Classification of Mooring Systems for Permanent and Mobile Offshore Units

December 2015

Rule Note
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MARINE & OFFSHORE DIVISION
GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine & Offshore Division (the "Society") is the classification (" Classification ") of any ship or vessel or offshore unit 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 safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

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 a collection of minimum requirements but not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

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 applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

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.**

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 or their omission 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. These limits apply regardless of fault including breach of contract, breach of warranty, tort, strict liability, breach of statute, etc.**

The Society bears no liability for indirect or consequential loss whether arising naturally or not as a consequence of the Services or their omission such as 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. Time is to be interrupted thereafter with the same periodicity.

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. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, 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, where appropriate, 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, as well as general technical information related to hull and equipment damages, may be passed on to IACS (International Association of Classification Societies) according to the association working rules;
- "the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies 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, or to another Court as deemed fit by the Society.

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. They are not varied by any purchase order or other document of the Client serving similar purpose.**

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.

RULE NOTE NR 493

NR 493

Classification of Mooring Systems for Permanent and Mobile Offshore Units

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SECTION 1 GENERAL

1 General

1.1 Application

1.1.1 The present Note provides requirements for the classification of the mooring system (station-keeping system) of:

- floating offshore units with permanent installations (disconnectable or not) as defined in [4.1]
- mobile units as defined in Sec 5
- units moored at a jetty, as detailed in Sec 6.

This Note covers, in general terms, the station keeping of any free-floating body by means of a principally passive system.

1.1.2 This Note deals with all the different types of anchoring patterns (such as spread mooring, internal or external turret, etc.), line make up, and the associated materials (such as chain, wires, fibre ropes, etc.) in catenary or taut configuration.

1.1.3 The present Note gives technical requirements, criteria and guidance on the design, construction and installation of the mooring systems, as a complement to the Rules mentioned in [4.2], for the granting of the following additional service features (referred to as 'notation' in this Note):

- **POSA**
- **POSA-HR** (higher redundancy)
- **POSA MU** (mobile unit)
- **POSA JETTY** (unit moored at a jetty).

1.2 Exclusion

1.2.1 The operational procedures for installation, anchoring line deployment, decommissioning, maintenance, etc. are not covered herein.

The integrity of risers, if any, connected to the moored unit is not addressed.

The Sec 4 and the NI 605, Geotechnical and Foundation Design, give methodology, requirements and recommendations on the anchoring point , e.g. drag anchor, driven pile, suction caisson, etc.

1.2.2 The **POSA** notations do not cover the tension leg platforms, which are not deemed free-floating bodies, nor their (tendons) mooring systems. This type of units is addressed in NR578, Rules for the Classification of Tension Leg Platforms (TLP).

1.2.3 The **POSA** notations cover the thruster assisted mooring (see [2.4.3]). However, the dynamic positioning installations are covered by the additional class notation **DYNAPOS** (refer to the Ships Rules, Pt E, Ch 10, Sec 6).

2 Classification

2.1 Scope

2.1.1 The classification activities span over all the phases of the project (considered as equivalent to the construction of a structure):

- design of the mooring system and of its components (engineering), including the related documentation, reviewed by the Society
- detailed design, manufacturing and testing of all the components of the mooring system (procurement) under survey of the Society,
- installation on unit and deployment at site of the mooring system under survey of the Society
- in-service inspection, for the maintenance of Class.

2.2 Class notations

2.2.1 Within the context of the classification of a floating offshore unit as defined in the Offshore Rules, the **POSA** notations are addressing the station-keeping capability of the unit, within the limits of applicability defined in [1.2] and [2.4].

2.2.2 In addition to the criteria required for the notation **POSA**, the notation **POSA-HR** covers strength analysis of the mooring system with two lines damaged (see Sec 3, [6.4.1]).

The notation **POSA MU** covers the station-keeping system of mobile units such as surface and column-stabilized mobile offshore units (list not exhaustive), in compliance with the requirements of the IMO MODU Code (see [4.2.3]) related to anchoring arrangements. The applicability, limits and scope of the notation **POSA MU** are defined in Sec 5.

The notation **POSA JETTY** is addressing the station-keeping capability of the floating offshore units moored at a jetty. This notation typically applies to FSRU's and FLNG's. The applicability, limits and scope of the notation **POSA JETTY** are defined in Sec 6.

2.3 Construction mark

2.3.1 In accordance with the provisions of Part A, Chapter 1 of the Offshore Rules and considering the provisions of [2.3.2] to [2.3.4], one of the construction marks ✠, ✠ or • is to be placed before each notation **POSA**, **POSA-HR**, **POSA MU** or **POSA JETTY**.

2.4 Limits of notations POSA and POSA-HR and interfaces with Class

2.4.1 The notations **POSA** and **POSA-HR** cover all the outboard elements of a mooring system, namely:

- the anchors, whatever the type (drag anchors, piles, suction piles, etc.)
- all the components of the load bearing lines, including line segments and connecting devices
- all the ancillary components such as buoys, clump-weights, and their attachment to the main lines (excluding installation aids).

2.4.2 These two notations also cover:

- fairleads and stoppers on the unit (totally, i.e. including unit-side female support parts)
- any associated load monitoring and control systems.

2.4.3 The notations **POSA** and **POSA-HR** do not cover windlass, winches and sheaves used for deployment of the system or for occasional handling of lines during unit operation, nor the associated monitoring and control systems (separate certification may be performed, on request). The NR595 gives specific requirements for Offshore Handling Systems (OHS).

Note 1: The notations **POSA MU** and **POSA JETTY** may have different scope and limits, especially regarding winches and windlass. Refer respectively to Sec 5 and Sec 6 for these notations.

However, the foundations of these items into the hull or on the turret are considered as part of the unit hull and, so, are covered by the classification of the unit.

For the granting of the notations **POSA** and **POSA-HR**, the pieces of equipment and systems related to thruster assistance, if any, are to comply with applicable sections of the Offshore Rules.

For other configurations not explicitly addressed hereabove, the limits of the notations **POSA** and **POSA-HR** are to be specified on a case-by-case basis.

2.5 Survey of installation and deployment

2.5.1 Installation on unit

Installation of the unit-side items (fairleads, stoppers, chain hawses, etc.) and on-board equipment, including the related systems, is to be performed under survey of the Society, in accordance with the applicable provisions of the Offshore Rules (these activities are usually to be carried out within the scope of the unit classification surveys).

The survey is to cover the quality of the construction work, particularly welds through non destructive tests (NDT). Load tests are normally not required but, if performed, are to be attended by a Surveyor. The NR426 gives specific recommendations for the surveys.

2.5.2 Deployment at site (installation)

The survey of the installation is to be performed on the basis of the general provisions of the Offshore Rules, particularly those given in Pt B, Ch 3, Sec 6 of the Offshore Rules.

The installation procedures prepared by the relevant Contractor are to be submitted to the Society for information.

The allowed tolerances for the installation are to be specified in the installation procedures, and are to be taken into account in the design calculations through sensitivity studies.

The installation operations are to be surveyed, including, but not limited to:

- installation of the anchors
- deployment of the mooring lines
- traceability of the components
- load tests of the anchors and lines (see Sec 3, [11.5])
- connection to the unit and tensioning
- post-installation inspection of the mooring system: survey by divers and/or remotely operated vehicles (ROV).

Reviews and surveys address the issues only under the scope of the Classification, particularly:

- conformity of all the components to the Classification requirements (as attested by the inspection certificates)
- integrity of the installed parts
- conformity to design of the as-installed system, particularly the setting of the line pretensions.

The operations at site are to be carried out in the presence of a Surveyor of the Society, following an agreed program.

The Surveyor is to review the records and other documentation of the installation operations, prior to the delivery of the certificate.

Note 1: The survey by the Society is, by no way, intended to be a substitute for the installation contractor's duty to fully document the mooring system installation.

2.6 Issuance of the class notation

2.6.1 Upon satisfactory completion of the mooring system installation, of all the prior activities and of the related surveys performed by the Society, one of the **POSA** notations defined in [2.2] is granted and entered in the Initial Hull Classification Certificates of the unit.

2.7 Maintenance of Class

2.7.1 Maintenance and renewal of the classification certificate are subject to the completion of in-service surveys, as described in Sec 2, to be performed by the Society.

3 Documents to be submitted

3.1 Design data

3.1.1 General

The Offshore Rules, Part A, Ch 1 and Part B, Ch 2, give general recommendations additional to those of this Article.

The party applying for classification is to provide the Society with the classification data and assumptions.

The design of the mooring system is to be performed on the basis of the design data, operational data and environmental data of the unit.

3.1.2 Site data

The party applying for classification is to specify:

- for permanent installations: the site at which the unit is to operate
- for mobile units: conditions in which the unit is to operate.

3.1.3 Operating conditions and loads

The operational data are to include the following information:

a) environmental conditions:
   - extreme (survival conditions)
   - fatigue (operational conditions)

Note 1: Operational conditions are to be understood as usual conditions (day-to-day conditions). This notion does not take into consideration any process or production.

b) characteristics and range of loading conditions, with the associated responses, of the unit

c) description of the mooring lines components from anchor to stopper

d) mooring system layout (paid-out length and mooring leg azimtuths, anchors locations)

e) the following loads, in all the relevant loading conditions mentioned in item b):
   - environmental loads
   - anchoring/mooring loads
   - hawser line loads
   - risers loads
   - thruster loads
   - loads induced by other pieces of equipment.

3.2 Components of mooring system

3.2.1 Line components

Design specifications and design documentation are to be submitted to the Society for review.

For units with the construction marks ✠, the manufacturing of materials and sub-components, and the construction of components are to be performed under survey of the Society, according to an approved program as described in NR320 (see [4.2.2], item e)) and NR266.

The certificates are to be delivered for each set of items, upon satisfactory completion of all the related reviews and surveys.

3.3 List of documents to be submitted

3.3.1 The submitted documents are to include the following information, in addition to the documentation specified in the Offshore Rules, Pt A, Ch 1, Sec 4:

a) Design criteria and data, as defined in [2]:
   - metocean data, soil data, and background information (see the Offshore Rules, Pt B, Ch 2, Sec 2 and NI 605)
   - characteristics and range of loading conditions of the unit
   - reports of design analysis.

b) General drawings:
   - layout description including positions of the anchor points, water depth, surrounding equipment (riser, well head, …) and layout of the units located in close proximity (see Sec 3, [10.6.1]
   - description of the mooring lines (from anchor to stopper)
   - general arrangement showing location of fairleads and stoppers
   - turret structure, if any.

c) Structural drawings, specifications and supporting documents:
   - mooring systems foundations (fairleads, stoppers, winches, bollards, etc.), as applicable.

d) Drawings and specifications of the mooring fitting:
   - connecting systems
   - ancillary elements
   - anchoring systems.

e) Model tests (when performed):
   - specification
   - final report.

f) Monitoring and control system:
   - monitoring system description
   - control system description.

4 Definition and references

4.1 Definition

4.1.1 Permanent mooring

As defined in the Offshore Rules, a permanent installation is an installation performing its service for a duration not less than 5 years on a single site.

The mooring system of a permanent installation is considered as a permanent mooring system.

4.1.2 Disconnectable permanent mooring

As defined in the Offshore Rules, a disconnectable permanent installation is a permanent installation able of disengaging from its mooring and riser systems in extreme environmental or emergency conditions.

The mooring system of a disconnectable permanent installation is considered as a disconnectable permanent mooring system.

When the installation is disconnected, the mooring system stays at location.

4.1.3 Mobile mooring

As defined in the Offshore Rules, a mobile unit is a unit which is neither a permanent installation nor a disconnectable permanent installation.

The mooring system of a mobile unit is considered as a mobile mooring system and is designed for station keeping at a specific location for less than 5 years.

Mobile mooring systems can be removed and redeployed.

4.1.4 Unit moored at a jetty

A unit moored at a jetty is a specific type of permanent or disconnectable permanent installation as defined in [4.1.1] and [4.1.2].

The mooring system of a unit moored at a jetty is considered as a permanent or disconnectable permanent mooring system.

4.2 Rules and related documents

4.2.1 Rules

a) NR216 Rules on Materials and Welding for the Classification of Marine Units

   referred to as the Rules on Materials and Welding in this Rule Note

b) NR445 Rules for the Classification of Offshore Units

   referred to as the Offshore Rules in this Rule Note

c) NR467 Rules for the Classification of Steel Ships

   referred to as the Ship Rules in this Rule Note.

4.2.2 Guidance Notes (NI) and Rule Notes (NR)

a) NI 425 Software Assessment for Shipboard Computer Based System

b) NI 432 Certification of Fibre Ropes for Deepwater Offshore Services

c) NI 604 Fatigue of Top Chain

d) NI 605 Geotechnical and Foundation Design

e) NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units

f) NR426 Construction Survey of Steel Structures of Offshore Units and Installations

g) NR494 Rules for the Classification of Offshore Loading and Offloading Buoys.

4.2.3 IMO Publications

Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 (2009 MODU Code).

4.2.4 IACS Unified Requirements

a) IACS UR W18: Materials and Welding - Anchor Chain Cables and Accessories Including Chafing Chain for Emergency Towing Arrangements

b) IACS UR W22: Materials and Welding - Offshore Mooring Chain

c) IACS UR Z17: Survey and Certification - Procedural Requirements for Service Suppliers.

4.2.5 IACS Recommendations

a) IACS Rec. 34 (2001): Standard Wave Data

b) IACS Rec. 38 (2010): Guidelines for the Survey of Offshore Mooring Chain Cable in Use.

4.2.6 Other industry documents

a) API RP 2SK: Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures, 3rd edition, 2005

b) API Spec 9A: Specification for Wire Rope, 26th edition, October 2011

c) API RP 2I: Recommended Practice for In-service Inspection of Mooring Hardware for Floating Structures, 3rd edition, April 2008

d) API RP 2A-LRFD: Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Load and Resistance Factor Design, 1993

e) API RP 2A-WSD: Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design, 2007

f) API RP 2GEO: Geotechnical and Foundation Design Considerations

g) ISO 1704:2008: Ships and marine technology - Stud-link anchor chains

h) ISO 2232:1990: Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes - Specifications

i) ISO 10425:2003: Steel wire ropes for the petroleum and natural gas industries - Minimum requirements and terms of acceptance

j) ISO 18692:2007: Fibre ropes for offshore stationkeeping - Polyester

k) ISO/TS 14909:2012: Technical specification on Fibre ropes for offshore stationkeeping - High modulus polyethylene (HMPE)

l) ISO 19901-7:2013: Petroleum and natural gas industries - Specific requirements for offshore structures - Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units

m) OCIMF-MEG3 2008: Mooring Equipment Guidelines, Oil Companies International Marine Forum

n) NORSOK U-102: Underwater operation - Remotely operated vehicle (ROV) services, 2012.

