes at tension T_0 is obtained (see 5.4.1 and A1-5.3).

Note 1 : when another loading sequence than used at time of qualification test is anticipated, the corresponding load-elongation measurements may be performed on a sub-rope. (see note 3 in A3-3.3).

Note 2 : for ropes other than polyester ropes for stationkeeping, in applications where knowledge of the as-installed length is deemed less essential, and subject to Society agreement, either the load-elongation results of a previous qualification test performed on a rope of the same model, or measurements on a sub-rope (see note 3 in A3-3.3) may be used.

7.3.2 Quasi-static and dynamic axial stiffness

The load-elongation properties of rope under variable loading, i.e. the rope quasi-static and dynamic axial stiffness (see A1-5) are to be verified at time of prototype testing, following the procedure in Annex 3.

These tests need not be performed when data is available from the previous qualification test of another rope with the same model of rope core, and a size not less than 6000 kN MBS.

Tests may be performed on a separate rope sample, or as an intermediate sequence within the breaking test, either all on the same sample or by distributing the measurements over the three test samples, as detailed in Annex 3.

Note : these tests are minimum tests, when the stiffness for ropes with a given fibre has been adequately characterised (see A1-5.4) .

If required, or if data for some particular service conditions are needed, further tests should be conducted, that can be performed on a sub-rope, in case of a parallel construction.

7.3.3 Response in torsion

For ropes that are not inherently torque neutral, the response in torsion is to be verified at time of prototype testing, by testing on one sample, following the applicable procedure and the criteria in ISO 18692, as quoted in Annex 3. Such test need not be performed when data is available from the previous qualification test of another rope with the same model of rope core and termination, and a size not less than 6000 kN MBS.

7.3.4 Creep

For HMPE ropes intended for use as stationkeeping lines, a test is to be performed following the procedure in Annex 3, at time of prototype testing, to calibrate long term rope creep rates with data and model of fibre creep.

For parallel construction ropes, this test may be performed on a sub-rope.

This test need not be performed when data is available from the previous qualification test of another rope (or a sub-rope of it) with the same model of rope core, and a size not less than 3000 kN MBS.

Note : this is not applicable to materials such as polyester or aramids. See A1-3.4 for background information.

7.4 Endurance and durability

7.4.1 Cyclic Tension-Tension loading endurance

The endurance under cyclic Tension-Tension loading is to be verified by testing on one sample.

This tests need not be performed when data is available from the previous qualification test of two other ropes, with the same model of rope in all respect (i.e. including terminations and cover), if the size (MBS) of the rope to be qualified is within the following interval :

- 50% of the lower MBS of these two ropes,
- 200% of the higher MBS.

The endurance test is to be performed following the procedure in Annex 3, for a load range LR between 40% and 50% of rope MBS, with a mean load such that the maximum load during cycling is between 52 and 55% of rope MBS.

The rope sample is to withstand cyclic loading for a number of cycles N to be taken, in function of the load range LR (in % of the specified MBS), such that :

$$N \, . \, LR^{5.05} = 166$$

Note 1 : with above limits on load range, N will be between 5 500 and 17 000 .

At the end of cycling, the rope is to be loaded to break, to determine the residual strength, for information.

Note 2 : this test is intended as a verification tests for polyester ropes having a tenacity and an end-of-bedding-in stiffness meeting the requirements of 7.2.3 and 7.2.4 above, or other products for which the endurance under cyclic loading at larger number of cycles (above 10^6), including at low tensions, have been quantified. Further tests could be required for other products.

Further tests could be also required, or limitation in the range of application, should the residual strength be drastically lower than the MBS (below say 60%).

7.4.2 Particle ingress protection

A test is to be performed following the procedure and criteria in ISO 18692, as quoted in Annex 3, to verify the effectiveness of the particle ingress protection.

Such test need not be performed when data is available from the previous qualification test of another rope with the same model of rope, as to overall construction, particle ingress protection, and rope cover, and a size not less than 3000 kN MBS.

7.5 Sub-sea lowering lines and other applications

7.5.1 The testing requirements in 7.2 to 7.4 generally apply to ropes intended for sub-sea lowering lines and other applications, taking into account that :

- Loads levels in the linear density and in static and dynamic stiffness tests may be adjusted to suit the need of intended application,
- The lower bound MBS, specified in 7.3 and in 7.4.2 for the acceptance of previous tests for another rope size, will be considered on a case by case basis, depending on rope construction.

Note : a lower bound in the range of 1000 kN is generally applicable.

7.5.2 Additional tests are to be considered for particular application, and/or a particular product or usage or service conditions. Testing methodology and acceptance criteria will be considered on a case by case basis.

For sub-sea lowering lines, or other applications where a rope is repeatedly passed over a sheave or equivalent device, the Cyclic Bending Over Sheave behaviour of the rope is to be documented by full size testing in representative conditions.

Note : these tests should be generally backed-up by CBOS tests on small or intermediate sizes, as needed to qualify the fibre and to evaluate the sensitivity to geometrical or other parameters.

8. REFERENCES

[1] Bureau Veritas Guidance Note : « Classification of Mooring Systems for Permanent Offshore Units », NI 493 DTM R00E , 2004

[2] Bureau Veritas Rule Note : « Approval and inspection at works of materials and equipment for the classification of ships and offshore units. Principles and procedures », NR 320 R01 E , as amended

[3] Bureau Veritas , « Rules on material and welding for the classification of marine units », NR216 DT R03E, 2005

[4] ISO 18692:2007 : « Fibre ropes for stationkeeping systems - Polyester »,

[5] OCIMF , « Guidelines for the purchasing and testing of single point mooring hawsers », 2000, Witherby & Co., Ltd., London

[6] Bureau Veritas : "Type Approval of fibres and yarns for the manufacturing of fibre ropes " 2007 (enclosed in Annex 4)

ANNEX 1
Design and Operating criteria
-
Ropes for stationkeeping

A1-1 Subject

This Annex outlines the design and operating criteria specific to fibre rope mooring systems, complementing and updating the requirements in Rules (reference [1] in section 8) - In case of discrepancy, the latest edition shall prevail), and provides information on the background of certification requirement (see also references in A1-6 at the end of this annex).

A1-2 Arrangement of Mooring System

A1-2.1 Lay-out

The requirements for fibre ropes used as stationkeeping lines or similar applications, in this Guidance Note and in the present Annex, are generally intended for arrangements where the rope is fully immersed and free-standing between termination points.

A fibre rope mooring system thus generally includes, for each line :

- a bottom steel section, most often chain, attached to the anchor point,
- the fibre rope section,
- a top steel section.

Note 1 : other arrangement would require specific considerations of applied loads (e.g. loads in rope passing over a fairlead) and exposure (UV, chaffing, particle ingress, etc…).

Note 2 : the system may be a taut leg system, with only a short bottom steel section, or a semi-taut / catenary system, where a longer bottom chain section is provided. The top section is usually made of chain in permanent mooring, or may be a wire rope (e.g. in MODU's)

The fibre rope section may be made of several segments, if needed for practical reasons of fabrication or handling. For permanent offshore units, this is generally to include short rope segments (inserts), as discussed in A1-4.3.

A1-2.2 Torsional behaviour

A torque neutral construction is generally used in permanent systems, where other line sections are made of chain or torque neutral spiral-strand wire ropes.

Note 1 : a parallel construction is most often used, that is inherently torque neutral

A torque-matched construction should be used in lines including non-torque-neutral wire ropes, such as six-strand wire ropes, unless other arrangement is provided to avoid cyclic torsion at the interface.

Note 2 : the cyclic variations of line tension would induce, in a non-balanced line, a cyclic torsion leading to degradation by fatigue of the wire rope near terminations.

A1-2.3 <u>Line top section</u>

The line top section shall have a suitable length so that, with due allowance for the initial elongation of fibre rope under system pretension, further elongation over platform life, and creep where applicable (see A1-4.2 and A1-5.3) :

- an adequate pre-tension can be maintained,
- the upper part of fibre rope is kept well below surface and clear of platform fairleads.

Note 1 : some extra length is generally provided for line hook-up and initial tensioning.

(see also note 5 in A1-5.3)

In addition, in areas where marine growth (micro-organisms with a mineral shell) can develop inside the rope, the top of the rope is to be kept at a sufficient depth (100 m at least) to avoid such growth.

Note 2 : a particle ingress protection (see A1-2.4) is expected to have some beneficial effect in this respect. This is however currently not quantified.

A1-2.4 <u>Line bottom section</u>

The line bottom section shall have a suitable length to keep the fibre rope clear of sea bottom in leeward lines, and thus avoid detrimental chaffing or ingress of soil particles.

When ropes are fitted with a particle ingress protection, this condition need to be applied only to the "intact condition" of the system, provided it can be ensured that sea-bottom do not include hard soil areas and is free from other obstructions. Otherwise, this condition shall apply to any design condition of the system.

(see also note 1 in A1-2.1)

A1-3 Design criteria

A1-3.1 <u>Strength (maximum tension)</u>

The design criteria for the strength of line components, i.e. the Safety Factors for each of the design condition examined, are to be in accordance with the relevant requirements in Rules ([1] in section 8 of this Guidance Note).

Note : the reference strength is the specified Minimum Breaking Strength, as verified by the testing procedure in Annex 5. Adjusting the breaking strength, upward or downward, from test results is not permitted : doing so would require that a larger number of test results (5 minimum) is available, from which a "characteristic breaking strength" could be obtained by suitable statistical derivation. Such procedure might be considered by Rope Manufacturer at time of rope design, using small size ropes or sub-ropes, but is not required for Rope Approval.

A1-3.2 <u>Minimum tension in leeward line</u>

The minimum tension in leeward lines is to be evaluated.

For materials that are sensitive to compression failure (e.g. aramids), or do not have demonstrated performance in this respect, a minimum dynamic tension (10% of MBS) is to be maintained in the rope, for both the “intact” and the “damaged” design conditions, unless a more refined analysis is performed and product specific data are available to document other criteria.

The above is not applicable to Polyester and HMPE ropes, provided, in principle, that a positive tension is maintained in the fibre rope under operating and design conditions. As a guideline, a minimum quasi-static tension of 2% of MBS in the "intact" design conditions may be considered.

Note : keeping a positive tension is today current practice, to avoid complete slackening of the line in normal (non-exceptional) conditions of the installed system (see also A1-4.1) , and for considerations of the overall stiffness of the system.

A1-3.3 Endurance under cyclic Tension-Tension loading

The fatigue life of the lines under cyclic Tension-Tension loading should be evaluated, in accordance with the relevant requirements in Rules ([1] in section 8 of this Guidance Note).

The T-N curve for polyester ropes therein is applicable to carefully designed and manufactured long lay ropes, meeting all requirement of this Guidance Note. This is including, for polyester ropes, having the tenacity and end-of-bedding-in stiffness specified in sections 7.2.3 and 7.2.4, and in principle, a rope core made of a fibre with documented in-rope properties as to cyclic loading endurance (see section 2.3.5 in the document enclosed in Annex 4). Same T-N curve apply to long-lay HMPE ropes, meeting all relevant requirements of this Guidance Note, and having a rope core made of a fibre with documented in-rope properties as to cyclic loading endurance.

Note 1: with respect to the data from the Rope Durability project (see A1-[6]), this T-N curve account - conservatively - for scale effects that have been observed at medium load ranges. A cut off could be applied (at a load range of 5% of MBS), but will only make clearer that fatigue is more critical in adjacent (steel) components of the line.

Little or no data is available for other materials or constructions, that would require a proper documentation of their endurance properties under tension-tension cycling, including at low minimum load (compression failure).

Note 2 : the T-N curve for spiral strand wire ropes may be considered, in the absence of better data, subject to further validation.

A1-3.4 Creep

Where relevant, e.g. for HMPE, a prediction is to be made of the long-term creep of the rope. This prediction is to be based on fibre data of creep rates (see A1-[5] and A1-[9]) and on the correlation between fibre and rope obtained from prototype testing (see 7.3.4).

Note 1 : “creep” is referring here to the progressive, about proportional to elapsed time, non-recoverable increase of length of the fibre or rope under a constant load, that is exhibited by some materials, such as HMPE.

This prediction will provide an evaluation of the expected creep per year, thus of the expected life time of rope (for this criterion) with respect to intended service life, taking into account the allowable creep elongation for a section of the rope, that is defined as the smaller of :

- the extension at which the strength of the rope is still at least 95 % of the original specified MBS; or
- 10 % of the installed length.

Note 2 : an evaluation method is outlined in A.14.4 of ISO standard on stationkeeping systems A1-[8] .

Note 3 : creep is both load and temperature dependent. Then, only the most critical section (usually the top part) needs to be evaluated with respect to allowable creep. An evaluation for the whole length could be also made to indicate expected total creep elongation, where needed.

A1-4 Installation, Operation and Inspection

A1-4.1 <u>Installation,</u>

The installation of the mooring system is to be performed following detailed and carefully engineered procedures, in order to avoid torsion and damage by over-bending on obstacles, chaffing or cutting, as well as contamination by solid or liquid projections.

Guidance on rope handling care, identification of damages and repair may be found in Annex D of ISO 18692 ([4] in section 8 of this Guidance Note). This is also applicable to other materials, as a minimum.

Lines are to be generally deployed under a low tension, with a suitable minimum tension being ensured to avoid risk of damage by local over-bending in a free-span, and are to be generally kept clear of sea-bottom.

Seizing of line, or seizing of ancillary installation devices on line, is to be performed by soft rope seizing only. The accumulation of twist in line is to be avoided.

Ropes fitted with a particle ingress protection may be pre-laid on bottom, provided it is ensured that sea-bottom do not include hard soil areas and is free from other obstructions.

A rope without particle ingress protection that has been dropped or laid on the sea-floor is not to be used as a long-term component of a permanent mooring system.

Note : the particle ingress protection specified in 5.1.6 is primarily intended to protect rope in case of accidental drop-off on, or contact with the sea floor. It is thus considered as an elementary precaution.

As possible, a pre-stretching of rope (see A1-5.3) through appropriate hold load or cycling is to be performed within the installation sequence. However, the tension in rope during pre-stretching (and for anchor testing, if applicable) should not exceed 50% of fibre rope MBS.

For materials that are sensitive to compression failure, pre-deployed lines are to be maintained under tension, in a way that is preventing high cyclic straining (by bending or torsion) at rope ends. A minimum mean tension of 2 % of MBS may be considered, provided that the rope has not been pre-stretched before.