4.3 Other references

4.3.1

a) L. Leblanc, J.L. Isnard, H. Wilczynski: A Complete and Consistent Methodology for the Assessment of Mooring Systems, OTC-7709, May 1995

b) M. François & al: Statistics of extreme and fatigue loads in deep water moorings, OMAE'01-2162, June 2001

c) X. B. Chen: Approximation on the quadratic transfer function of low-frequency loads, 7th International BOSS conference, 1994

d) M. Le Boulluec & al.: Recent advances on the slow-drift damping of offshore structures, 7th International BOSS conference, 1994

e) M. Francois, P. Davies, F. Grosjean, F. Legerstee: Modeling Fiber Rope Load-elongation Properties - Polyester and Other Fibers, OTC 20846, May 2010

f) P.J. Clark, S. Malenica and B. Molin (1993): An heuristic approach to wave drift damping, Applied Ocean Research, 15, 0141-1187/93, p. 53-55

g) B. Molin (1994): Second-order hydrodynamics applied to moored structures - A state-of-the-art survey, Ship Technology Research, Vol. 41, 2, 59-84

h) B. Molin (2002): Hydrodynamique des structures offshore", Editions Technip

i) C. Morandini, F. Legerstee, J. Mombaerts: Criteria for Analysis of Offloading Operation, OTC-14311-MS, May 2002

j) M. François & al.: Multi-variate I-FORM contours for the design of offshore structures (practical methodology and application to a West Africa FPSO), ISOPE-2007-JSC-434

k) F. Legerstee, M. François, C. Morandini, S. Le-Guennec: Squall: Nightmare for Designers of Deepwater West African Mooring Systems, OMAE2006-92328, 171-176

l) G. de Hauteclocque, F. Rezende, O. Waals, X. B. Chen: Review of Approximations to Evaluate Second-Order Low-Frequency Load, OMAE2012-83407, 363-371

m) C. Monroy, G. de Hauteclocque, X. B. Chen: Systematic Accuracy Assessment of Two Frequently Used QTF Approximations in the Case of a Rectangular Barge, OMAE2014-24600.

SECTION 2 IN-SERVICE SURVEYS

1 General

1.1 Application

1.1.1 Remotely operated vehicles (ROVs)

The use of ROVs for carrying out the in-water survey is acceptable. The company providing this service is to be approved as a service supplier for carrying out in-water surveys, as per the requirements of IACS UR Z17 (see Sec 1, [4.2.4]).

ROVs are to be equipped in order to produce general visual inspection (GVI). ROV capacity is to comply with Sec 1, [4.2.6], item n), or equivalent.

For all testing and inspection performed by sampling, the number of links surveyed is to be agreed by the Society.

1.2 Permanent mooring

1.2.1 The in-service mooring system surveys of permanent units granted with the notation **POSA**, **POSA-HR** or **POSA JETTY** are carried out the unit being on site. No disruption of the unit's operation is required.

1.3 Mobile mooring

1.3.1 The in-service mooring system surveys of mobile units granted with the notation **POSA MU** may lead to an offshore inspection, as for the permanent offshore units, or dockside inspection. The document API RP 2I (see Sec 1, [4.2.6], item c)) gives recommended in-service inspection procedures and methods for chains, wire ropes, anchor jewellery and anchor handling equipment.

1.3.2 According to the definition of mobile mooring (see Sec 1, [4.1.3]), all the mooring lines are to be inspected out of the water every five years.

1.4 Units moored at a jetty

1.4.1 For units granted with the notation **POSA JETTY**, the hawsers are to be replaced at regular intervals. The exact replacement interval is to be specified by the hawser manufacturers.

1.4.2 At constant time intervals, the entire length of the hawser is to be inspected. The frequency of these inspections is to be determined on a case-by-case basis, according to the rope manufacturer recommendations.

1.4.3 Specific guidelines for inspection and removal of wire and fiber ropes can be found in the OCIMF-MEG3 Mooring Equipment Guidelines (see Sec 1, [4.2.6], item m)).

2 Annual surveys

2.1 All units

2.1.1 The records of operation of the -keeping equipment and the records of the examination carried out by the unit's crew at the time of tensioning changes, if any, are to be presented to the Surveyor at each annual survey, for review.

2.1.2 The examination of the mooring components (chain wires or fiber ropes) adjacent to winches or windlasses, stoppers and fairleads is to be performed.

Where relevant, visual inspection of the winches and quick release hooks is also to be performed.

2.1.3 In the case of significant damages revealed during these examinations, or if the Surveyor determines that problems have been experienced since the last annual survey, a more extensive survey may be required by the Surveyor.

3 Intermediate surveys

3.1 Permanent units

3.1.1 General

An intermediate survey is to be performed every two and a half years (2,5) between two renewal surveys. Due to season alternance, a tolerance of ± 9 months may be accepted.

The overall integrity of the mooring system is to be examined, e.g. by general visual inspection of:

- all the lines, in their critical areas
- selected lines, over their full length.

Examination, by visual inspection or other appropriate methods, of the integrity of the critical components with respect to corrosion, wear, overload, fatigue and other possible modes of degradation is to be performed.

The condition of the corrosion protection systems, as applicable, is to be verified.

Pretension setting (or angle value) of each line is to be confirmed.

Additional inspections/tests in accordance with the specific inspection programme are also to be performed.

3.1.2 Global anchoring lines

The records of operation of the -keeping equipment and the records of the examination carried out by the unit’s crew at the time of handlings, if any, are to be presented to the Surveyor at each intermediate survey, for review.

3.1.3 Connection with the stoppers

For all the lines, a visual inspection is to be performed, as far as practicable, for the links closest to the stopper. This requirement could be mitigated in case of difficulty of access to this part of the chain (e.g. bell hawse stopper).

3.1.4 Fairleads or stoppers above water level

For units having fairleads or stoppers above water level, the following inspections are to be performed, for all the mooring lines:

- visual examination of the whole line length above water level
- dimensional checks of at least one link in the last 5 meters of chains measured from above water level (two measurements per link is deemed sufficient)
- additional dimensional checks of a link sample in this portion
- measurement of chain angle (or chain tension) at top.

3.1.5 Underwater fairlead or stoppers

For units having fairleads or stoppers below water level, the following inspections are to be performed:

- for all the lines, visual examination of the first 10 m of chain from the fairlead or stopper
- dimensional checks of a link sample in the first 10 m of this chain portion, for a representative number of lines (at least one per bundle in case of bundle configuration).

Specific provisions applicable to fibre rope mooring lines are given in NI432 (see Sec 1, [4.2.2], item b)).

3.1.6 Bottom line segments

For all types of anchoring systems, general visual inspection by divers or ROVs of a representative chain length close to the contact with seabed is to be performed for all the lines.

3.1.7 Jewelleries

General visual inspection of all the jewelleries (sockets, shackles, ...) is to be performed for a representative number of mooring lines.

4 Class renewal surveys

4.1 Permanent units

4.1.1 General

Every five years, at class renewal survey, the overall integrity of the mooring system of permanent units is to be examined, e.g. by general visual inspection of all the lines, over their full length, by ROVs or divers.

Examination, by visual inspection or other appropriate methods, of the integrity of the critical components with respect to corrosion, wear, overload, fatigue and other possible modes of degradation is to be performed.

Marine growth cleaning is not to be performed for the whole length of the mooring line.

When the strength of the upper part of chains, the wire rope sockets and the anchoring devices is relying on corrosion protection systems, the condition of these systems is to be verified by proper means, as applicable. The condition of the anodes, where installed, is to be verified by visual inspection, as applicable. The cathodic protection is also to be verified by direct measurements of the cathodic potential along the cathodically protected parts of the mooring lines and the outcropping parts of the anchors.

Pretension setting (or angle value) of each line is to be confirmed.

Additional inspections/tests in accordance with the specific inspection programme are also to be performed.

4.1.2 Global anchoring lines

The records of operation of the -keeping equipment and the records of the examination carried out by the unit's crew at the time of tensioning changes or modifications, if any, are to be presented to the Surveyor at each class renewal survey, for review.

4.1.3 Fairleads or stopper above water level

For all the lines, an inspection, a dimensional check and a visual inspection are to be performed, as far as practicable, for the links connected to the stopper.

4.1.4 Underwater fairleads or stoppers

For units having fairleads or stoppers below water level, the following inspections are to be performed, for all the mooring lines:

- visual inspection of the chain portion adjacent to the stopper
- dimensional checks of all the links in this portion
    - 3 links just below the fairlead or stopper
    - 3 links bewteen 5 to 10 meters from the fairlead or stopper
- measurement of chain angle (or chain tension) at top.

4.1.5 Wire ropes

Visual inspection is to be performed all along the wire rope segment and any excessive corrosion, visible broken wire, bird-caging damages, damages in the sheating (if any) are to be reported. The diameter of the wire rope is to be measured all along the wire rope segment of the line.

4.1.6 Fibre ropes

Specific provisions applicable to fibre rope mooring lines are given in NI 432 (see Sec 1, [4.2.2], item b)).

4.1.7 Anchors and buried chains

For anchors and buried chains, the following inspections are to be performed:

- visual inspection of the soil around the anchors, in particular to check the absence of scouring in the vicinity of the anchors

- the buried part of the chains and the connection with the anchors being generally not inspectable, the operation logs are to be examined to have the confirmation that each leg was recently subjected to a significant loading and that the segment has not failed.

Note 1: In addition, IACS Rec. 38 (see Sec 1, [4.2.5]) is to be applied.

4.1.8 Jewellery

General visual inspection of all the jewelleries (sockets, shackles, ...) of all the lines is to be performed.

4.2 Mobile units

4.2.1 The class renewal survey of the mooring system of mobile units granted with the notation **POSA MU** is to be carried out, as far as practicable, the unit being in sheltered waters.

4.2.2 Every five years, at class renewal survey, the following inspections of the mooring system of mobile units are to be performed:

- inspection of chain cables, wire ropes and fiber ropes, consisting in:
  - close visual inspection of their whole length
  - NDT, such as Magnetic Particle Inspection (MPI) of their whole length
  - dimensional checks
- examination of joining shackles and other accessories
- general examination of fairleads, including testing of free rotation capability and NDT (MPI) as necessary, together with visual examination of all the fairlead chain pockets
- general examination of windlasses, including testing of holding ability, together with visual inspection of all the windlass chain pockets
- general examination of winches, including testing of holding ability and of proper laying down of the wire on drum
- examination of the soundness of the load path from the deck appliances to the unit's structure
- functional test of the mooring system during anchor handling operation
- anchor visual examination.

4.3 Units moored at a jetty

4.3.1 Where relevant, the provisions of [4.1] are to be applied for Units moored at a jetty.

4.3.2 Every five years, at class renewal survey, the following inspections of the mooring system of units moored at a jetty are to be performed where relevant:

- general examination of quick release hook, including testing of release ability
- general examination of winches, including testing of holding ability and of proper laying down of the wire on drum
- Visual examination of fenders
- General examination of mooring fittings

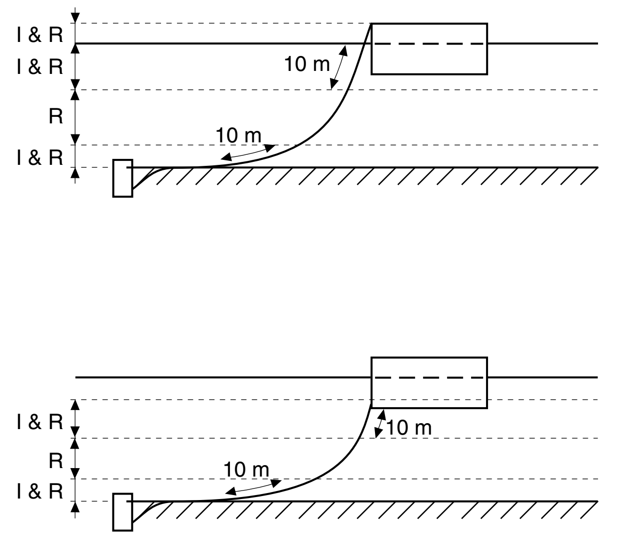
5 Survey summary

5.1 Intermediate and renewal surveys

5.1.1 Fig 1 summarises the intermediate and class renewal surveys to be performed along the anchoring lines of permanent units.

For mobile units, the intermediate and class renewal surveys are to be performed all allong the mooring lines (100% of the line is to be inspected).

Figure 1 : Survey summary for permanent units



I : Intermediate survey
R : Class renewal survey.

6 Renewal criteria for chains, steel wire and fibre ropes of permanent installations

6.1 General

6.1.1 For the requirements in this Article, measurements are to be performed after cleaning of the marine growth only at the measurement points.

Note 1: For the purpose of [6.1], it could be referred to API RP 2I (see Sec 1, [4.2.6], item c)).

6.2 Chains

6.2.1 As a rule, for studless or studlink chains, a link is to be considered as defective if one of the following criteria is not satisfied:

- the average of the two measured diameters (90 degrees apart) is to be greater than 95% of the nominal diameter
- the diameter, in any direction, is to be greater than 90% of the nominal diameter.

The final criterion to replace chains is linked to the initial computation hypotheses (mainly the hypotheses on wear and corrosion during design of the mooring system).

6.2.2 In the case of mooring systems designed taking into account a corrosion margin, the following criterion is to be fulfilled:

Dm > 95% (D – C)

where:

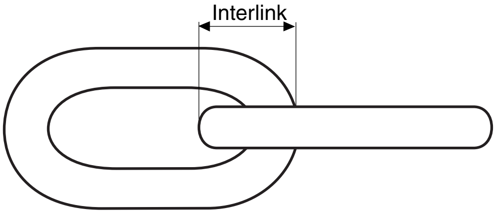
Dm : Weakest measured diameter

D : Nominal diameter

C : Total design corrosion margin (annual corrosion rate multiplied by the initial design life).

6.2.3 At least one measurement at the interlink (see Fig 2) and one measurement in another location visually judged as the worst are to be performed.

Figure 2 : Interlink measurement



The presence of large pitting corrosion patterns or remarkable corrosion patterns near link flash butt welding is to be checked with proper means.

Pitts are to be identified and measured. An evaluation of the criticity of the damage is to be submitted to the Surveyor.

6.2.4 In the case the criterion in [6.2.2] is not fulfilled, the party appliying for the classification has to demonstrate the compliance of the mooring system with the present note, or is to replace the defective segment.

6.2.5 For studlink chain, if a stud is missing, the link is considered as defective.

6.2.6 Replacement of a link considered as defective is to be based on a plan subject to the Society approval.

6.3 Wire ropes

6.3.1 Damage on the core of the wire ropes or on the sheathing is to be analysed on a case-by-case basis. The API RP 2I (see Sec 1, [4.2.6], item c)) give criteria and recommandations for wire ropes analysis.

6.4 Fiber ropes

6.4.1 For the recommendations and requirements regarding the fiber rope renewal criteria, reference is to be made to NI 432 (see Sec 1, [4.2.2], item b)).