A1-4.2 <u>Re-tensioning</u>

During operation, and primarily in the first months after installation, lines tend to slacken due to bedding-in of the fibre ropes. (see also A1-5.3). Adequate means are to be available to control line tensions (see 2.4.2 in section 2 of Rules ([1] in section 8 of this Guidance Note), and to re-tension the lines, whenever needed, to design pretensions (see also note 1 in A1-5.3).

A1-4.3 <u>Inspection of rope</u>

For permanent offshore units, besides periodical inspection (by ROV), short rope segments (inserts) are to be provided (one at the top of each line) for eventual recovery, then inspection and testing, when needed (e.g. after a significant accidental event), or periodically when required within the frame of agreed plans for inspection of the mooring system.

Note 1 : periodical recovery would include, as a guideline, one insert at the first intermediate survey - 2 ½ years after installation - and one at each special survey - every 5 years. This could be adjusted or dispensed when insert recovery can be performed on other units of the same type, previously installed in the same area. When a substantial in-service experience have been accumulated, the inserts could be omitted provided the Operator is prepared to plan the removal of a full line, or at least the top length, whenever needed, and a section be cut for inspection.

Note 2 : the length of inserts is usually taken same as for test ropes, so that a break test can be performed (see note 3). Removed inserts generally need not be replaced, their length being compensated by an adjustment of top-chain segment.

Note 3 : on a recovered insert, after inspection, a break test is usually performed to assess its residual strength. This however provides only an overall indication when the rope has seen substantial degradation. For parallel construction ropes, the break test should be preferably performed on one sub-rope, and another sub-ropes dissected, to perform a more accurate assessment for deteriorations, by visual and SEM examinations, and through yarn re-testing (see note in 6.2.3).

For mobile offshore unit, the lines are to be subject to comprehensive inspection when recovered between platform moves, with attention to damage by cutting, chaffing, or contact with sea-bottom. At every special survey, in principle, and whenever needed a section is to be cut for inspection and testing, at one or the other end, unless inserts have been provided to that effect.

A1-4.4 Creep monitoring

Where relevant, e.g. for HMPE, creep in a top section of the rope should be monitored, through adequate marking.

The maximum allowable creep elongation defined in A1-3.4 should not be exceeded.

Other criteria (e.g. a maximum service time) recommended by fibre or rope Manufacturer(s) are to be also met.

A1-5 Load-elongation of fibre ropes

A1-5.1 General

A proper knowledge of the load-elongation properties of fibre ropes is needed for designing a system. However, these properties are rather complex to evaluate and specify, in comparison with the linear elastic behaviour of equivalent steel components. The model below defines rope properties for engineering and analysis of a fibre rope mooring system, in a consistent manner with the testing procedures specified in this Guidance Note.

Note 1 : due to the nature of constituent material (a complex assembly of long chains of organic molecules), fibres and fibre ropes exhibit a visco-elasto-plastic behaviour (i.e. non-linear and time dependent) that cannot be reduced to a load-elongation “characteristic”, be-it non linear.

A particularly important aspect, quite specific to fibre ropes, is the modification of the properties of a rope during the first loading(s) and during the early stages of rope service. This process, called “bedding in”, involves changes at both a macroscopic level (e.g. compaction of the structure) and, primarily, at a molecular level within fibres. Bedding-in results in an essentially permanent - not recoverable - elongation with respect to rope initial length at time of manufacturing (unless the rope is returned to a loose condition for a substantial time - what does not happen in an operating mooring system), and in changes in the rheological properties ($d\varepsilon / dF$ and $d\varepsilon / dt$).

Most of the bedding-in happens during the initial loading, at time of installation, or quickly after. Rope pre-stretching during installation improves bedding-in. Further - delayed - bedding-in occurs with the variations of mean loads and the cyclic loading imposed by metocean or other (e.g. re-tensioning) actions.

This may be schematised as the combination of two terms :

- A load dependent incremental permanent (non recoverable) elongation, happening principally when the tension in rope exceeds the maximum tension achieved in a previous storm or other event (see also note 4 in A1-5.3),
- A time dependent visco-elastic term tending, under stationary conditions, toward a stabilisation of the rope elongation (depending on end conditions and previous history this term can be creep, recovery, relaxation or inverse relaxation).

Note 2 : both bedding-in and time dependence are affecting somewhat differently the response in-situ of each line (a mooring system does not reduce to ascending load in the most loaded line) and the response of a rope on a test bench. This is important to consider in the definition of test sequences and the derivation of engineering data.

A1-5.2 Model

Based on earlier work (e.g. A1-[1] , A1-[2]), a practical Engineering model has been developed (see A1-[3]), for modelling in analyses the load-elongation characteristics of polyester ropes. Tests performed since on other materials (see e.g. A1-[4]) have generally confirmed the applicability of this model for a number of materials, but less calibration data are available.

The elongation of a rope working as a line in a stationkeeping system can be written as the sum of three terms, related to the time scale of actions :

- elongation under permanent load (line pretension),
- variations of elongation induced by variations of the mean load in each line, under the effect of changing weather conditions, i.e. a time scale of several hours, or days, that is the field of application of the "quasi-static" stiffness,
- rapidly varying (cyclic) loading (or imposed cyclic displacements), i.e. a time scale ranging from seconds (e.g. wave induced motions) to minutes (e.g. slow drift motions or VIM, around the natural period of the system) : this is modelled by a "dynamic" stiffness.

This separation is also matching the typical steps of a mooring analysis, whatever frequency or time domain is used :

- set-up of the model,
- static response to mean loads,
- low and wave frequency response.

A1-5.3 Elongation under permanent load

The elongation of the rope under permanent load (system pretension) is accounted for by considering the length under pre-tension of the rope (see below).

In analysis, it is normally assumed that, at a given time, the pre-tensions have been reset to their design values.

Note 1 : analysis with lower-bound pretensions should be considered when relevant.

The length of finished ropes L_{T0} is defined, in section 5.4 as a bedded-in length at a specified tension. This may be deemed a lower-bound evaluation of the as-installed length under pre-tension. The length under pre-tension however increases with time, and re-tensioning may be needed from time to time, e.g. after an important storm. For HMPE, creep further increases rope length with time.

Note 2 : a loading sequence that is deemed representative of a typical installation condition of a stationkeeping system is specified in the testing procedure (the "linear density test", see A3-3.3), so that the bedded-in length is representative of the as-installed length of the ropes at a reference pre-tension T_0 of 20% of MBS. Other tension or bedding-in conditions may be specified if deemed more appropriate (see 5.4.1), e.g. in relation with pre-stretching of lines and in-situ load test, if any (see A1-4.1).

Note 3 : an evaluation of the length in the design conditions could be derived from the mean elongation during the test for quasi-static stiffness (see also note 4). Some margin for later elongation should be considered.

Note 4: for the purpose of analysis, the length under load can be backed-up to a theoretical "length-at-zero-tension", using the stiffness specified in the particular step of analysis. As the rope, once installed, is kept under a sustained tension, a true length at zero tension is not very relevant, and its evaluation by tests would raise experimental difficulties.

Note 5 : delayed permanent elongation would tend to relax the most loaded line and increase the offset. However, from the statistical viewpoint of the extreme tensions (or offset) being the response at a specified return period, such relaxation should be generally ignored.

For the evaluation of offset in the damaged case (i.e. one missing line - redundancy check), an additional elongation of the most loaded line(s) may be considered, if not taken into account in the static stiffness (see note 2 at end of A1-5.5).

Note 6: for the purpose of installation planning, the "length at reference tension" L_0 (see 5.3.1) can be deemed representative of the length on storage reel (new rope, spooled at a very low tension).

A1-5.4 <u>Stiffness</u>

Under the assumption of a linear elastic behaviour around a given mean condition, the load-elongation relation of a line subject to a varying load is written as :

$$\Delta F = Ku \,.\, \varepsilon$$

with :

ΔF : the variation of tension in a rope segment of length L, under a variation of length ΔL,

$\varepsilon = \Delta L / L$,

Ku : the spring constant (sometimes noted EA) of a unit length of line.

Normalisation of Ku , either by the rope MBS, or by the rope (core) linear density m , leads to the following expressions :

$$\Delta F / \text{MBS} = Kr.\, \varepsilon$$

where Kr is a reduced stiffness, which is dimensionless (% / %); or :

$$\Delta F / m = (E / \rho) \,.\, \varepsilon$$

where E / ρ is a modulus, in tenacity unit (N / tex).

Note 1 : in fibre ropes, normalisation by m have been found appropriate for comparisons over a rather large range of sizes (from yarn to ropes), but normalisation by MBS, more practical for users, is used in this Guidance Note.

Once the stiffness of ropes with a given fibre has been adequately characterised, only a limited amount of full size testing is needed, on one rope size, to verify and calibrate, if necessary, the properties of a particular rope model. Then, the measurement of "*Krebi*", the dynamic stiffness at end of bedding-in, within the breaking test performed for each rope size, will confirm these data for any other size.

Note 2 : the quasi-static and the dynamic stiffness of fibre ropes are depending on rope construction, but, primarily, on fibre material. A proper characterisation should thus start by testing at the fibre level, then on representative sub-ropes or ropes.

Note 3 : as noted in A1-5.1 , the rope properties are depending on load history. In this respect, a Phase 1 (initial loading and bedding-in) is included in the test sequences defined in Annex 3, so that the measured stiffness may be deemed representative of the conditions at the time when the design conditions happen.

A1-5.5 "Quasi-static" stiffness

The variations of line elongation under a load varying at a very slow rate can be generally modelled by a linear "quasi-static" stiffness *Krs*.

Note 1 : the "quasi-static" stiffness is addressing the effect of mean load variations, under changing weather conditions such as the build-up and decay of a storm or the occurrence of a loop current. Among other effects, these changing conditions are causing an increase or a decrease of the mean tension in the lines (in "windward" or "leeward" lines, respectively) from the initial pre-tension, at a very slow rate. This does not include the "slow-drift" motions, for which the dynamic stiffness is applicable (see A1-5.6).

Note 2 : the wording "quasi-static" stiffness is used to differentiate from other approaches or measurement sequence, particularly the stiffness over a monotonic ascending loading at standard cross-head rate, often but unduly termed "static stiffness".

The quasi-static stiffness is obtained by the quasi-static stiffness test described in Annex 3. In this test, after a proper bedding-in, the rope is cycled between two tension levels, over several cycles, each having a duration of 1 h (twice ½ h).

Note 3 : cycling is performed to get rid of the initial condition of rope on the test bench, not representative of actual condition. Result can be averaged over several cycles, to verify stabilisation and eliminate eventual measurement errors, in all cases ignoring the first half cycle.

From test results (load and elongation versus time), cycles of longer duration can be simulated as follows, to get a stiffness that is more representative of the loading duration in the events intended to be modelled (see note 1).

1) The elongation L□τ at the end of each ½ cycle of duration τ, is derived from a fitting of the creep (or recovery) plateau as :

$$L(t) = L_p + a_c \,.\, \log\left[\, 1 + (t - t_p) / t_a \,\right]$$

where :

- t_p : the time at a point along the load plateau (any point),
- a_c : the creep « per decade » over the plateau,
- t_a : a time scale constant,
- L_p : the elongation of the rope sample at time t_p,

a_c, t_a, and L_p being obtained by a three parameter fit of the elongation versus time over the loading plateau (see A1-[3]).

2) From L(t) , the elongation L□τ can be obtained as :

$$L\tau \approx L_p + a_c \,.\, \log\left[\, \tau / t_a \,\right]$$

3) The (linearised) quasi-stiffness is then taken as a secant stiffness, i.e. :

$$Krs_\tau = (T2 - T1) / (L_{2\tau} - L_{1\,\tau})$$

where :

- *T1* and *T2* are the loads during the plateau of two successive ½ cycles (in % of MBS),
- $L1_\tau$ and $L2_\tau$ are the calculated elongation at the end of these ½ cycle (in %).

The load T1 and T2 are normally taken as 10% and 30% of MBS, and the duration τ is normally taken as 12 h.

Note 4 : longer duration τ (e.g. 7 days) could be more appropriate for some metocean events (e.g. the rising time of a loop current event).

Note 5 : for large amplitude of the variation of mean load (e.g. for analysing a damaged case), a more accurate (non linear) stiffness, or different stiffness for each line, could be inferred from the same test performed at several load levels (see A1-[10]).

A1-5.6 Dynamic stiffness

A linear stiffness *Krd*, dependent on the mean load in the line (see A1-[1], A1-[2], and A1-[3]), can be used to model the response to dynamic loadings (both the "wave frequency" and the "low frequency" loadings - see [1] in section 8)

Note 1 : other parameters influencing the dynamic stiffness (load range, frequency) are deemed negligible (at least less significant), and would be also difficult to account for in the analysis process.

Note 2 : for characterisation, the dynamic stiffness is typically obtained from tests under cyclic loading around a number of mean loads, including primarily tests under a constant amplitude (harmonic) loading and some tests under representative stochastic loadings.

For rope qualification, measurement at three levels of mean load and one load range are deemed sufficient.

During cycling on a test bench at a constant mean load, the stiffness rapidly increases at the beginning of the run, then tends to stabilise. The measurements of the dynamic stiffness with a limited number of cycles (100 to 300) after a standard bedding-in condition, as specified in Annex 3 will provide adequate reference data.

Note 3 : long duration tests indicate that the stiffness would continue to increase, even over a very large number of cycles, but such observation were made in conditions (constant amplitude, no prior bedding-in) that may not be representative of the actual conditions in the field, where mean load variation and cycling happen together. The design values of stiffness should include some margin in this respect.

A1-5.7 Data for polyester ropes

The following data (based on A1-[3] and A1-[10]) may be considered for polyester ropes.

These data are applicable to "normally stiff ropes", i.e. ropes with a "*Krebi*" between 18 and 23, i.e. in the lower half of the range specified in 7.2.4 .

Quasi-static stiffness : *Krs = 13 to 15*

Dynamic stiffness : *Krd = 18.5 + **0.33** . ML*

where *ML* is the mean load, in % of MBS

Note 1 : *Krd* given above is a practical upper-bound, somewhat conservative at very low mean loads (below say 7%),

Note 2 : when needed, a lower-bound *Krd* may be taken as $Krd_m = 15 + 0.25 \,.\, ML$

Note 3 : for the evaluation of behaviour at time of pre-tension adjustment, at the end of installation, a stiffness at tensioning may be taken as: $Kr_T = 10$.

Note 4 : the increase of length between the supplied length under pretension L_{T0} and stabilised conditions may be evaluated as being in the order of 2%.