SECTION 3 DESIGN OF MOORING SYSTEM

Symbols

T_P : Peak period of the wave spectrum, in s

T_Z : Zero-upcrossing period of the wave spectrum, in s

T_0 : Largest natural period of the system for motions in the horizontal plane, in s

n_f : Number of elementary Airy wave components.

1 General

1.1 Scope

1.1.1 The scope of the present Section is to provide Class requirements related to the design of a mooring system, with a view to the assignment of one of the **POSA** notations to a floating offshore unit.

The present Section includes:

- guidance methodology for mooring analysis
- design criteria.

Consideration will be given to alternative methodologies, on a case-by-case basis, provided they are demonstrated to provide a safety level equivalent to the one resulting from the application of the present Rule Note.

Note 1: Unless otherwise specified, the documents quoted in Sec 1, [4.2.6] are for general reference and may complement, but not replace, the requirements of the present Rule Note.

1.2 Review of design

1.2.1 For the granting of the **POSA** notations, the proposed design and supporting documentation are reviewed, including the documents in Sec 1, [3.3.1].

Verification is generally performed by independent analysis, following the methodology of this Rule Note.

Note 1: Independent analysis is, by no way, intended to be a substitute for the designer's duty to fully document his design.

1.3 General methodology

1.3.1 The assessment for the assignment of a **POSA** notation covers the following items:

- global lines
- mooring components
- fairleads / stoppers
- anchors.

The global lines are to be assessed for strength (intact, damaged and transient conditions) and for fatigue endurance: Tension-Tension (T-T) and In-Plane/Out-of-Plane Bending (OPB/IPB).

Additional considerations for the integrity of the lines are also to be given (contact of connectors with soil, up-lift at anchor, clashing, synthetic rope minimum tension, …). All these items are covered by this Rule Note.

2 Methods of evaluation

2.1 Purpose

2.1.1 The purpose of the analysis is to obtain information on the unit motions, the resulting excursions and the line tensions, under some specified metocean conditions representative of:

- either the extreme conditions at intended site, or some limit operating conditions, for the evaluation of design (extreme) values, or
- more frequently occurring conditions, for the assessment of components fatigue.

2.1.2 Available methods

The available analysis methods vary based on the approach taken to evaluate:

- overall system response and resulting excursions and unit motions
- line response and resulting tensions.

Model tests are another possible source of information (see [2.5].

Guidance and criteria in the present Section are made with reference to the quasi-static, quasi-dynamic and dynamic line response analyses, as defined from [2.4] to [2.5].

2.2 Fully coupled analysis

2.2.1 This method is based on floater dynamic response to a dynamic behavior of the mooring system. The dynamic anchor leg response affects the first and second order motions of the floaters.

Fully coupled analysis is the most accurate and general method.

Fully coupled analysis might be used when couplings are deemed important, or for calibration purpose.

2.3 Quasi-dynamic analysis

2.3.1 Methodology

The quasi-dynamic analysis is a methodology for the analysis of mooring systems developed by the Society, as mentioned in Sec 1, [4.3.1], item a).

This method is based on floater dynamic response to a static behavior of the mooring system.

This method is generally considered as the most adequate for moorings in shallow and moderate water depths, in the conditions specified in [2.3.2]and [5.3].

Background information is provided in Sec 1, [4.3.1], item b).

2.3.2 Limitations of the calculation methodology

The mooring system is assumed not to be subjected to resonance at the wave frequency. In addition, out-of-horizontal-plane low-frequency motions are supposed to be negligible. Hence, this methodology may not be appropriate to spars or certain types of semi-submersibles operating at very deep drafts.

It is supposed that horizontal low-frequency and wave frequency phenomena do not interfere. Compliance with this assumption is reasonably satisfied if the natural period of the mooring system in surge, sway and yaw is greater than five times the zero-up crossing period of the wave.

The variation of the suspended line weight with the motion of the moored unit is supposed not to significantly modify the average unit draft, trim or list angles.

2.3.3 Coupling between low and wave frequency components

When the mooring system resonance frequency is close to the wave frequency range, the interference between low and wave frequency motions may be taken into account in the quasi-dynamic analysis.

This calculation method allows to solve low and wave frequency motions together in 6 degrees of freedom (6-dof) to take into account the interference between these two phenomena.

In this method, the second order loads at wave frequencies may no longer be insignificant compared to 1st order wave forces and thus are to be accounted for in the calculation of the 6-dof motions.

2.3.4 Dynamic line response

In a dynamic line response analysis, the dynamic unit response is computed by the same method as in quasi-dynamic analysis, but the line tensions are evaluated from a dynamic analysis of the line response to the fairlead motion.

This method is recommended for deep water moorings, or very harsh metocean conditions, where the acceptance criteria for a quasi-dynamic analysis are not met, and, in all the cases, for fatigue analysis.

2.4 Quasi-static analysis

2.4.1 In a quasi-static analysis, the line tensions are evaluated from the static line response to loads/displacements applied on the unit as static actions.

For permanent mooring, this method is often used at an initial planning stage, but is not deemed acceptable for system design nor for classification assessment.

2.5 Model tests

2.5.1 As a rule, tunnel (or basin) tests are to be performed to obtain load coefficients for wind and current on the unit. Model tests in the basin are to be carried out for validation of the overall behavior of the system and for calibration of the analyses.

Consideration may be given, on a case-by-case basis, to the model tests performed on a very similar system, in equivalent metocean conditions and water depth.

However, the model tests are generally not deemed sufficient to fully document a design, due to the practical limitations in the modelling of the system (e.g. with respect to water depth), and in the number of system configurations and combinations of metocean parameters which can be addressed within a testing program.

3 Environment, actions and unit response

3.1 Environment

3.1.1 Waves

Waves are defined by the parameters of a wave energy spectrum. In certain areas, it is relevant to split the incoming energy in two (or more) parts (e.g. swell and wind sea), modelled by two (or more) spectra with different directions of approach.

For the modelling of waves by elementary Airy wave components, through the technique of random frequency and random phase, the number n_f of elementary Airy wave components, in each spectrum, is to be such that:

$$n_f \geq \text{Max}\left(100\ ;\ 30 \cdot \sqrt{T_0 / T_P}\right)$$

provided the range of circular frequency $\Delta\omega = \omega_M - \omega_m$ does not exceed 15 / T_P

with:

ω_M : Maximum circular frequency for wave spectrum, in Hz

ω_m : Minimum circular frequency for wave spectrum, in Hz.

Otherwise, n_f is to be increased accordingly.

3.1.2 Wind

A description by an appropriate wind spectrum combined with a wind speed $V_{1\text{-hour}}$ is to be used.

In the discretisation of spectrum, the minimum frequency f_m, in Hz, is not to be taken less than the frequency corresponding to a 1-hour period, i.e.:

$$f_m = 2{,}8 \cdot 10^{-4}$$

The upper frequency f_M may be taken in the range of 0,03 to 0,05 Hz. However, a higher frequency content is to be taken into account if the smallest natural period of the system (for horizontal motions) is lower than 1 minute.

The number of frequencies is to be selected so that the frequency interval Δf satisfies the following relation:

$\Delta f < Min (0,1 / T_0 ; f_m)$

A description by a constant speed $V_{10\text{-}min}$ (without wind spectrum) may be used for initial evaluations or when the natural period T_0 is greater than 120 s. Otherwise, and if no other description is available, $V_{1\text{-}min}$ is to be considered.

3.1.3 Squalls

Strong and sudden winds (squalls) occurring in inter tropical convergence zone (ITCZ) are to be modelled by representative time series of wind speed and direction.

As a rule, the calculation methodology is to follow these steps:

a) A set of squalls is defined for the site under consideration. Squalls are rescaled as per App 2, [2.4.2].

b) Each squall is considered as a governing element and, so, combined with wave(s) and current in accordance with App 2, [5] and metocean specification. The directional scanning interval and the scanning methodology are to comply with App 2, [3].

c) The design response (of tension, offset, ...) is the maximum value of the responses obtained over all the squall cases, except otherwise agreed.

Note 1: This methodology is based on the current level of knowledge about squalls.

Note 2: When no time series is available, the use of a constant wind is not sufficient to assess squalls.

Note 3: Scanning methodology with step b) optimized could be send to Class for agreement, on a case-by-case basis.

Note 4: Additional information about squalls can be found in the document mentioned in Sec 1, [4.3.1], item k).

3.1.4 Current

A description of near-surface current by a constant speed is normally sufficient (see App 2).

Sudden changes (local surface currents, loop currents) occurring in certain areas may induce significant transient effects and are to be modelled by representative time series of current intensity and direction.

3.2 Actions

3.2.1 Wave drift load

Quadratic Transfer Functions (QTF) are the second order low-frequency wave loads for floating bodies occurring at the frequency equal to the difference ($\omega_1 - \omega_2$) between two wave frequencies (ω_1 and ω_2) of bichromatic waves.

Approximations may be used in given cases. The most popular one is the Newman's approximation. Newman's variants Molin or BV are widely used in practice. Both are valid for deep water or soft mooring systems, but invalid for shallow water or stiff mooring systems. As a guidance, Newman's approximation may be used in deep water for resonance frequency below 0,05 rad/s.

The most general way to reconstruct the 2nd order loads in time domain is to use the full QTF matrix (see documents quoted in Sec 1, [4.3.1], items c), d), l) and m)). The low-frequency wave loading is computed by a double summation (Quadratic Transfer Functions Complete -QTFC- formulation). This requires the full QTF matrix determination and can induce large amounts of computing time.

Consideration is to be given to the use of this "full QTF", in the case where the Newman approximation might not be sufficient (when the resonance frequency is higher than 0,05 rad/s or in shallow water).

As a guidance, $\Delta\omega_{max} = Max (\omega_1 - \omega_2)$ may be taken equal to 0,3 rad/s for the determination of full QTF matrix.

3.2.2 Wind and current loads

a) Load coefficients for wind and current loads are to be obtained from tunnel (or basin) tests. Consideration will be given to derivation of data from tests on a very similar model.

In such tests, a model is maintained in a turbulent flow of adequate intensity and profile, in a fixed position, with a given incidence. The loads thus measured are projected on the unit axes:

$$F_x = \frac{1}{2}\rho C_x(\theta)V^2$$

$$F_y = \frac{1}{2}\rho C_y(\theta)V^2$$

$$M_\Psi = \frac{1}{2}\rho L_{pp} C_\Psi(\theta)V^2$$

where:

- F_x : Force, in N, along the unit longitudinal axis
- F_y : Force, in N, along the unit transverse horizontal axis
- M_ψ : Yaw moment, in N·m
- C_x , C_y , C_ψ : Force coefficients corresponding, respectively, to F_x , F_y and M_ψ
- V, θ : Flow (reference) velocity and incidence
- ρ : Fluid density
- L_{pp} : Length between perpendiculars of the unit.

Note 1: Concerning yaw moment, a particular attention is to be paid to the reference point where the moments are calculated (origin O of the axis system, centre of gravity G, midship section, etc., of the unit).

When applicable, the data in publications 'OCIMF Prediction of Wind and Current Loads on VLCCs' and 'OCIMF/SIGTTO Prediction of Wind Loads on Large Liquefied Gas Carriers' incorporated in the OCIMF-MEG3 2008 (see Sec 1, [4.2.6], item m)) may be used for tanker shaped units.

Note 2: These data are relevant for tankers or LNG Carriers but not applicable to other hull shapes or other arrangement of superstructure.

At initial design stage, the load coefficients may be obtained from analytical expressions (e.g. extended Duchemin Formula) or other heuristic expression, provided all three components of the force are taken into account (reduction to the in-line component is not considered adequate in this respect).

b) Wind Loads

Wind loads are evaluated by the formulae given in item a), taking into account the wind speed at a reference elevation (typically 10 m above sea level - the same as in tests), and the incidence of wind with respect to the unit.

c) Current Loads

1) As the unit is moving in water, the instantaneous loads (combining current load and drag induced by motions) are evaluated by the formulae given in item a), taking account of the equivalent current velocity U_c , in m/s, and the current relative incidence α_c , in degree, defined as follows:

$$\vec{U_c} = \vec{V_c} + \vec{V}$$

$$\alpha_c = \beta_c + \psi$$

where:

V_c : Current velocity, in m/s

V : Unit instant velocity, in m/s

β_c : Current angle from the north, in degree

ψ : Unit heading, in degree.

2) When the unit is fixed during current model tests, the force coefficient C_ψ does not include any effect due to the rotation of the unit in the fluid. In such a case, the Molin's yaw moment (only valid for barge or shipshape units) is therefore to be added to the yaw moment derived from model tests. Additional information can be found in Sec 1, [4.3.1], item h).

Note 3: With the above relative velocity formulation and the equations of motions expressed in the unit axes, the hydrodynamic yaw moment includes a steady component: the Munk moment. As this moment is already included in the moment calculated from the current force coefficients, it is to be subtracted in the load balance.

3.2.3 Riser loads

Risers and other fluid carrying lines (e.g. export lines) are generally kept under tension (possibly resulting in permanent pull on the unit), and are subjected to the action of current over the water column. The resulting forces may represent a significant part of the total load on the unit.

The reactions on the unit may be obtained from a static analysis of the lines.

Attention is to be given to the effect of varying direction and intensity of current along the water column.

The mean static load, depending upon the instantaneous low-frequency position of the unit, may be modelled by:

- either a static load, corresponding to a mean offset condition, and dummy lines to represent variations of load around this position, or
- tabulated loads, for a range of positions around the expected mean position (see Ref. 4 in the document quoted in Sec 1, [4.3.1], item b).

3.2.4 Damping

a) The sources of damping on a moored unit are multiple and of various nature. Different theories exist to explain and model these effects. However, all of them are based on either fully empirical or semi-analytical formulations the range of validity of which is necessarily limited.

Three main sources of damping can be listed:

- viscous damping on the hull
- wave drift damping
- damping due to the mooring lines (including bottom friction).

b) A direct assessment of damping terms requires that these main contributing terms are separately evaluated:

- viscous damping on the hull is modelled together with current loads since these loads are calculated on the basis of the relative fluid velocity (see [3.2.2])
- wave drift damping may be obtained from the drift forces and its derivates. Reference may be made to the formulation given in the documents mentioned in Sec 1, [4.3], items f) and g). In these documents the quadratic transfer function matrix is modified, taking into account the slow drift velocity, the current speed and the instantaneous heading
- damping due to the lines (risers and mooring lines, including bottom friction effect) may be estimated from line dynamic calculations.

c) Any damping model requires to be calibrated and its field of applicability clearly identified. Limitations of the present approach are specified in [2.3.2].