A1-6 References

A1-[1] "Appraisal of Lightweight Moorings for Deep Waters", C.R. Chaplin and C.J.M. Del Vecchio, OTC6965, 1992

A1-[2] "The Elastic Modulus Characteristics of Polyester Ropes", Bosman, R.L.M., Hooker, J., OTC10779, 1999

A1-[3] "Fibre Rope Deepwater Mooring : a Practical Model for the Analysis of Polyester Mooring Systems" , François M, Davies P, IBP 247 00, Rio Offshore 2000

A1-[4] "Synthetic Mooring Lines for Depths to 3000 Meters", Davies P et al. , OTC 14246, 2002

A1-[5] "Prediction of the Long Term Behavior of Synthetic Mooring Lines", Davies P et al. , OTC 15379, 2003

A1-[6] "Durability of Polyester Deepwater Mooring Ropes", Banfield, S.J., Casey N.F., Nataraja R., OTC 17510, 2005

A1-[7] "Fiber ropes for Stationkeeping : Engineering properties and qualification procedures" , François M. , OCEANS 2005

A1-[8] ISO 19901-7:2005 "Petroleum and natural gas industries – Specific requirements for offshore structures- Part 7 : Stationkeeping systems for floating offshore structures and mobile offshore units"

A1-[9] "Predicting the Creep Lifetime of HMPE Mooring Rope Applications", Vlasblom M.P., Bosman R.L.M. , OCEANS 2006

A1-[10] "Characterisation of Polyester Mooring Lines" François M, Davies P. , OMAE 2008

ANNEX 2

Rope Data Sheets

A2-1 Rope Approval Data Sheet

Manufacturer	…………………..
Product name / rope model	…………………..
Type of Service	…………………..
Fibre Material	………………….
Supplier	…………………..
Designation	…………………..
Rope core Construction	………………..
Torque behaviour	………………..
Cover Material	………………….
Construction	………………….
Particle ingress protection	………………….
Termination type	………………….
Termination fittings	………………….
Typical Assembly DWG	………………….

DIMENSIONS		
Outside Diameter	mm	……………
Minimum Breaking Strength (MBS)	kN	…………….

Other information		

A2-2 Rope Supply Data Sheet

PROJECT		………………………………….			
Manufacturer		………………………………….			
Product name / rope model		………………………………….			
Type of Service		………………………………….			
Minimum Breaking Strength (MBS)	kN	……			
Reference Rope Approval		………………………….			
		Manufacturer's signature	…………………….		
Fibre Material		………………….			
Supplier		…………………..			
Designation		…………………..			
Rope core Construction		………………..			
Torque behaviour		………………..			
Cover Material		………………….			
Construction		………………….			
Particle ingress protection		………………….			
Termination type		………………….			
Termination fittings		………………….			
Supplier		………………….			
Typical Assembly DWG		………………….			
Other fittings type					
size					
Supplier					
Outside Diameter	mm	……	Linear density at ref. load (LD_0)	M Tex (Kg/m)	……
Stiffness at end of bedding-in *"Krebi"*	% / %	……	**Linear density at …. % load $LD_{...}$**	M Tex	……
Item designation	Number in Supply	Length at ……load	Assembly drawing		

Notes: [1] ...
[2] ....
....

A2-3 Rope Design - Summary Data Sheet

Manufacturer	…………………..			
Product name/rope model - size	…………………..		……………	
Type of Service	………			
Rope core fibre Material				
Fibre Supplier & Designation				
Size (dTex)				
Cover fibre Material				
Fibre Supplier & Designation				
Size (dTex)				
ROPE CONSTRUCTION				
item [1]	number of components	construction [2]	size (dtex or mm or kg/m)	pitch (mm) or torsion (t/m)
CORE				
yarn				
intermediate yarn				
strand				
sub rope				
rope core				
	Linear density	(kg/m)	………..	
COVER				
Particle ingress protection	weight	(kg/m)	…………….	
yarn				
intermediate yarn				
strand				
cover	Linear density	(kg/m)	…………..	
	thickness	(mm)	………	
ROPE	Linear density	(kg/m)	…………..	
	diameter	(mm)	………	
TERMINATIONS				
Type				
Dimensions	inside radius	(mm)		
	Eye length	(mm)		
	Length of Splice (mm)			
Cover material				
Coating				
Thimble	Material			
	Supplier			
	test load			
	DWG			
Assembly DRWG				
Other information				

Notes: [1] list to be adjusted to proposed construction

[2] specify: parallel or twisted or braided

[3]...

ANNEX 3
Rope Testing

A3-1 Subject

This Annex defines the procedures for the testing of fibre ropes, following the provisions of section 7 of this Guidance Note.

Note 1 : for polyester ropes for stationkeeping, the procedures herein are in line with those of ISO18692 ([4] in section 8 of this Guidance Note).

Other testing procedures could be considered if, in the opinion of the Society, they can be deemed equivalent to those herein, or more appropriate for a particular product or usage or service conditions.

Any additional tests, when required, are to be performed following previously agreed procedure

Note 2 : for some tests, reference is made to the testing procedures defined in ISO 18692.

A3-2 Testing conditions

A3-2.1 Testing equipment

The testing machine is to have adequate capacity and stroke for the intended tests, and is to be fitted with a control system such that applied load (or crosshead movement) is continuously monitored, at any time during the testing sequence (i.e. during both loading and unloading).

Note 1 : in the testing steps described in the following sections, loads are defined as a percentage of the (specified) rope MBS.

For testing on sub-ropes of a parallel construction rope, the same percentage of a reference strength RBS is to be taken, with RBS given by :

$$RBS = MBS / n \qquad \text{(kN)}$$

where n is the number of sub-ropes in rope core.

Note 2 : during ramp loadings (both increase -including for breaking- or decrease) the rate of loading, specified in % of MBS per minute, may be obtained either as a tension rate or as the equivalent cross head velocity.

For cyclic loadings, the period of cycling is to be taken between 10 s and 30 s, unless otherwise specified.

Note 3 : the triggering signal is to be - or as close as possible to - a harmonic (sinusoidal) signal. The period of the first 20 cycles in a sequence may be larger than specified here above, but is not to exceed 60 s in principle.

Note 4 : for stiffness measurements, cyclic loading, defined in the following sections as load ranges, may be also applied as the equivalent imposed displacement, provided mean load can be kept constant over the duration of cycling.

A3-2.2 Condition of rope samples

Samples

Rope samples are to be fully representative samples of the rope model, in all respect, and of the size to be qualified, unless otherwise accepted in section 7.

Rope samples for break test and cyclic loading endurance tests are to be mounted on the specified thimbles, or on fittings with same radius and groove shape, and same type of material as the specified fittings.

Note : samples for load-elongation measurement and linear density tests may have shorter splices and eyes, with fittings that are suitable for the purpose of the tests. In such case, due attention is to be given that rope samples are selected and mounted in accordance with the test to be performed.

Sample condition

Tests are to be generally performed with samples in a wet condition, obtained by soaking the sample in fresh water, for a minimum of 4 hours.

The linear density test, however, is to be performed on a dry sample.

Note : provided the material is not sensitive to the effect of water, tests for load-elongation or torque measurements can be performed on dry samples.

For the cyclic loading endurance test, the sample is to be kept wet by water spraying, or by performing the test with the sample immersed, using fresh water.

Creep test of HMPE are to be performed in temperature controlled conditions.

Cover

For the breaking test of prototype rope and other gauge length elongation measurements, the cover is to be cut for the marking of rope core (measurement by video image processing) or for fixing the extensometer.

Note 1 : the rope cover is not meant to contribute to rope strength. However, cutting of cover may be omitted for the breaking strength test of a production sample.

Note 2 : for the cyclic loading endurance test, no extensometer is to be fixed to the sample, to avoid any damage to the rope that could bias the test result.

For the linear density test, at the contrary, the marking is to be made on the cover, and the cover is to be fastened to rope core, so as to avoid any slippage between core and cover.

A3-2.3 Recording

The ambient conditions (such as temperature and humidity, water or air temperature) during each test are to be recorded.

The crosshead elongation and rope tension are to be continuously recorded over each test. The recording of rope tension is to be performed by a properly calibrated strain gage system.

For stiffness measurements, the elongation over a gauge length of 1 m minimum set at middle of the test rope, clear from terminations, is to be performed by a system of adequate sensitivity, taking into account rope material and intended sequences.

Note 1 : the cross-head elongation provides an overview of the rope behaviour along each test, but can only give qualitative indications on stiffness. Gauge elongation measurements, by eliminating the effect of splice and eye, provide quantitative data that are representative of the response of a long line.

As possible, gauge elongation and load are to be continuously recorded. As a minimum, the gauge length and elongation are to be continuously recorded as follows, during the breaking test and stiffness measurement test defined in A3-3.2 and A3-4 :

- over phase 1 b) and c) of the test,
- over the last cycles (at least three full cycles) of the phase 1d), for the measurement of the dynamic stiffness at end of bedding-in,
- over the full three cycles of the “quasi-static” stiffness test (load and elongation versus time),
- over the last cycles (at least three full cycles) of each step of the phase 2 - D, for the measurement of the dynamic stiffness.

Note 2 : sampling rate may be adjusted according each sequence e.g. , as a minimum, one per 30 s during load ramps, one per minute during a load holding plateau, one per second during cycling for dynamic stiffness.

For the calculation of elongation in % (i.e. strain), the variation of gauge length is normalised by the gauge length at the time of the lower load, in the last cycle of each step.

Note 3 : in theory, the variation of gauge length should be normalised by either the gauge length at the start of a sequence or an average gauge length, depending on the test.

A suitable reference gauge length, taken as a constant over the whole test may be more convenient and can be also use.

Other pertinent test conditions and results are to be duly recorded.

A3-3 Testing sequences

A3-3.1 <u>General</u>

Each test generally includes the following three phases, unless otherwise specified for a particular test:

- Phase 1 : initial loading and bedding-in
- Phase 2 : cycling
- Phase 3 : loading to break

with the following steps for each phase :

<u>Phase1 - initial loading and bedding in</u>

a) mounting of the sample and loading to 2% of MBS, for marking and for setting of extensometer (when needed),
b) increase tension to 50% of MBS, in approximately 5 min and hold load for 30 min,
c) unload to 10% of MBS, at about same rate (approximately 10% / minute)

Note 1 : if a resetting of fixed end is needed, steps b) and c) are to be repeated.

d) bedding-in : cyclic loading (see A3-2.1), between 10% and 30% of MBS, for 100 cycles.

Note 2 : if the bedding in sequence need be interrupted, e.g. to reset video image following slippage of sub-ropes or strands, step d) is to be repeated for the full number of cycles.

Phase 2 - load steps and cycling

performing load steps and cycling (see A3-2.1) between the limits, and for the number of cycle that are specified in A3-3.2 to A3-5 for each test.

Phase 3 - breaking

a) unloading of the sample to 2% of MBS
b) loading to break, at a rate of about 20% of MBS / min

A3-3.2 Breaking test

A breaking test includes the following :

- phase 1 , as defined in A3-3.1 , with measurement of *Krebi*, the stiffness at end of bedding-in (phase d). *Krebi* is to be obtained in the same way as the dynamic stiffness in other conditions (see A3-4.3),
- phase 2, when load-elongation measurements are performed during the test (see A3-4), otherwise this phase is skipped,
- phase 3, to get the tension and elongation at break of the sample.

A3-3.3 Linear density test

A linear density test includes the following steps, without interruption :

- phase 1 , with following changes :
  - in step a), marking of a length LR_0 of about 2 m
  - in step b), maximum load 20% of MBS , and no holding time
  - no step c) (unloading)
  - in step d), cycling between 15% and 25% of MBS, for 100 cycles
- phase 2 , as follows :
  - at end of cycling, hold load at 20% of MBS and measurement of the length LR_{20} (m) between marks,
  - unloading to 2% of MBS, and measurement of the length LR_2 between marks,
- No phase 3, but :
  - cutting of the sample at the marks, and weighing.

    The linear density LD_{20} is then obtained as

    $$LD_{20} = MR / LR_{20} \qquad (MTex)$$

    where MR (kg) is the mass of the cut sample,

  - separating cover and weighing of the rope core.

    The linear density LDC_0 of rope core at reference load is then obtained as

    $$LDC_0 = MC / LR_0 \qquad (MTex)$$

    where MC (kg) is the mass of rope core of the cut sample

Note 1 : linear densities LD_0 and LD_2 are obtained in the same way as LD_{20} , from LR_0 and LR_2 . These data are for information.

Note 2 : when another hold load T_0 (instead of 20% of MBS) or other initial loading and bedding-in sequence is specified, the linear densities LD_{T0} is obtained in the same way as LD_{20} , from LR_{T0} .

Note 3 : in the conditions specified in notes 1 and 2 in 7.3.1 , this test may be performed on a sub-rope (or on the rope sample itself), using an extensometer, and omitting the phase 3 (cutting of rope).

The linear density LD_{T0} (or LD_{20}) is then obtained as :

$$LD_{T0} = LD_0 \cdot L_{T0} / L_0$$

where LD_0 is the linear density at reference load, obtained from the QA/QC rope sample (see section 6.2),

and the ratio L_{T0} / L_0 is obtained from extensometer data during the test,

If reference is made to a previous qualification test performed on a rope of the same model, the ratio L_{T0} / L_0 is to be taken from that test.

Note 4 : if a lower reference load than 2% of MBS is used in QA/QC samples (see note in 6.2.1), the length L_{0Q} at that tension is to be measured first.

A3-4 Stiffness tests and measurement

A3-4.1 Tests

The measurements of the quasi-static stiffness and of the dynamic stiffness on prototype rope are to include, as a minimum, the following steps when performed on a separate sample than those for break tests :

- phase 1 , as defined in A3-3.1 , with measurement of the stiffness at end of bedding-in,
- phase 2-QS : quasi-static stiffness test,
- phase 2-D : dynamic stiffness test, for a minimum of three mean loads.
- No phase 3.

Alternatively :

- the tests of phase 2-QS and 2-D may be performed, in the same order, as phase 2 within one of the breaking test of prototype rope,
- these tests may be distributed over the three breaking tests of prototype ropes and performed as phase 2 within each of these tests.

A3-4.2 Quasi-static stiffness test

For the measurement of the quasi-static stiffness, phase 2-QS includes three cycles, without interruption, between two levels (10% and 30% of MBS), with the following steps for each cycle :

a) load slowly the rope from 10% to 30%, at a rate between 3% and 10% of MBS / min,
b) hold load at 30% until 30 min after the start of a),
c) unload load slowly the rope from 30% to 10%, at a rate as in a),
d) hold load at 10% until 30 min after the start of c),

Continuous records of load and elongation versus time are to be taken, from which the static stiffness is to be obtained, following the procedure in A1-5.5.