Some sources of damping may be modelled by a linear damping, i.e. forces proportional to the absolute speed of the unit, according to the following formulae:

$$F_{Bx} = -B_{xx}\, u$$

$$F_{By} = -B_{yy}\, v$$

$$M_{B\Psi/0} = -B_{\Psi\Psi}\frac{d\psi}{dt}$$

where:

F : Force induced by damping, in N

M : Moment induced by damping, in N·m

B_{xx} : Linear damping coefficient in surge, in $kg{\cdot}s^{-1}$

B_{yy} : Linear damping coefficient in sway, in $kg{\cdot}s^{-1}$

$B_{\psi\psi}$: Linear damping coefficient in yaw, in $kg{\cdot}m{\cdot}s^{-1}$

u : Absolute velocity in surge of the origin O of the unit axis system, in $m{\cdot}s^{-1}$

v : Absolute velocity in sway of the origin O of the unit axis system, in $m{\cdot}s^{-1}$

Ψ : Function versus time of the unit heading.

d) The result of the simulation is quite sensitive to the linear damping coefficients. Great care is therefore to be paid to their evaluation.

e) If no data is available from direct calculations or model tests, the formulae in Tab 1 may be used as a preliminary approach.

These formulae tentatively account for the damping due to the mooring lines and the wave drift damping. They apply only to usual mooring systems.

Great care is to be paid to the use of these formulae, since they are only based on experience and empirical calibrations.

For units moored by surface lines only, as units moored on a single point mooring or shuttle tankers moored to a FPSO, the values obtained from Tab 1 for tanker on a SPM are to be multiplied by the factor 0,37.

3.2.5 Other loads

Thrusters are sometimes used to assist a passive mooring system.

The driving system of the thruster loads may be either very simple (e.g. constant load in a constant direction relative to the unit heading) or more complex.

Note 1: See document ISO mentioned in Sec 1, [4.2.6], item k).

In any case, the loads that the thrusters actually induce on the moored unit are to be computed at each time step as a function of the applicable parameters.

Recognized methods are to be used for the load calculations, with due account for the possible interferences between the thrusters themselves or between the thrusters and the hull and for all the other phenomena that may modify, alter or degrade the thruster performances.

3.3 Unit response

3.3.1 Quasi-dynamic analysis

In a quasi-dynamic analysis, the dynamic unit response is computed through an analysis mixing time and frequency domains and taking into account the quasi-static line response.

The calculation procedure consists in the determination of the low-frequency response of the moored unit under the effect of waves, wind and current, by time domain simulations, followed by the superimposition of the wave frequency motions. It is assumed that low and wave frequency components do not significantly interfere with each other because of very different time scales (see [2.3.2]). As a consequence, they are assessed separately in the framework of this approximation and added together at the end of each time step of the simulation.

At the end of each time step, the line tensions are evaluated from the quasi-static line response to the fairlead motion.

3.3.2 Low-frequency response

The mean- and low-frequency responses (three motions) of the unit in the horizontal plane are calculated by resolving, in a time domain simulation, the equations of the dynamic equilibrium of the unit (equation of manoeuvrability, expressed typically in a system of axes linked to the unit), for predefined time series of wave elevation and other parameters.

The different actions as detailed in [3.2] (waves, wind, ...) are taken into account, all evaluated considering the instant of low-frequency position and the relative heading of the unit with respect to each action, as well as:

- the restoring mooring force (see [4.2])
- the mass matrix and the added mass of the unit (added mass calculated for ω converging toward 0)
- a linear damping as per [3.2.4].

Table 1 : Low-frequency linear damping coefficients for different types of usual mooring systems

Mooring system	B_{xx}	B_{yy}	$B_{\psi\psi}$
Barge or tanker in spread mooring **(1)**	$0,06\sqrt{K_{Oxx}(m+Ma_{xx})}$	$0,06\sqrt{K_{Oyy}(m+Ma_{yy})}$	$0,10\sqrt{K_{O\psi\psi}[I_{\psi\psi}+Ma_{\psi\psi}+(m+Ma_{yy})x_G^2]}$
Barge or tanker on a SPM **(2)** **(3)**	$0,01m\sqrt{\frac{g}{L}}$	$0,02m\sqrt{\frac{g}{B}}$	$0,083\ L^2\ B_{yy}$
Semi-submersible unit at operating draft	$0,20\sqrt{K_{Oxx}(m+Ma_{xx})}$	$0,20\sqrt{K_{Oyy}(m+Ma_{yy})}$	$0,10\sqrt{K_{O\psi\psi}[I_{\psi\psi}+Ma_{\psi\psi}+(m+Ma_{yy})x_G^2]}$

(1) For spread mooring, B_{xx} and B_{yy} correspond to 3% of the critical damping and $B_{\psi\psi}$ corresponds to 5% of the critical damping.
(2) The values of B_{xx}, B_{yy} and $B_{\psi\psi}$ are given assuming that the origin O of the unit axis system is in the midship section.
(3) For units moored by surface lines only, the values are to be multiplied by the factor 0,37.
Note 1:
K_{Oxx}, K_{Oyy}, $K_{O\psi\psi}$: Diagonal terms of the mooring stiffness matrix $[K_O]$, evaluated at the average position of the unit during the storm, in $N \cdot m^{-1}$ for K_{Oxx} and K_{Oyy}, and in $N \cdot m \cdot rad^{-1}$ for $K_{O\psi\psi}$
Ma_{xx}, Ma_{yy}, $Ma_{\psi\psi}$: Diagonal terms of the asymptotic added mass matrix of the unit, in kg for Ma_{xx} and Ma_{yy}, and in $kg \cdot m^2$ for $Ma_{\psi\psi}$
$I_{\psi\psi}$: Moment of inertia in yaw, in $kg \cdot m^2$, calculated at the centre of gravity G of the unit
m : Mass of the unit, in kg
L : Length of the unit, in m
B : Breadth of the unit, in m.

3.3.3 Wave frequency motions

a) Unit motions (Response Amplitude Operators, RAO’s)

As a pre-requisite to mooring analysis, the six motions of the unit in the frequency domain (RAO’s) are to be determined.

The RAO's may be obtained by model tests or by a recognized first order diffraction-radiation analysis program, with due account for the actual site water depth.

It is assumed that the wave frequency motions of the unit are not significantly disturbed by the variation of the mooring stiffness with the low-frequency offset. An average mooring stiffness may therefore be used for predetermining the RAO's of the unit.

In motion analysis, account may be taken of hydrodynamic damping on the floating body (e.g. roll damping), by appropriate formulation.

The effects of suspended load of the mooring lines and of risers (vertical and horizontal components) around the mean unit position is be accounted for, not as mass but as terms in the stiffness matrix, together with the stiffness of these systems.

Additional wave frequency dynamic effects of lines (primarily damping) might be significant in some cases, and may be estimated from line dynamic calculations or inferred from a fully coupled analysis.

b) Wave frequency motions

The wave frequency motions are obtained by linear summation of those due to each component of the waves, taking into account the instant low-frequency position and the relative heading of the unit with respect to waves.

At each time step of the simulation, the six wave frequency motions are superposed to the low-frequency motions in order to get the instant position of the unit and hence the position of each fairlead from which the line response (see Article [5]) can be evaluated.

3.3.4 Coupling between low-frequency and wave frequency components

For some cases, interferences between horizontal low and wave frequencies can occur. If compliance with the assumption of non-interference (see [2.3.2]) is not satisfied, a specific quasi-dynamic analysis with coupling between low and wave frequencies is to be carried out.

This method is still considered as quasi-dynamic since it is based on floater dynamic response to a static behavior of the mooring system. However a coupling between low and wave freqencies is added to the analysis described in [3.3.1]

For this type of analysis, the low-frequency and wave frequency responses of the structure are solved simultaneously in the six degrees of freedom. In this case, the radiation and first order loads are to be taken into account.

The coupled motions are calculated taking account of the:

- mass matrix and infinite frequency added mass of the unit
- radiation loads
- linear damping
- low-frequency external loads
- high-frequency external loads.

4 Mooring system

4.1 Mooring pattern and initial tensions

4.1.1 The mooring pattern is the theoretical description of the mooring system as installed on site. It includes the general layout of the mooring system and the elevation of each line in its initial vertical plane. To achieve the description, the following information is needed:

- site bathymetry
- unit position and heading
- unit draft and vertical centre of gravity
- fairlead position
- anchor position
- mooring line composition
- paid-out line lengths
- reference points for anchors (for calculations).

4.1.2 The knowledge of all the information listed in [4.1.1] automatically settles the initial tensions, since a relation of the following form exists for each line as soon as its vertical plane is known:

$f(L, D, T) = 0$

where:

L : Paid-out length of the line, in m

D : Horizontal distance between the anchor and the fairlead, in m

T : Tension at fairlead, in N.

In practice, an iterative process is needed to set the initial tensions to their prescribed values and to ensure that the three parameters are compatible together.

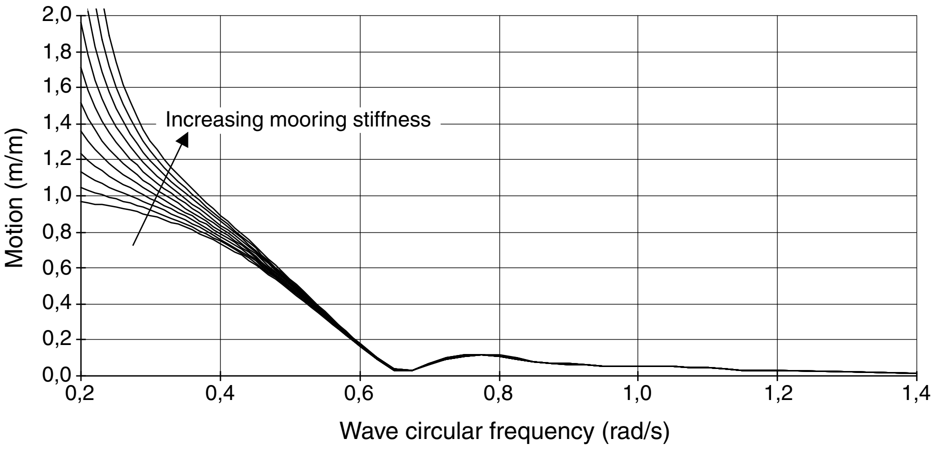
4.2 Mooring response

4.2.1 Following the assumptions in [5.1.1], the load induced by any mooring line on the moored unit depends only on the anchor-to-fairlead distance.

The azimuth of a mooring line is defined by the relative position of fairlead and anchor.

In the time domain simulation of low-frequency motion, the mooring restoring force (horizontal force and yaw moment) at each time step is obtained by summation of the horizontal components of line tensions at each fairlead, as resulting from fairlead position under the low-frequency motion.

Figure 1 : Effect of mooring stiffness on surge RAO's



4.3 Mooring stiffness

4.3.1 The mooring stiffness is the 6x6 matrix which links the elementary external loads applied to the unit with its resulting elementary displacements around a given position.

The mooring stiffness is to be considered for the calculation of the unit motions RAO's. In most cases, the stiffness induced by the mooring system for out-of-horizontal plane motions is negligible in comparison with the hydrostatic stiffness.

The sensitivity to input is illustrated in Fig 1 (example of unit surge motion).

4.3.2 The stiffness matrix [K] is obtained by the summation of the contributions of all the mooring lines under six elementary displacements of the unit.

Note 1: The stiffness matrix can be also obtained by multi-linear regression, versus the time series of unit motions, of a time series of the mooring force, computed after an analysis taking into account both low-frequency and wave frequency motions.

5 Line response

5.1 Quasi-static line response

5.1.1 Assumptions

The lower end of the mooring line is anchored to a fixed point. The upper end is connected to a fairlead of the moored unit which may be either emerging or immersed. The mooring line cannot penetrate the seabed.

The mooring line is made up of a series of homogeneous segments attached end-to-end, the bending stiffness of which is negligible. An homogeneous segment is characterized by constant mechanical properties over its whole length. A buoy or a sinker may be connected at the upper end of any segment.

At any time, the mooring line is assumed to be in the vertical plane passing by its anchoring point and its fairlead. This implies that:

- wave, current, wind and dynamic loads on any of the mooring line components are neglected
- friction effects, transverse to those parts of the line laying on the seabed, are not taken into account.

5.1.2 Line elements

The quasi-static line response is based on the equations of the elastic catenary.

For chains and wire ropes, the elastic response is linear:

$$\frac{d\ell}{\ell} = \alpha T$$

where:

$d\ell$: Elongation of an elementary length ℓ of the line at rest, when submitted to a tension T at both ends

$$\alpha = \frac{4}{\pi E \phi^2}$$

with:

ϕ : Nominal diameter of the chain or wire rope, in mm

E : Equivalent Young modulus, in N/mm^2.

For some other materials (e.g. some synthetic materials, see [5.1.5]), the relation $d\ell/\ell = f(T)$ is not linear. In this case, it may be approximated, e.g. by a polynomial function of the tension.

The elasticity properties of different materials are given from [5.1.3] to [5.1.5].

5.1.3 Wire ropes

Specific data are to be obtained from the manufacturer since the stiffness properties depend upon the wire rope design.

5.1.4 Fibre rope mooring lines

A model for the load-elongation characteristics of polyester deep water mooring lines is given in NI 432 (See Sec 1, [4.2.2], item b) and Sec 1, [4.3]).

The equivalent linear elastic properties are here expressed as a non-dimensional stiffness:

$$Kr = \frac{\Delta T / MBS}{d\ell / \ell}$$

where:

MBS : Minimum breaking strength of the line, in N.

Thus α is given by:

$$\alpha = \frac{1}{Kr \cdot MBS}$$

Note 1: A polynomial fit of the break load test load-elongation curve is not appropriate in this case.

For polyester ropes, the quasi-static stiffness Krs and the quasi-dynamic stiffness Krd are to be taken as follows:

$13 \leq Krs \leq 15$

$Krd = 18,5 + 0,33\ ML$

with:

ML : Mean load, in % of MBS.

Note 2: Krd as given above is a practical upper-bound, somewhat conservative at very low mean loads.

Note 3: When needed, a lower-bound value of Krd may be taken as equal to:

$Krd_m = 15 + 0,25\ ML$

The application range of the stiffnesses for polyester ropes is defined in NI 432, Annex 1, A1-5.7.

5.1.5 Hawsers

Hawsers and other fibre ropes are generally substantially more compliant to the quasi-static line response assumption than deep water mooring ropes. In the absence of better data, the load-elongation curve corresponding to a worked rope of the same material and construction may be used, but may still over-predict mean offset and under-predict maximum load. Data taken from a new rope (first extension) are not acceptable.

Manufacturer's data (usually presented as a curve giving the tension in percent of the breaking load BL versus the relative elongation of the material) may be converted into a relation as given in [5.1.2].

5.1.6 Buoys and sinkers

A buoy or a sinker induces, respectively, an upward or a downward load to the point of the line to which it is attached.

Buoys and sinker are to be carefully modelled so that the net action that they exert to the mooring line remains correct whatever the tension in the line and the resulting position of the element with respect to sea level or seabed.

5.2 Dynamic line analysis

5.2.1 The dynamic line response is obtained from a finite element model of the line.

a) The hydrodynamic drag coefficient CD and inertia coefficient CA may be taken as shown in Tab 2.