A3-4.3 Dynamic stiffness

For the measurements of dynamic stiffness, phase 2-D includes, as a minimum, cycling (see A3-2.1) with a load range of 10% (i.e. ± 5%) around each of the following mean loads, in ascending order, for a minimum of 100 cycles :

- 25% of MBS,
- 35% of MBS,
- 45% of MBS,

When the tests are performed separately for each mean load, as phase 2 of the breaking test of each rope, the number of cycles is to be increased to 200 for the 35% mean load, and 300 for the 45% mean load

Continuous records of load versus elongation are to be taken, at least over the last cycles (minimum three full cycles) of each step, from which the dynamic stiffness for the conditions of that step (mean-load, load range, period) can be obtained by linear regression.

Note : subject to suitable sampling intervals and accuracy of elongation measurements, the dynamic stiffness may be also obtained from maximum and minimum loads and elongations over the last cycle.

A3-5 Endurance tests

A3-5.1 <u>Tension-Tension cyclic loading endurance test</u>

A cyclic loading test endurance for Tension-Tension endurance includes the following:

- phase 1 , steps a) to c), terminating at a load of about 30% of MBS , and no step d),
- phase 2 : cycling for the specified mean load and load range, until sample breaks, or the specified number of cycle is achieved, whichever happens first,
- phase 3, to get the residual breaking strength and elongation at break of the sample.

A3-6 Other tests

A3-6.1 <u>Creep</u>

The following test may be performed, on one sub-rope sample, to calibrate creep rate of an HMPE rope with fibre data.

- A load level (typically in the range of 33 to 50% of MBS) is to be selected,
- The sample is to be held at the specified load, over a duration of 1 week minimum; the temperature is to be controlled and kept as constant as possible over test duration,
- The creep rate is obtained by fitting of the elongation versus time (in natural scale) over the end of the test (e.g. the last one or two days).

Note 1 : see discussion in A1-[5].

Note 2 : a phase 1 (initial loading and bedding-in) can be performed to accelerate rope stabilisation

A3-6.2 <u>Response in torsion</u>

The assessment of the response in torsion of a rope, when needed, is to be performed following the method and the criteria in ISO 18692.

Note : specific testing procedures apply to "torque-neutral" and to "torque-balanced" ropes.

A3-6.3 <u>Particle ingress protection</u>

The assessment of the efficiency of the particle ingress protection system is to be performed following the method in ISO 18692. The specified criteria (see 5.1.6) are to be met.

ANNEX 4
Fibre Qualification

Type Approval of fibres and yarns for the manufacturing of fibre ropes

Rev 6
Nov. 2007

1. General

1.1 Subject

This document is applicable to fibres and yarns that are intended for the manufacturing of fibre ropes for marine applications such as :

- ship (harbour) mooring lines, tow lines, or other marine applications,
- SPM hawsers,
- Deepwater anchoring lines for the stationkeeping of offshore platforms, or other specific offshore applications.

This document defines the procedures and technical requirements for the Type Approval of fibres and yarns for such applications.
Type approval is delivered following the general procedures of Bureau Veritas Marine Division [1] [2] and the provisions of the present document.

Evaluation of fibres is performed according to the present document and based on the procedures laid down in the OCIMF guideline for Hawsers [6] . Reference is also made to the requirements of Bureau Veritas NI 432 [4] , where applicable

The services are performed within the frame of the General Conditions of Bureau Veritas Marine Division.

1.2 Definitions

The definitions below apply in the present document (see also ISO 1968 [7] and OCIMF [6]).

1.2.1 Fibres

- Fibre (base yarn) : a man-made multi-filament or mono-filament or tape product, as resulting from extrusion and subsequent treatments (the present document does not address natural fibres).
- Fabricated yarn/ composite yarn : a product made of several fibres, of one or several material or size, assembled together, generally by twisting.
- Marine grade fibre : a fibre that is provided with a marine finish to improve the yarn-on-yarn abrasion performance of the product. (see 2.3.3)

1.2.2 Applications

- SPM hawser : fibre rope used for single point mooring of ships and conforming to the OCIMF guideline for Hawsers [6] , or for other application, where conformity to same guideline is called for.
- Deepwater line : fibre rope used as line for deepwater anchoring (stationkeeping) of offshore platforms or for other specific offshore applications (e.g. sub-sea lowering lines), and conforming to the requirements of Bureau Veritas NI 432 [4] .
- Marine application : fibre rope used for general marine service, other than those quoted above, reference being made to Bureau Veritas Rules [3] .

Note : In the following sections, the specific provisions applicable to SPM Hawsers are marked "SH" ; the specific provisions applicable to DeepWater lines are marked "DW".
Unmarked provisions apply to all cases.

2. Design and manufacturing documents

2.1 General

Design and manufacturing documents are to be provided by the Producer/Manufacturer for review, as detailed in the sections below, and covering :

- general documentation on Producer/Manufacturer and on the product(s) intended for approval, including at least the following :
  - name and site address of the manufacturer, location of workshops
  - organization and quality
    (organizational chart, total staff, ISO9001 certification if any, etc ...)
  - manufacturing facilities
    (flow-chart of manufacturing process, equipment and capacities etc.)
  - catalogues of product(s)
- technical documentation including :
  - material specification,
  - general material properties,

  documentation of :
  - physical and mechanical properties,
  - marine finish efficiency and persistence, (1) (SH, DW)
  - other specific fibre properties (1) (DW)
  - other in-rope properties specific to intended application, as available (1) (DW)
- Quality plan and proposed forms for Quality Control.
- routine test programme,
- format of certificate,

(1) : As applicable : see 2.3

2.2 Material specification (fibres)

The material specification shall define :

- producer of fibre,
- fibre designation and material,
- size and construction data
- fibre physical and mechanical properties,
- designation and content of marine finish or other lubricant/additive (SH, DW).

A detailed check list of relevant data is given in Annex 1 of this document.

2.3 Technical documentation (fibres) and type testing

(see also check list in Annex 1)

2.3.1 General material properties

The general properties of material (physical and environmental properties) are to be provided.
Where applicable, reference may be made to table A1 in ISO 9554 [8] .
The material safety data sheet should be provided for information.

2.3.2 Physical and mechanical properties

The detailed specification of fibre physical and mechanical properties are to include tolerances on specified characteristics (properties marked * in the check list).
Mechanical properties are generally determined on fibre in dry condition. Where relevant (e.g. for PA), properties in both dry and wet conditions are to be specified.

These properties are to be documented by samples of production tests results.

Samples of the load-elongation characteristic during standard breaking test are also to be provided.
Further documentation of the load-elongation properties of fibre, as available, may be provided for information. (DW) (see also 2.3.4)

2.3.3 Marine finish efficiency and persistence (SH, DW)

The following provisions are applicable when a fibre (e.g. PA, PET) is specified to be a “marine grade fibre"

Efficiency (SH, DW)

Testing for qualification of the efficiency of finish is to be performed by yarn-on-yarn abrasion tests on wet yarn, following CI 1503 [10] . Reference tests on yarns without finish shall be available.
Criteria for yarn-on-yarn abrasion tests during fibre production are to be specified. Another testing method to verify the effectiveness of the application of the marine finish shall be duly documented.

Tests execution and results are to be in accordance with ISO 18692 [9] (DW)

Persistence (DW)

The persistence of the marine finish in a marine environment is to be demonstrated, e.g. by Yarn-on-Yarn abrasion tests after artificial ageing. Another assessment method shall be duly documented.