CD and CA are given considering, respectively, the reference diameter and the volume per unit length of a rod, with the effective diameter D_{eff} based on:

- for chains: the nominal chain diameter d
- for wire and fibre ropes: the rope outside diameter D.

Note 1: The force coefficient $CM_N = 1 + CA_N$ is also used to specify the normal inertia coefficient.

b) The length ℓ_i of each line segment i in the finite element model is not to exceed:

$$\ell_i = T_P \sqrt{\frac{F_{mean}}{m_{Ni}}}$$

where:

F_{mean} : Mean line tension, in kN

m_{Ni} : Total normal (transverse) mass per unit length, in kg/m, of the line segment i, in water

m_{Ni} may be obtained from Tab 2 based on the mass per unit length m_i of the line segment i, in air.

Note 2: A smaller length of the line segments is generally necessary:

- in the touchdown area
- for the top chain, and
- close to the fairlead.

Table 2 : Hydrodynamic coefficients

	D_{eff}	CD_N **(1) (2)**	CA_N **(1)**	CA_L **(1)**	m_{Ni} **(3)**
Chain	1,8 d	0,8	1,0	0,50	1,13 m_i
Wire rope	D	0,7	1,0	0	1,20 m_i
Fibre rope **(4)**			1,1	0,15	2,00 m_i

(1) Suffix N is for normal (transverse) direction. Suffix L is for longitudinal (tangential) direction.
(2) CD_N are specified as lower bound, to avoid unconservative over-estimate of damping effects.
(3) m_i is the mass per unit length, in air, of the line segment i.
(4) For fibre rope, CA_N and CA_L are inclusive of entrapped water.

5.2.2 The mean position is set to get the mean tension F_{mean} from the unit response analysis, and the 3D fairlead motion is applied as an imposed displacement at the top of the line.

Current and time dependent water particle kinematics are also applied, but this latter term gives a marginal contribution and may be neglected.

5.2.3 As the time domain analysis involves iterations at each time step, the iteration parameters (particularly the maximum number of iterations) are to be set so as to get an unspoiled solution.

5.3 Characterization of the line response

5.3.1 When the quasi-dynamic line response has been obtained, a test-run of dynamic response is to be performed in order to characterize the dynamic response and evaluate, or confirm, whether the quasi-dynamic response may be used for the evaluation of the extreme loads.

Details of methodology and criteria for this evaluation are given in App 1.

Such an evaluation may be omitted for chain moorings in moderate water depths (less than 150 m) when all the other conditions specified in [2] are met, and the safety factors for quasi-dynamic analysis are used accordingly.

5.4 Dynamic line response

5.4.1 For a given simulation, the maximum tension over the duration of this simulation (at least three hours) is to be obtained.

This can be achieved by performing dynamic analyses over a limited number of windows, each of them with a duration not less than the natural period T_0 of the unit low-frequency motion.

From three to five windows are to be selected, based on the maxima of dT_{qd}/dt, or of T_{qd}, if relevant, with:

T_{qd} : Time series of the quasi-dynamic tension, in N, as defined in App 1, [1.1].

Alternatively, when the correlation between T_{dyn} (time series of the dynamic tension, in N, as defined in App 1, [1.1]) and dT_{qd}/dt is clearly established, an option is to limit the analyse to the window corresponding to the expected maximum.

5.4.2 The maximum tension for the simulation is then taken as the maximum among the several windows, or the maximum in the selected one-window, as relevant (see App 1).

6 Design tensions

6.1 Intact condition

6.1.1 For any sea-state to be considered, n simulations of at least three hours each are to be performed, using different sets of elementary waves representative of the whole spectrum. If a wind gust spectrum is used, the same provision applies.

Note 1: For squalls analysis, duration of the simulation depends on the squall time series record.

Note 2: Guidances for metocean combinations are given in App 2.

The response signals are to be built up with a time step equal to, or less than, one tenth of the peak or zero-up crossing period of the wave spectrum, whichever is the most appropriate.

The design tension T_D of a line in intact condition, for a specified set of unit and metocean conditions, is defined from the mean and the standard deviation of the n maximum values of T_k, each obtained from n simulations, using different random "seeds", i.e. different sets of elementary waves and wind components, with:

T_k : Definition

The maxima are either the maximum values of the quasi-dynamic tension or those of the dynamic tension, obtained as defined in [5.4].

The design tension T_D for the condition analysed is given by:

$$T_D = T_M + a\,T_S$$

where:

T_M : Mean of the n maximum values of T_k:

$$T_M = \frac{1}{n}\sum T_k$$

T_S : (n – 1) standard deviation, given by:

$$T_S^2 = \frac{1}{n-1}\sum (T_k - T_M)^2$$

a : Factor depending on the type of analysis actually performed and the number of simulations, as given in Tab 3.

Note 3: A high number of simulations with different random seeds gives a more converged value of T_D.

Table 3 : Factor a

Method of analysis	Number of simulations			
	n = 5	n = 10	n = 20	n ≥ 30
Dynamic	0,60	0,30	0,10	0
Dynamic – 1 window	1,20	0,80	0,55	0,45
Quasi-dynamic	1,80	0,90	0,50	0,40
Note 1: For intermediate values of n, a is obtained by interpolation.				

6.2 One-line damaged condition

6.2.1 The design tension T_D of a line in one-line damaged condition is obtained by the same method as for a line in intact condition, considering a system with any one line removed or a thruster failure as specified in [6.6].

Note 1: The failure of an ancillary line component (buoy or sinker, etc.) is also a damaged condition. In most cases however, such a condition is covered by the previous analysis.

6.3 One-line failure (transient) condition

6.3.1 The design tension T_D of a line in one-line failure (transient) condition is defined as the average, for a set of possible failure instants, of the maximum transient tensions (see also [10.6]).

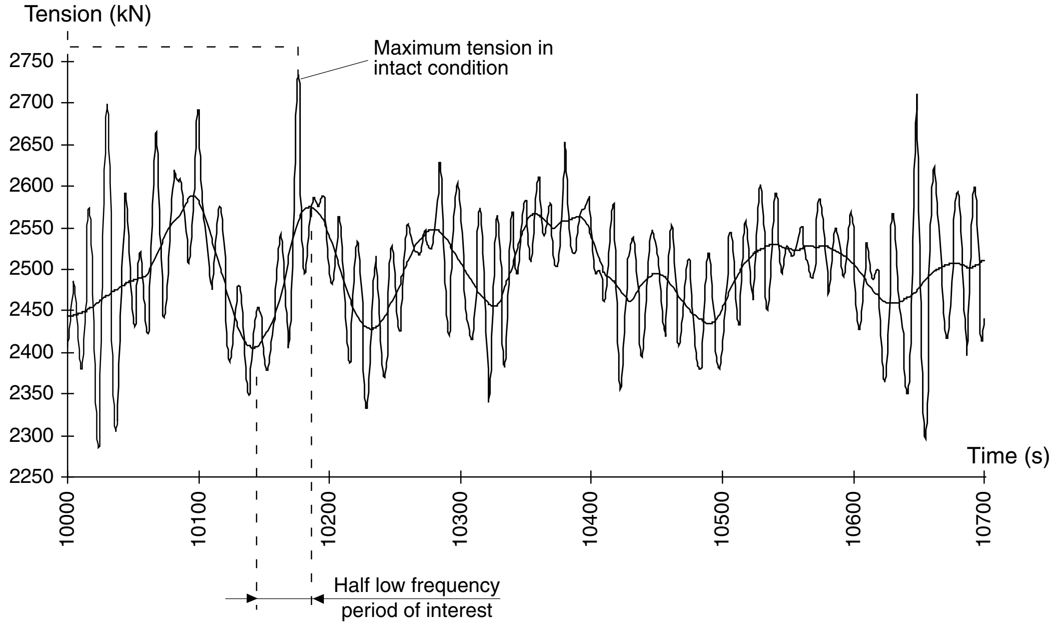
The procedure described in the following items a) and b) is to be repeated for each line:

a) For the sea-state to be considered and for each mooring line, the simulation to be selected for the study of the one-line failure case is to satisfy the following criteria:
   - the maximum fairlead tension is the closest to its design tension in intact condition as defined in [6.1.1], and
   - this maximum value occurs while the low-frequency component of the tension is increasing.

   If the second criterion is not met, the selection procedure is to be resumed with the second highest maximum tension in the same simulation or in the second closest simulation.

   The two instants around the maximum tension where the low-frequency component of the tension is respectively minimum and maximum are to be identified. See Fig 2.

Figure 2 : Range of time to be selected for the one-line failure condition



b) Using always the same sets of Airy waves and wind components as those used in the simulation identified in item a), five simulations are repeated. During these simulations, the line is to be broken at different times equally distributed between the two instants identified in item a), with the objective of catching maximum.

   The five simulations are to be run from the beginning, in order to ensure the same initial numerical transient. They may be terminated after two low-frequency cycles following the line failure.

   The maximum tension obtained at the fairlead of each remaining line after the line failure is to be identified for the five simulations. For this particular one-line-failure case, the design tension in damaged condition of each remaining line is the average of the five maximum values identified for this line.

c) For a given line, the design tension in damaged condition is the maximum tension of all the possible one-line failure cases.

6.4 Two-line damaged condition

6.4.1 The residual strength based on a system with two lines removed is to be estimated. The design tension T_D of a line in two-line damaged condition is obtained by the same method as for a line in intact condition, considering a system with two adjacent lines removed.

This criterion is requested for the notation **POSA-HR** only and does not concern the other **POSA** notations.

6.5 Loss of clump weights

6.5.1 For a mooring system design including clump weights, an additional sensitivity study on clump weight loss around the touchdown point is to be considered.

6.6 Thruster failure

6.6.1 The thruster failure is assumed not to be concomitant with a mooring line failure.

6.6.2 Two cases of failure are to be investigated:

a) the total loss of one thruster, the other thrusters having two thirds of their maximum thrust capacity available

b) the loss of half the total thrust capacity.

Note 1: These two cases lead to the same remaining thrust capacity for a unit equipped with four identical thrusters.

6.6.3 The design tensions T_D in the mooring lines are to be determined by a method similar to the one described in [6.3] for the one-line failure condition. The instants of failure, however, may be randomly selected during the simulation identified in [6.3.1], in a sufficient number to ensure that the statistics derived from the response samples are reasonably representative.

6.7 Design tension in line components

6.7.1 The tensions at different locations along the lines, as required for sizing of the line components, are to be obtained by the same methods as those defined from [6.1] to [6.3].

When a quasi-dynamic analysis is performed, the design tension T_D and other parameters (e.g. uplift angle at anchor point) may be obtained from the catenary with a fairlead position corresponding to the situation leading to the design tension at fairlead.

Note 1: There may be several positions, with different combinations of offsets and vertical positions, that are governing for different locations along the line.

6.8 Minimum design tension

6.8.1 For fibre rope moorings only, and when required, the minimum design tension T_{Dm}, in N, is to be obtained from dynamic line analysis, by the same method as for the maximum tension (see [6.1]), i.e.:

$T_{Dm} = T_m - a\,T_{ms}$

where:

T_m : Mean of the n minimum values of T_{mk}:

$$T_m = \frac{1}{n}\sum T_{mk}$$

with:

T_{mk} : Definition

T_{ms} : (n – 1) standard deviation, given by:

$$T_{ms}^2 = \frac{1}{n-1}\sum (T_{mk} - T_m)^2$$

a : Factor as defined in [6.1.1].

7 Offset

7.1 Intact conditions

7.1.1 For offset calculations, the methodology used for the tensions may be applied (see [6.1]).

The design offset O_D for the condition analysed is given by:

$O_D = O_M + b\,O_S$

where:

O_M : Mean of O_k:

$$O_M = \frac{1}{n}\sum O_k$$

with:

O_k : Definition

O_S : (n – 1) standard deviation, given by:

$$O_S^2 = \frac{1}{n-1}\sum (O_k - O_M)^2$$

b : Factor depending on the number of simulations, as given in Tab 4.

Table 4 : Factor b

	Number of simulations			
	n = 5	n = 10	n = 20	n ≥ 30
b	0,60	0,30	0,10	0
Note 1: For intermediate values of n, b is obtained by interpolation.				

The same methodology may be applied to calculate the azimuth Φ_D of the offset:

$\Phi_D = \Phi_M \pm b\,\Phi_S$

where:

Φ_M : Mean of Φ_k:

$$\Phi_M = \frac{1}{n}\sum \Phi_k$$

with:

Φ_k : Definition

Φ_S : (n – 1) standard deviation, given by:

$$\Phi_S^2 = \frac{1}{n-1}\sum (\Phi_k - \Phi_M)^2$$

b : Factor as defined in Tab 4.

8 Fatigue analysis

8.1 Tension range

8.1.1 For each environmental condition selected as specified in [10.7], the distribution of tension ranges is to be obtained from dynamic line analyses (see App 1), with a minimum duration of 30 min each and a minimum of 10 T_0. Both windward and leeward lines are to be analysed.

An appropriate cycle counting method accounting for both low and wave frequency cycles, such as rainflow, is to be used.

8.1.2 Miner summation

The fatigue damage D_j accumulated over one year by any component of the mooring line, for the environmental condition j, is obtained by means of the Miner's ratio (yearly average over 4 years: 31 557 600 seconds):

$$D_j = p_j \frac{3,15576 \cdot 10^7}{d_j} \sum_k \frac{n_{jk}}{N_k}$$

where:

p_j : Probability of occurrence for the environmental condition j (the sum of the probabilities of all the selected environmental conditions is to be equal to 1)

d_j : Duration of the simulation for the environmental condition j (normally 10 800 seconds, as specified in [10.7])

n_{jk} : Number of cycles, within interval k of the tension range, encountered by the component for the environmental condition j

N_k : Number of cycles to failure within interval k of the tension range, as given by the appropriate T-N curve.

The total fatigue damage D accumulated over one year by any component of the mooring line is then given by the following formula:

$$D = \sum_j D_j = \sum_j \sum_k p_j \frac{3,15576 \cdot 10^7}{d_j} \cdot \frac{n_{jk}}{N_k}$$

The maximum width of each tension range interval to be considered is to be less than, or equal to, one thousandth of the mooring line component breaking load, or 10 kN, whichever is the lesser.

8.2 In-Plane/Out-of-Plane Bending (OPB/IPB)

8.2.1 Fatigue damage due to OPB or IPB is to be assessed for chain mooring line with pretension greater than 10% of the minimum breaking strength (for API-ORQ equivalence, see [9.4.3]) of the top part of the mooring line.

For pretension less than 10% of the minimum breaking strength (MBS), special consideration may be required by the Society, on a case-by-case basis.

8.2.2 A complete methodology to evaluate top chain combined fatigue, including fatigue damage due to OPB and IPB, is presented in the Guidance Note NI 604 Fatigue of Top Chain.

9 Strength of line

9.1 General

9.1.1 The line arrangement is to take duly into account the position limitations with respect to surface/sea bottom, for certain line segment materials, as specified in Sec 4.

9.1.2 Line segments and connecting devices are to ensure an homogeneous strength along the line. As a general rule, no weak link is to be provided.

9.2 Breaking strength of line components

9.2.1 The reference load for the evaluation of the safety factor is the MBS of the mooring line component (see Sec 4), taking into account the reduction resulting from corrosion and wear, where applicable (see [9.3] and Sec 4).

9.3 Corrosion

9.3.1 Chains

For chains, the following allowances for corrosion and wear are to be taken into account as a minimum.

The minimum breaking strength to be considered for applying the criteria given in [11] is obtained by decreasing the nominal chain diameter by 0,4 mm/year in the splash zone area and at the bottom area.

Note 1: The splash zone area is between ± 5 metres around the free surface. Change of unit draft, if any, is to be accounted for in the definition of the splash zone area.

Note 2: The bottom area is the length of the line in contact or potentially in contact with seabed, plus 10 metres.

The decrease could be reduced to 0,3 mm/year in the remaining length.

Note 3: These corrosion rates seem relevant for cold seas but may be insufficient in tropical seas.

This change in chain diameter (the 0,4 mm/year decrease) is also to be applied for the 5-metre length of line in the vicinity of the stopper.

At a design stage, the current practice for a chain with a specified diameter D (see Fig 3) is to consider the minimum breaking strength of a chain of the same grade, having a diameter D_c reduced by the specified corrosion (or wear) allowance for the duration of the design life L, i.e.:

$$D_c = D - c \cdot L$$

However, the weight of the non-corroded link is to be used for mooring computation.

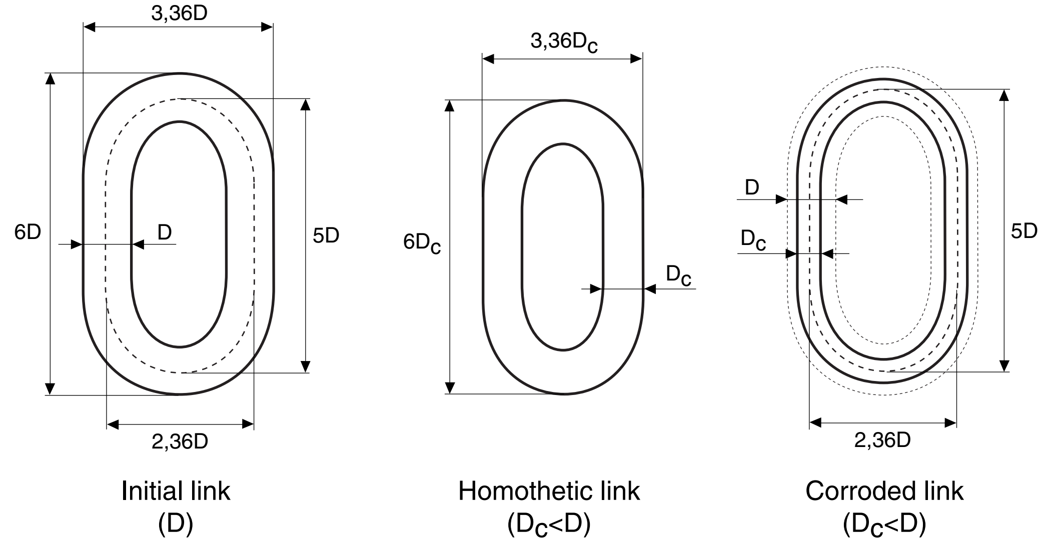
For fatigue assessment, a minimum of half the corrosion (or wear) allowance for the duration of the design life is to be taken into account.

Note 4: Higher corrosion rates may be defined, based on local regulations or on-site data.

9.3.2 Other line components

For other line components subjected to corrosion, the thickness to be considered for design purpose is obtained decreasing the nominal thickness by 0,2 mm/year per face.

Figure 3 : Modelisation of corrosion for studless links



9.3.3 In-service system

The common practice mentioned in [9.3.2] is implicitly assuming an homothetic reduction of all the dimensions in the ratio D_c/D.

For the evaluation of an in-service system, the minimum breaking strength of a link is to be evaluated by strength analysis, taking into account the reduced diameter (see Sec 2, [6.2.4]) but based on non corroded distance between neutral fibre.

9.4 Tension-tension (T-T) fatigue endurance

9.4.1 General

A fatigue analysis is to be performed for installations intended to stay moored on site for a period longer than two years. Change of unit draft, if any during the period of exposure, is to be accounted for.

9.4.2 Fatigue endurance curve

The fatigue endurance under tension-tension (T-T) cyclic loading is given here for typical line components. Reference is also to be made to the relevant requirements of Sec 4.

The fatigue endurance (T-N curve) of a line component is written as:

$N R^m = K$

where:

R	:	Ratio of tension range (double amplitude) T to a reference load equal to the line minimum breaking strength, unless otherwise specified
N	:	Allowable number of cycles under tension range T
m	:	Inverse slope parameter of T-N fatigue curve
K	:	Constant (for a given component).

The T-N curve used is to be appropriate to the mooring line component and to the type of excitation encountered. Without further information, the T-N curves specified from [9.4.3] to [9.4.5] may be used for mooring line components under pure tension cycles.

The fatigue resistance of the other components is to be evaluated from appropriate sources or by analysis (see Sec 4).

9.4.3 Chains

For chains, the reference load is to be taken as the minimum breaking strength of an element of the same diameter but in API-ORQ (5,5% less than QR3) quality, for all the grades.

For studlink chain common links, the following parameters of T-N curve may be considered:

m = 3

K = 1000

Note 1: See also [12.1.2].

This T-N curve may be assumed to be also applicable to standard end links and to D shackles (see document API RP 2SK mentioned in Sec 1, [4.2.6], item a)).

The fatigue strength of studless chains is lower:

K = 316

The stress concentration factor (SCF) in Tension-Tension for the evaluation of the global damage (T-T + OPB/IPB) is to be taken equal to 5, unless otherwise documented.

9.4.4 Wire ropes

The following parameters of T-N curve may be considered:

- for six/multi-strand wire ropes:

  m = 4,09

  K = 231

- for spiral strand wire ropes:

  m = 5,05

  K = 166

Note 1: These data are for a mean load equal to 30% of the rope minimum breaking strength. Fatigue endurance at a higher mean load is lower (see documents referenced in Sec 1, [4.2.6]). This should be given into consideration, where applicable.

Note 2: The above T-N curves do not cover termination sockets. Fatigue of these structures is to be separately evaluated.

9.4.5 Polyester fibre ropes

The fatigue endurance of polyester fibre ropes may be conservatively assumed to be at least five times the one of a spiral strand wire rope of the same minimum breaking strength, i.e.:

m = 5,05

K = 1000

Note 1: Other published curves, with a large slope parameter m, would lead to unconservative evaluations and shall not be used.

Attention is drawn to the fact that, in a fibre rope mooring, the adjacent steel components are generally to have a fatigue strength significantly lower than the one of the rope itself.

Further guidance for polyester fibre rope analysis may be found in NI 432 (see Sec 1, [4.2.2], item b)).

9.4.6 Other types of fibre ropes

Other types of materials may be used for fibre rope manufacturing, such as nylon.

Further guidance for fibre rope analysis may be found in NI 432 (see Sec 1, [4.2.2], item b)).

9.5 In-plane/out-of-plane bending endurance

9.5.1 The Guidance Note NI 604 Fatigue of Top Chain gives methodologies, requirements and recommendations to be considered regarding in-plane and out-of-plane bending loadings.

9.5.2 T-T cycling, OPB cycling and IPB cycling are to be considered as acting together, unless otherwise documented.

10 Selection of design conditions

10.1 General

10.1.1 For a given design condition, a set of time domain simulations provides a design tension T_D (see [6]) which is a short-term extreme value over the duration of the simulations (3 hours), and for the condition analysed.

The design tension for each line (or component) is then to be taken as the maximum value of T_D obtained from all the relevant design conditions, i.e. all the possible combinations of metocean parameters and configurations of the system, as defined in [10.2] to [10.6].

10.1.2 The intact, damaged, and transient conditions are separately analysed (for transient conditions, see [10.6]).

10.2 System configuration

10.2.1 A set of representative configurations of the system is to be selected for analysis so as to cover all the intended situations of operations of the unit and to ensure that the conditions the most onerous for the mooring system have been examined.

This may include:

- variations of the unit draft in relation with operations (e.g. draft of a storage unit) or weather considerations (operating/survival draft)
- connected/disconnected situations between, e.g., a floating offshore unit and an export tanker or between adjacent units (multi-unit systems)
- other relevant conditions.

Note 1: For the analysis of a unit in the offloading conditions, further guidance is given in document OTC14311 (see Sec 1, [4.3.1], item i)).

10.3 Metocean conditions

10.3.1 Metocean data

The metocean data (see Pt B, Ch 2, Sec 2 of the Offshore Rules) are described by the intensity distributions of each element as a function of the return period (marginal distribution of the independent all-direction extremes), and by associated parameters (e.g. spectral shape and peak period, for waves).

Directional data may be used under the conditions specified in the Offshore Rules and in App 2.

10.3.2 Design conditions

The metocean design conditions for a N-year return period (see [10.4] to [10.6]) are to be defined as combinations of intensity and direction of the waves, wind, current and associated parameters.

Depending on the climate, several sets are to be defined, in which one of the elements is generally governing, such as:

- wave (wind sea or swell) governed conditions
- current governed conditions
- concomitant swell and wind sea
- etc.

More detailed information is given in App 2.

10.3.3 Combinations of intensity and direction

For each set, the intensity of the elements is to be selected with values depending on the degree of correlation of the extremes, both in intensity and in direction, and on the relative directions between the elements.

For both governing and other elements, scanning on the incoming directions is to be performed, over a large enough range for each, so as to provide the evidence that the maximum response has been caught.

The criteria in App 2 may be considered for guidance, unless more accurate data are available for the site under consideration.

Note 1: In a set of conditions where one element is governing, this element is generally to be taken with an intensity corresponding to the N-year return period. Other parameters are to be taken as “associated values”, with an intensity corresponding generally to a lower return period.

10.3.4 Associated parameters

Associated parameters are usually given to obtain a best estimate (or most likely) value.

For the spectral peak (or zero-crossing) period T_P (or T_Z) of a sea-state, a range is to be considered around the specified value, as a minimum. For a significant wave height H_S , response contour ratio H_S/T_P (or H_S/T_Z) may be used when available (inverse FORM approach detailed in App 2, [2.3]).

A similar approach may be applied to other parameters, when relevant.

10.3.5 The same sets of design conditions are typically applicable to both intact and damaged conditions of the mooring system. However, the governing conditions may be different.

For transient conditions, see [10.6.2].

10.4 Extreme metocean conditions

10.4.1 For a permanent installation, the extreme metocean conditions to be considered are those corresponding to a return period N of 100 years.

10.4.2 For mooring systems of installations other than permanent installations (e.g. mobile drilling units, installation units, …) far away from any other offshore structure, N may be reduced to five times the duration of the operation, without being, nevertheless, taken less than 5 years.

10.4.3 For mooring systems of installations, other than permanent installations, which are in the vicinity of other offshore structures, N is not to be taken less than 10 years. Special considerations as regards the risk of collision may however require a larger value of N.

10.4.4 If a unit working alongside another platform can move away and reach a pre-defined stand-off position within a time reasonably compatible with the local metocean forecast, the provisions of [10.4.2] may be applied to the stand-off position. The environmental conditions beyond which the unit is to move away are to be specified in the operation manual and taken into account as an operating condition for the mooring system in working position.

10.4.5 Return periods N defined from [10.4.1] to [10.4.4] apply to manned installations and to offloading buoys. For unmanned installations, criteria are to be defined on a case-by-case basis.

10.5 Operating conditions

10.5.1 The limiting conditions for particular operations (e.g. offloading, maintenance, working alongside, etc.) are to be specified either as an envelope of possible combinations of elements, or as a discrete set of conditions. In such a case, the acceptable envelope is to be determined at a later stage, for incorporation in the unit operation criteria.

10.5.2 When the limiting conditions are infrequent, such as 1-year return period conditions or above, the combinations of metocean parameters are to be considered as per [10.3], taking into account the specified return period N.

10.5.3 For more frequently occurring conditions, the limiting conditions are to be defined by a set of ascertainable limiting values on some metocean parameters. The design operating conditions are then to be established by application of theses limiting values to the sets of N-year (extreme) return period conditions.

10.5.4 For short-duration infrequent operations not requiring particular conditions, the operating metocean conditions, when they need to be considered, may be taken as the metocean conditions with 1-year return period conditions.

10.6 Transient conditions

10.6.1 A transient analysis (see [6.3.1]) is to be performed in the following cases:

a) when the unit is moored in close proximity to a fixed installation or another floating structure

   In this case, the analysis may, however, be limited to the critical lines (line TYPE I, see [11.1.1]).

b) for operating conditions with specified metocean limiting conditions as defined in [10.5.1] (e.g. tandem offloading)

   The analysis may, however, be omitted in case of a system with large redundancy, as demonstrated to the satisfaction of the Society (e.g. when an analysis in damaged condition for the same operating situation was far from critical).

In the other cases, the transient analysis may generally be omitted.

Note 1: Mooring systems are considered to be in close proximity to an installation if any part of the other installation lies within a contour described by the set of offsets coinciding with each line reaching 100% MBS in the intact or redundancy check condition, whichever is larger (see Sec 1, [4.2.6], item h)).

10.6.2 When required, the transient analysis is to be performed for the most critical design conditions of the intact system.

10.7 Fatigue analysis

10.7.1 For fatigue analysis, a series of metocean conditions representative of the long-term conditions at the intended site or of the intended operations are to be considered. This series may be time series obtained by adequate hind-casting or may be derived from available statistical data (typically directional scatter diagrams of sea-states or wave systems in multimodal sea-states), combined with wind and current in an appropriate way taking into account joint occurrences.

For each condition selected, the fatigue damage D, in each segment or component of the lines, is calculated by the Miner sum, taking into account the fatigue capacity (see [9.4]) and the duration of the sea-state.

Fatigue analysis is to be conducted all along the lines, at each critical point where specific issues could occur (contact point with the seabed, connexion points, etc.).

Dynamic line analyses are to be performed for at least a group of sea states as defined in [10.8.3].

The fatigue life FL, corresponding to the duration of exposure for which the cumulative damage (Miner sum) would be equal to 1, is obtained as follows:

$$FL = \frac{L_{ref}}{D}$$

where:

D : Fatigue damage calculated by summation over all the conditions considered, for a reference duration of exposure L_{ref}.