2.3.4 Other fibre properties (DW)

Other properties specific to fibre, such as the following, are to be documented as relevant.

Creep

For fibres (e.g. HMPE) where creep is a potential mode of failure at load levels in the range of those considered for service, documentation of creep properties, as a function of load and temperature, is to be provided.

Tension-compression

For fibres (e.g. AR) that are sensitive to compression failure, fibre properties in this respect are to be documented.

2.3.5 Other in-rope properties (DW)

Documentation of in-rope properties specific to intended application, such as the following, should be provided, as available.

Endurance under cyclic Tension-Tension loading

The endurance under cyclic T-T loading that can be achieved in a rope made from proposed fibre, thus the applicability of the "Polyester fibre rope T-N curve" in NI493 [4] to such rope, may be documented by testing on scaled sub-ropes with a construction typical of rope for this application (see [11]). Endurance should be documented for a number of cycles in the range of 1 000 000 and above.
Rope endurance at low minimum load (Tension-Compression) may be documented in the same way.

Tension-bending

For applications such as sub-sea lowering lines, involving the running of a rope over sheaves or winches, documentation of the Cycling Bending Over Sheaves (CBOS) endurance of a rope made with proposed fibre should be available for reference.

2.4 Certification of produced fibres (SH, DW)

Fibre are to be delivered with a work's certificate (such as type 3.1 as per EN10204:2004) including :

- product and batch identification
- results of routine tests (marked * in check list) : the mean value, and standard deviation (or range), and the number of tests are to be reported.
- result of test of finish application (SH, DW)

Note : when the product is for internal use, same information is to be given in a test report.

2.5 Fabricated yarns

The following provisions are applicable to yarns made of several fibres, of one or several material or size, assembled together, generally by twisting, with eventually the addition of a marine finish to obtain a "marine grade" fibre.
Note : further mechanical or thermal treatment will be given special consideration.

2.5.1 Material specification

The material specification shall define :

- Producer of yarn and designation,
- material(s), with designation and Producer of base fibres,
- size and construction data,
- fibre physical and mechanical properties,
- designation and content of marine finish or other lubricant/additive (SH, DW).

2.5.2 Technical documentation

Technical documentation shall include :

- general properties of material(s) (see 2.3.1)
- specifications of base fibres, with documentation of properties by test certificates issued by fibre producer(s) (see 2.4 , as applicable)
- process sheets
- Detailed specification and documentation of yarn mechanical properties, as per 2.3.2 to 2.3.4 .

2.5.3 Yarn certificate/test report

The certificate or test report for yarn is to be as per 2.4

3. Manufacturing / Surveys

As part of the type approval procedure, a general assessment of factory including the laboratory for production control and testing is to be made for the recognition in accordance with BV Mode II scheme as per NR320 [1]. A recognition certificate on appropriate form is issued upon satisfactory completion of the procedure. This recognition is subject to intermediate assessment as agreed.
A survey of production (see Annex 2) is to be performed, with spot inspections and review of the production, testing and Quality Control records, to cover :

- implementation of Quality Control procedures,
- in-coming material,
- control of manufacturing parameters (base fibre)
- yarn manufacturing (fabricated yarns)
- testing,
- identification/marking of product.

A report of inspection is issued by the Surveyor.

4. Type Approval

The documentation prepared by the Producer/Manufacturer and the above reports of inspection are to be reviewed by the Society.
Based on the above and the satisfactory completion of all activities, a « Type Approval Certificate », with a validity of 5 years (renewable), is delivered.

The type approval certificate will mention the intended usage(s) for which the fibre or yarn is type approved (see 1.2.2)

5. References :

[1] Bureau Veritas NR320 DNC - 1993 : "Approval and inspection at works of materials and equipment"
[2] Bureau Veritas NP420 DSC: "Approval and inspection at works of materials and equipment for Classification of ships and offshore installation"
[3] Bureau Veritas NR216DT R03 2005 : “Rules for material”
[4] Bureau Veritas NI 432 DTO R01E : "Certification of fibre ropes for deepwater offshore services"
[5] Bureau Veritas NI493 DTM "Classification of Mooring Systems for Permanent Offshore Units"
[6] OCIMF, « Guidelines for the purchasing and testing of single point mooring hawsers », 2000, Witherby & Co., Ltd., London
[7] ISO 1968:2004 : Fibre ropes and cordage - Vocabulary
[8] ISO 9554:2005 : Fibre ropes - General specifications
[9] ISO 18692:2007 : Fibre ropes for offshore stationkeeping - Polyester
[10] CORDAGE INSTITUTE CI 1503 : Test Method for Yarn-on-Yarn Abrasion.
[11] Banfield S.J., Casey N.F., Nataraja R.: "Durability of Polyester Deepwater Mooring Rope", OTC 17510, 2005.

Annex 1 : Check list of fibre data

General				
producer of fibres				
fibre designation				
fibre material				
nominal size (linear density)				
average tenacity				
marine finish designation				
finish content				
finish solubility in water				
Material properties				
density				
moisture regain				
melting point				
shrinkage				
abrasion resistance				
creep resistance		(1)	SH	
sun resistance				
environmental resistance				
resistance to chemical exposure				
Physical properties				
number of filaments				
linear density	*			
Mechanical properties				
testing conditions (dry/wet, twist)				
dry break strength	*			
dry elongation to break EAB	*			
wet break strength	*	(1)		
wet elongation to break (EAB)	*	(1)		
elongation at a specified load level EASL	*		SH	
(or Load at specified elongation LASE)	*		SH	
Yarn-on Yarn abrasion performance			SH	DW
Other specific properties (see 2.3.4)				DW

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* : including tolerances on specified characteristic.
(1) As applicable
SH, DW : for "SH" or "DW" application : see 1.2.2

Annex 2
Scope of work for Survey of Fibre Manufacturing Plant

Subject

For the Type Approval of a fibre, a visit to Production Plant is made, with the purpose of :

- Assessment of the works and testing laboratories (recognition for BV Mode II Survey).
- Spot inspection of fibre production process, QA/QC, and testing

A report of inspection is issued by the Surveyor.

Type Approval is delivered following the relevant procedures of the Society, after review of applicable documentation and the Survey subject of the present document.

References :

- Bureau Veritas NR320 DNC - 1993 : "Approval and inspection at works of materials and equipment"
- OCIMF guidelines for Hawsers – 2000
- Bureau Veritas NI 432 DTO R01E - 2007 "Certification of fibre ropes for deepwater offshore services" (when specified)

Documentation

Following documentation is to be available to Surveyor :

- Documentation of ISO 9000 certification,
- Fibre specification,
- Quality plan for the production of fibres.

Scope of Survey

Production

The visit is to cover the following topics, with respect to the proper operation of manufacturing and QA/QC procedures for the fibre subject of the Survey.

<u>Fibre production</u>

- Acceptance of in-coming material (granulates),
- Control of manufacturing parameters (from extrusion to winding),
- Acceptance/rejection criteria of production fibre,
- Traceability of product until packaging,
- Identification/marking of product.

<u>Marine Finish or other lubricant/additive (where applicable)</u>

- Identification of specification,
- Control of preparation,
- Control of application.

<u>Testing</u>

- Calibration of load testing machine(s),
- Reporting system.

Test spot-witnessing

- Fibre breaking test,
- Yarn-on-Yarn abrasion test (where applicable),
- Other specific test (where applicable).