10.8 Sensitivity studies

10.8.1 Sensitivity studies are to be performed on all the parameters able to affect the results of the mooring analysis, such as:

- metocean parameters (T_P, spectra parameters, ...)
- line pre-tension
- theoretical anchor point
- dynamic line response
- loss of clump weights (see [6.5]),

in order to assess the influence of these parameters.

Safety factors for intact case are to be applied for these sensitivity studies.

10.8.2 For extreme metocean conditions, it is recommended that sensitivity studies are carried out at least for the sea states giving a tension higher than 95% of the maximum tension.

10.8.3 To assess the influence of the dynamic line response for fatigue analysis, sensitivity studies may be performed for the line where the maximum damage occurs. The following sea states are at least to be considered:

- the top 5% of the sea states sorted by damaging effect
- the sea states contributing to 50% of the total damage.

10.8.4 For fatigue analysis, a sensitivity study on the influence of the seeds is to be performed in order to assess the influence of the short-term variability.

It is recommended to considered the sea states defined in [10.8.3] for this sensitivity study.

11 Criteria

11.1 Mooring lines

11.1.1 Type of lines

Two types of mooring lines are defined:

a) lines of TYPE I are those lines the failure of which leads to a transient response that moves the moored unit towards an installation in close proximity (see Note 1 of [10.6.1]), if any

b) lines of TYPE II are the lines which are not of TYPE I.

11.1.2 Safety factor

The safety factor SF of mooring line components is defined as follows:

$$SF = \frac{BL}{T_{max}}$$

where:

BL : Catalogue breaking load of the mooring line component, in kN. For chains, BL is to be taken as the corroded breaking load of the mooring line component

T_{max} : Maximum tension, in kN, occurring over the mooring line component length when the design tension, as determined in Article [6], is applied to the fairlead.

11.1.3 Minimum values of safety factors

The safety factors SF calculated in [11.1.2] are not to be less than the values given in Tab 5.

Note 1: Tab 5 is not applicable to hawsers. The minimum values for hawsers may be obtained from NR494 (see Sec 1, [4.2.2], item g)) (NR494 is not applicable for the notation **POSA JETTY**).

11.1.4 Minimum tension in mooring lines

For deepwater fibre rope mooring lines, the following minimum tensions are to be considered (see also NI 432, as quoted in Sec 1, [4.2.2], item b)):

- Polyester and HMPE: a positive tension is to be maintained in the fibre rope under operating and design conditions. As a guideline, a minimum quasi-dynamic tension of 2% of rope minimum breaking strength (quasi-dynamic tension in intact condition) may be considered
- Aramid and other fibres: 10% of rope minimum breaking strength, in both intact and damaged conditions, unless otherwise documented.

11.2 Anchors

11.2.1 Safety factor

The safety factor SF of anchors is defined as follows:

$$SF = \frac{MHP}{Ta_{seabed}}$$

where:

- for drag anchors:

  MHP : Minimum expected holding power applicable to the mooring site, in kN

  Ta_{seabed} : Tangent-to-the-seabed component of the tension in the line at the anchoring point when the design tension is applied to the fairlead, in kN.

  The perpendicular-to-the-seabed component of the load applied to a drag anchor, when the line is submitted to its maximum tension (included damaged condition tensions) at fairlead, is to remain less than 20% of its wet weight projected onto the same direction.

- for driven pile anchors:

  MHP : Minimum expected load, in kN, that the pile can withstand, in compliance with the requirements of applicable codes and standards for structural and soil mechanics

  Ta_{seabed} : Tension in the line at the anchoring point when the design tension is applied to the fairlead, in kN.

11.2.2 Minimum values of safety factors for drag anchors

For drag anchors, the safety factors SF calculated in [11.2.1] are not to be lower than the values specified in Tab 6.

Tab 6 applies only in the case of no uplift at the anchor.

11.2.3 Minimum values of safety factors for pile anchors

For long (soft) pile anchors, the minimum values of safety factors SF specified in Tab 6 apply also to axial pull-out capacity, when the angle α of the maximum tension at pile (including inverse catenary effect, if any) does not exceed 15° with the horizontal. Otherwise, the required pull-out capacity is to be increased by a factor K_α equal to:

$K_\alpha = (1 + 0,33 \sin^2\alpha)$

Tab 6 applies also to lateral strength assessment (see Sec 4, [6.2.9]).

11.2.4 Suction anchors and vertical load anchors

A partial factor verification format is given in NI 605.

Table 5 : Minimum values of safety factors for mooring line components

Condition of system	Method of analysis **(1)**	
	Quasi-dynamic	Dynamic
Intact **(2)**	1,75	1,67
Damaged **(2)**	1,25	1,25
Transient **(3)** **(4)**	1,25	1,20
Damaged (two adjacent lines removed) **(2)** **(5)**	1,00	1,00

Note 1: Base factors are for line type II (see [11.1.1]) i.e. they do not apply to structures in close proximity. See **(2)** and **(4)**.
Note 2: For fibre ropes, the minimum values of safety factors are to be increased in the rope itself (i.e. not including other parts of the line) by 10% for polyester ropes and 20% for the other materials.
(1) The minimum values given for dynamic analysis may also be used with the results of a quasi-dynamic analysis, after agreement of the Society, when the characterization of the line response has provided a firm evidence of a dynamic amplification factor DAF lower than 1,0 in all the relevant conditions (see App 1).
(2) Minimum values to be increased by 25% for line type I.
(3) Applying the methodology in [6.3], and when required.
(4) Minimum values to be increased by 40% for the most loaded line, following the breakage of a line type I.
(5) Only for notation **POSA-HR**.

Table 6 : Minimum values of safety factors for drag anchors

Condition of system	Method of analysis **(1)**	
	Quasi-dynamic	Dynamic
Intact **(2)**	1,60	1,50
Damaged **(2)**	1,15	1,05
Transient **(3)** **(4)**	1,15	1,05

Note 1: Base factors are for line type II (see [11.1.1]) i.e. they do not apply to structures in close proximity. See **(2)** and **(4)**.
(1) The minimum values given for dynamic analysis may also be used with the results of a quasi-dynamic analysis, after agreement of the Society, when the characterization of the line response has provided a firm evidence of a dynamic amplification factor DAF lower than 1,0 in all the relevant conditions (see App 1).
(2) Minimum values to be increased by 25% for line type I.
(3) Applying the methodology in [6.3], and when required.
(4) Minimum values to be increased by 40% for the most loaded line, following the breakage of a line type I.

11.3 Minimum clearance

11.3.1 In any condition, the distance between any part of the moored unit and any external object normally not in contact with the unit is to remain, at a minimum, equal to ten (10) metres.

In any condition, the distance between any point of the mooring line and any external object, either suspended or laying on the seabed, the contact with which could be damageable for either the mooring line or the aforesaid object, is to remain, at a minimum, equal to ten (10) metres.

More stringent requirements may be specified by operators.

11.4 Fatigue life

11.4.1 The safety factor in fatigue is specified as a factor on fatigue life.

This safety factor is defined as the ratio between the calculated fatigue life and the design service life of the installation (as defined in the Offshore Rules, Pt B, Ch 3, Sec 3, [1.2.2]).

The design service life, for a moored unit, is the duration, in years, that this unit is intended to stay on site.

The fatigue life of the mooring lines is to be determined and compared to the design service life of the installation if this latter is greater than 2 years.

11.4.2 The minimum value of fatigue safety factors for each line component is:

- 3 for all line segments and other components of the line
- 10 for anchors and buried parts.

For mooring systems subjected to OPB/IPB fatigue (see [8.2]), the following additional requirements are to be considered:

- when the effect of in-plane/out-of-plane bending or of other local actions is taken into account, the safety factors specified in NI 604 (see Sec 1, [4.2.2], item c)) are to be considered, in addition to T-T fatigue loading
- a safety factor equal to 10 is to be applied otherwise.

11.5 Load testing of anchors and mooring lines

11.5.1 The load (at fairlead) for the load testing of anchors is to be taken not less than the following values, depending on the anchor type:

a) Drag anchors:

80% of the design tension T_D at fairlead, in intact conditions, during at least 15 min

b) Vertical load anchors (VLA):

as required to achieve target penetration and related holding capacity

c) Pile anchors and suction anchors:

as for the mooring lines, as specified in [11.5.2].

11.5.2 The load for the load testing of mooring lines is to be taken not less than the following values, depending on the line type:

a) Steel lines (chains or wire ropes):

the specified pretension, slightly increased (10% minimum is recommended) in order to ensure correct setting of the assembly

b) Fibre ropes (for rope pre-setting):

at least 30% of the rope minimum breaking strength (or an appropriate cycling) without exceeding 50% of the rope minimum breaking strength. More details are given in Annex 1, [A1-4] of NI 432.

12 Installation and service conditions

12.1 Chains and standard fittings

12.1.1 Deployment of the lines is to be performed in such a way as to avoid jamming on the bottom and accumulation of twists that may result in damage to the chain itself or to other components when the line is tensioned.

12.1.2 Attention is drawn to the fact that fatigue performance of a stud link chain might be significantly decreased in the case of lost studs. The T-N curve given in [9.4.3] applies to links with tight studs.

12.1.3 Attention is also to be given to the risks of bending fatigue for chains over stoppers, bending shoes of fairleads (see also Sec 4, [7.2.6]). Where possible, regular and frequent adjustments of the mooring lines are to be carried out in order to mitigate accumulation of fatigue damage in the lines at these locations.

12.2 Steel wire ropes

12.2.1 Unless periodical renewal is planned, the use of wire ropes is also to be avoided in the splash zone of long-term moorings.

Attention is also to be given to the risks of bending fatigue of wire ropes over fairleads. Where possible, regular and frequent adjustments of mooring lines are to be carried out in order to mitigate the accumulation of fatigue damage in the lines at these locations.

12.2.2 Deployment of the lines is to be performed in such a way as to avoid:

- damage caused by over-bending or chaffing over obstacles
- over-bending in free span, by permanent suitable minimum tension
- excessive bending at terminations, if necessary by provision of bending restrictors
- accumulation of twists, particularly in case of a non-torque compliant structure
- any damage to sheathing (when provided).

12.3 Fiber ropes

12.3.1 Deployment of the lines is to be performed in such a way as to avoid damage caused by chaffing, cutting or over-bending over obstacles, as well as contamination by solid or liquid projections.

Seizing of lines, or of ancillary installation devices on lines, is to be performed by soft seizing ropes only.

Lines are to be deployed under a low tension, with however a permanent suitable minimum tension to avoid the risks of local over-bending.

The accumulation of twists is to be avoided.

12.3.2 The service conditions of the fibre ropes are to be as specified in Guidance Note NI 432.

12.4 Anchoring devices

12.4.1 Installation on site of the anchoring devices is to be performed under survey of the Society (see Sec 1, [2.5]).

The installation procedures for anchor setting and pre-loading are to be submitted in advance, for review by the Society.

Load testing of anchors and mooring lines is to be performed as required in [11.5].

The installation records, with the related analyses, as needed, are to provide evidence that target penetration and holding capacity have been achieved.

12.5 Ancillary components

12.5.1 Failure in the functioning of any of these components is to be considered in the design of the mooring system as a damaged case.

12.5.2 Arrangements are to be made to ensure the integrity of the mooring system at any time. These arrangements are to be submitted to the Society for review.

12.6 Non standard fittings

12.6.1 Functional requirements

During navigation, the designer is to ensure that all the detachable parts are adequately locked in position by passive means.

Connectors are to maintain a positive stability under a low tension and are to be fitted with a locking system.

Note 1: Where applicable, a minimum tension is to be specified, and the device is not to be allowed for use in the touchdown area.

SECTION 4 COMPONENTS OF MOORING LINES

1 General

1.1 Purpose

1.1.1 The purpose of this Section is to provide Class requirements related to the components of a mooring system, with a view to the assignment of one of the **POSA** notations to a floating offshore unit.

1.2 Scope

1.2.1 The components under consideration in this Section include:

- main line components, such as:
  - chain cables and standard fittings
  - steel wire ropes and terminations
  - fibre ropes
- non-standard fittings and connectors
- anchors
- items fitted on units at ends, such as fairleads and stoppers
- ancillary components (buoys, sinkers)
- control system.

1.2.2 The compliance with the requirements of this Section is mandatory for the assignment of the **POSA** notations.

1.2.3 Deck appliances (winches and windlasses) are excluded from the scope of notations **POSA** and **POSA-HR**. For units granted with one of these notations, winches or windlasses used as stoppers are to be given special consideration.

1.2.4 For mobile units granted with the notation **POSA MU**, components such as winches and windlasses may be under consideration. The complete scope of this notation is detailed in Sec 5.

1.2.5 For units granted with the notation **POSA JETTY**, components such as release hooks may be under consideration. The complete scope of this notation is detailed in Sec 6.

1.3 General requirements

1.3.1 This sub-article [1.3] gives general requirements for all the mooring components. The particular requirements for each type of mooring components are given in Articles [2] to [8], in terms of:

- design
- fabrication and testing (at works or on board)
- installation and service conditions.

1.3.2 Rules and related documents

Reference is made to the Rules and related documents specified in Tab 1, as applicable to particular items, depending on their type of construction (such as forged, cast or fabricated, etc.).

1.3.3 Designation

The components of a mooring line are to be defined by the minimum breaking strength for which the item is designed and tested, and by other relevant parameters as specified in Articles from [2] to [8].

Table 1 : Rules and related documents or standards

Item	Defined in	Rules and related documents **(1)**	Standards **(1)**
General requirements	[1.3]	NR216, Rules on Materials and Welding NR445, Offshore Rules NR426, Construction Survey of Steel Structures of Offshore Units and Installations Other Rules and publications of the Society, as applicable	
Chains and standard fittings	[2]	NR216, Rules on Materials and Welding, Ch 4, Sec 2 IACS UR W22	ISO 1704:2008
Steel wire ropes	[3]		API Spec 9A ISO 10425:2003 ISO 2232:1990 API RP 2SK
Fibre ropes	[4]	NI 432, Certification of Fibre Ropes for Deepwater Offshore Services	ISO 18692:2007 ISO TS 14909:2012
Non standard fittings	[5]	NR216, Rules on Materials and Welding, Ch 4, Sec 2	
(1) Full title of the documents in Sec 1, [4.2].			

1.3.4 Manufacturing, testing and certification

Manufacturing and testing of the components of a mooring system are to be performed according to the applicable provisions of the Rules, and under survey of the Society.

Load tests, when performed, are to be witnessed by a Surveyor of the Society.

1.3.5 Type approval

When specified in Articles from [2] to [8], items are to be type-approved by the Society according to the requirements of this Section and to NR320 (see Sec 1, [4.2.2]).

For type approval, the documentation of design is to be submitted for review, and manufacturing and testing of the prototype items are to be performed under survey of the Society, as required for the items under consideration.

Note 1: The range of sizes, or other parameters for which approval is granted, is/are to be specified at the time of approval.

For a particular project, once an item is type-approved:

- the documentation of design may be limited to the project specific information and to the adequacy of the item for the intended project
- the provisions of [1.3.4] are applicable to manufacturing and testing of the item for the intended project.

2 Chains and standard fittings

2.1 General

2.1.1 The items covered by Article [2] are chain common links, connecting common links, enlarged links, end links, detachable connecting links, end shackles, swivels, and swivel shackles.

2.1.2 Kenter and Baldt links

The use of Kenter and Baldt links is not allowed for permanent mooring lines, for fatigue strength and durability reasons.

2.1.3 Rules and related documents or standards

Reference is made to the Rules and related documents specified in Tab 1.

2.2 Designation

2.2.1 Chain and accessories are to be defined by their grade, and either their minimum breaking strength or their nominal diameter.

Note 1: For accessories, the nominal diameter is the nominal (bar) diameter of the corresponding chain.

2.2.2 The specified minimum breaking strength/nominal diameter is to include an adequate margin for corrosion and wear over the intended service life (see Sec 3, [9.3]).

2.3 Design

2.3.1 Design documentation to be submitted

Drawings detailing the design of chain and accessories are to be submitted for review at the time of approval.

Fatigue documentation is to be submitted for review. See also [5.3.4].

2.3.2 Dimensions

The dimensions of stud link chains and standard fittings are to be as per NR216 Rules on Materials and Welding (typical designs).

For studless chains, dimensions are to be in accordance with IACS UR W22.

2.3.3 Materials

NR216 Rules on Materials and Welding, Ch 4, Sec 2 give specification for Chains and standard fittings materials.

The use of ORQ grade is not permitted within the framework of notations **POSA**, **POSA-HR** and **POSA JETTY**. However, this grade may be allowed for non-permanent mooring systems such as mobile units within the framework of the notation **POSA MU**.

Grades higher than QR5 are to be given special consideration.

2.4 Manufacturing and testing

2.4.1 General

NR216 Rules on Materials and Welding, Ch 4, Sec 2 give the requirements and specifications to be applied for manufacturing, testing and examination of Chains and standard fitting.

2.4.2 Manufacturing

Chains and standard fittings are to be manufactured only by manufacturers approved by the Society for the intended product.

2.4.3 Load tests

Each chain link or standard fitting is to be tested at a proof load PL depending on the minimum breaking strength MBS and the specified material grade. NR216 give the ratio PL/MBS to be considered.

Break load tests are to be carried out.

Note 1: Items that have been subject to a break load test are generally to be scrapped.

3 Steel wire ropes

3.1 General

3.1.1 Scope

Article [3] deals with the steel wire ropes intended for use as mooring lines and their associated termination fittings.

3.1.2 Standards

Reference may be made to the standards specified in Tab 1.

3.2 Designation

3.2.1 Steel wire ropes are to be defined by their minimum breaking strength, their construction type and their nominal diameter.

3.2.2 The specified minimum breaking strength/nominal diameter is to include, where applicable, a margin for additional corrosion and wear allowance (see [3.3.3]).

3.3 Design of steel wire ropes

3.3.1 Design documentation to be submitted

As a minimum, the following documents or information are to be submitted for review:

- reference standards
- rope construction drawing and specification
- wire specification
- specification of the other materials (galvanic coating, compound, sheathing)
- calculation of wire rope static strength
- documentation on torque properties (tension induced torque and torque compliance)
- cathodic protection calculations
- fatigue analysis for the intended application.

3.3.2 Construction

Rope constructions considered in this Rule Note include:

- six-strand construction (with steel core)
- multi-strand construction
- spiral-strand construction (including half-locked and full locked coils).

3.3.3 Protection

Protection against corrosion and resistance to wear is to be provided, including at least:

- wire galvanisation or equivalent
- stranding compound.

Complementary protection by one or several adequate means is to be provided as necessary, considering the service conditions and the intended life time. This may include means such as:

- selection of the type of construction and wire profile
- improved galvanic coating
- sacrificial anode wires
- sheathing
- additional corrosion and wear allowances.

Note 1: T-N data in Sec 3, [9.4.4] are valid only when a suitable corrosion protection is provided.

3.3.4 Strength

The calculated breaking strength is to be not less than the specified minimum breaking strength (see also [3.5.2]).

3.4 Design of terminations

3.4.1 Design documentation to be submitted

As a minimum, the following documents or information are to be submitted for review:

- drawings of termination fittings
- specification of materials
- strength and fatigue evaluations
- corrosion protection drawings and calculations
- details of electrical insulation and data sheets of relevant materials
- drawings of connection to ropes, with specification of socketing material.

3.4.2 Design requirements

Terminations are to be designed in accordance with the requirements given in Article [5].

The termination strength is to be not less than the specified minimum breaking strength of the wire rope (see also [3.5.2]).

Terminations are to provide an effective electrical isolation between the wire rope and the other parts of the mooring line.

Termination fittings are to be provided with cathodic protection, at a level consistent with the protection level of the wire rope.

3.5 Manufacturing and testing

3.5.1 Manufacturing

The following documents or information are to be submitted in due course:

- reference standards
- quality and test plans with the proposed witness points for the Surveyor
- process monitoring and recording (including traceability)
- acceptance criteria
- steel rod raw material certificates
- sheathing procedure
- repair procedures
- procedure for connection of terminations to rope
- individual wires records
- manufacturing documentation on terminations (see [5.3.1])
- records of connection of terminations to rope
- rope sample test procedures
- rope sample load test reports.

3.5.2 Break load test

A break load test is to be carried out on a sample of the wire rope and its terminations, taken from the production under survey.

The sample is to withstand the specified minimum breaking strength.

4 Fibre ropes

4.1 General

4.1.1 Scope

Article [4] is applicable to fibre ropes intended for use as anchoring lines and covers both fibre rope and termination thimbles.

Note 1: For mooring hawsers, see NR494, Sec 4, [5].

4.1.2 Rules and related documents

Reference is made to the Rules and related documents specified in Tab 1.

4.1.3 Designation

Fibre ropes are to be defined by their minimum breaking strength, the material type and their diameter or rope size.

4.1.4 Approval

Fibre ropes are to be type-approved by the Society, according to the requirements of Guidance Note NI 432.

Note 1: Type approval is based on full size testing of a prototype rope having the specified minimum bending strength.

Termination thimbles other than steel roller thimbles (spools) are to be in accordance with Article [5].

4.2 Design

4.2.1 The fibre rope is to be identical to the approved rope.

Termination thimbles are to be made of the same type of material (steel), the same groove profile and the same inside diameter (within –0/+10%) of those used for prototype testing.

4.2.2 Fibre ropes are not to be used in lines including six-strand wire ropes or other non-torque-balanced components, unless a torque-matched construction is provided.

4.3 Manufacturing and testing

4.3.1 Manufacturing and testing of fibre ropes are to be performed in accordance with Guidance Note NI 432, under survey of the Society.

4.3.2 Thimbles are to be manufactured and tested in accordance with the provisions of Article [5].

However, load tests may be omitted for steel roller thimbles (spools), when a thimble of the same material, and with the same or proportional dimensions, has been tested together with the rope, at the time of rope approval, for a similar or greater minimum bending strength.

5 Non standard fittings

5.1 General

5.1.1 Scope

Article [5] addresses fittings for connection between line elements, having general dimensions or use deviating from those given in the Rules or recognised standards, such as:

- special links and enlarged shackles with general dimensions different from ISO 1704 (e.g. for connection to a fibre rope thimble)
- H-links (straight and twisted)
- tri-plates
- connectors (for underwater connection)
- termination fittings for wire ropes
- termination thimbles (special type) for fibre ropes (see Article [4]).

5.1.2 Rules and related documents

Article [5] primarily addresses fittings made of cast steel or forged steel, or machined from steel plates, for which reference documents are specified in Tab 1.

5.1.3 Designation

Fittings are to be defined by their minimum breaking strength and, as relevant, the nature and nominal dimensions of the items they are intended to connect.

For items connecting ancillary line elements, the minimum breaking strength of the attached elements is also to be specified.

5.1.4 Type approval

Fittings that are not purpose-designed for a specific system are to be type-approved by the Society according to the requirements of this Section.

Fittings that are purpose-designed for a specific system are to be approved in accordance with this Article [5].

5.2 Design

5.2.1 Design documentation to be submitted

As a minimum, the following documents or information are to be submitted for review:

- drawings with the detailed design of the fittings and all the parts made by, or supplied through, the manufacturer
- specification of materials
- strength and fatigue evaluations
- corrosion protection drawings and calculations, where relevant.

5.2.2 Material

Fittings in cast or forged steel, or machined from steel plates, are to be made of materials satisfying the requirements of one of the following rule grades: QR3, QR3S, QR4, QR4S or QR5.

Where applicable, steels with yield and tensile strengths less than those corresponding to grade QR3 may be used, provided the other mechanical properties of grade QR3, as specified in NR216 Rules on Materials and Welding, Ch 4, Sec 2, Tab 2, are met.

The specification of materials is also to include the reference to a recognised material standard, with the details of chemical composition and heat treatments.

In the case of a welded assembly, the provisions of [7.2.3] are also to be met, with a design temperature of 4°C, unless otherwise specified.

Note 1: Any welding onto grade QR4 steel is generally prohibited.

5.2.3 Strength

Strength is to be documented by appropriate calculations, in accordance with the provisions of App 3.

As a rule, the design of the fittings is to be assessed considering a corrosion margin. See also Sec 3, [9.3].

5.2.4 Fatigue

Resistance to fatigue is to be documented for installations intended to stay moored on site for a period longer than two years.

Fatigue resistance is to be determined with reference to the data for the line components (see Sec 3, [9.4]) and, as a rule, is not to be less than the fatigue resistance of a chain of the same breaking strength in grade QR3.

Besides, for a particular project, the achieved fatigue life is to be documented and is to meet the relevant requirements of Sec 3.

5.2.5 Protection

Fittings are to be protected against corrosion by adequate means.

For high yield strength materials, attention is however to be given on the risk of hydrogen-induced cracking.

Electrical insulation of connectors is to be provided, as applicable.

5.3 Manufacturing and testing

5.3.1 Manufacturing

The following documents or information are to be submitted in due course:

- reference standards
- quality and test plans with proposed witness points for the Surveyor
- fabrication and testing procedures and records.

5.3.2 Qualification

The manufacturer is to be recognized and approved by the Society for the forging/casting of the intended mooring line accessories.

5.3.3 Break load tests

Break load tests are to be carried out on a prototype item, as per Rules.

Consideration is to be given to tests made on items of different sizes, with proportional dimensions.

For shackles, detachable links, and similar items, the break load tests are to be carried out as for standard items (see [3.5.2]).

Note 1: Items that have been subject to a break load test are generally to be scrapped.

5.3.4 Proof load tests

Proof load tests are to be carried out on a prototype item, as per Rules.

Each item is to be tested at a proof load PL depending on the minimum breaking strength MBS and the specified material grade, as given for studless chain in Tab 2.

When a load test is not achievable for technical reasons, replacement of the proof load test by other suitable examinations may be considered on a case-by-case basis by the Society.

6 Anchoring devices

6.1 General

6.1.1 Scope

Article [6] covers the anchoring devices such as:

- drag anchors, except as specified below
- vertically loaded anchors (VLA's)
- suction anchors
- anchor piles.

This Article does not address the conventional (ship type) drag anchors, that are designed, manufactured and tested in accordance with the relevant provisions of the Ships Rules. Such types of anchors are not normally used in permanent moorings.

The other types of anchoring devices are to be given special consideration, on a case-by-case basis.

6.1.2 Designation

The anchoring devices are to be defined, as a minimum, by the required ultimate holding capacity and the related uplift angle at anchor lug.

When required to verify the design (see [6.2]), the details of the loads in each design condition are also to be specified.

6.1.3 Approval

The drag anchors and the VLA's are to be type-approved by the Society on the basis of this Rule Note.

Note 1: The type approval is generally delivered for a specified range of sea bottom conditions.

Note 2: The other types of anchoring devices are generally approved for the particular application for which they are specifically designed.

6.2 Design

6.2.1 Design documentation to be submitted

As a minimum, the following documents or information are to be submitted for review, as applicable to the type of anchoring device:

- specification of design soil conditions (for type approval), and documentation on the conditions at the testing site (see [6.2.7])
- documentation on the site conditions (see the Offshore Rules, Part B, Chapter 2), including the study of possible geo-hazards
- design loads at anchor lug, with the details of derivation from the loads in line at sea bottom
- loads/design conditions at the time of installation
- drawings with the detailed design of all the parts made by, or supplied through, the manufacturer
- geotechnical strength evaluations, and supporting test reports
- specification of materials
- strength and fatigue evaluations
- corrosion protection drawings and calculations.

6.2.2 Geotechnical design

The geotechnical ultimate capacity of an anchoring device is to be documented (see [6.2.7] to [6.2.9]). The effects of cyclic loading are to be assessed.

The behaviour during installation and the related loads are also to be assessed and documented.

For a particular application, an evaluation of the feasibility of the proposed type of anchoring device with respect to the soil profile is to be provided, and the geotechnical ultimate capacity of the proposed device is to satisfy the requirements of Sec 3, [11.2].

NI 605 Geotechnical and Foundation Design gives additional requirements and detailed methodology.

Note 1: For most types of anchoring devices, the full design geotechnical capacity may not be available immediately after installation, due to the time required for set-up effect of soils (particularly clays). This should be given consideration in the overall scheduling of a project, taking into account the risk of occurrence of high load during that period.

6.2.3 Materials

Materials are to conform to the relevant Sections of the Offshore Rules and of the Rules on Materials and Welding (offshore grades), taking into account the design temperature and the structural categories, as defined in [6.3.2].

6.2.4 Strength

Strength is to be documented by appropriate calculations, in accordance with the provisions of App 3.

Anchor pad-eye, shank, and adjacent structure are to be designed to withstand the minimum breaking strength of the line.

The anchor body is to be able to withstand the ultimate holding capacity of the anchoring device (see Sec 3, [11.2] and NI 605), with deformations within such limits that they do not impair anchor geotechnical capacity. See also [6.2.7] to [6.2.9].

6.2.5 Fatigue

Resistance to fatigue is to be documented for installations intended to stay moored on site for a period longer than two years.

The data referenced in [5.2.4] may be used as a guidance for the purpose of type approval.

For a given project, the achieved fatigue life is to be documented.

Sec 3 gives the requirements for fatigue analysis.

6.2.6 Protection

Anchoring devices are to be protected against corrosion by adequate means.

When the geotechnical capacity of the anchor is relying on skin friction between soil and steel, the condition of the steel surface is to be consistent with the assumptions made at the time of design.

Note 1: Where appropriate, protective coating is to be avoided in the relevant area of the anchor.

If the steel structure under the mudline is not protected against corrosion, a minimum corrosion margin of 0,2 mm/year per metal face exposed to the soil is to be considered (see NI 605, Sec 3, [1.4.2]).

6.2.7 Particular provisions - Drag anchors and VLA's

Geotechnical behaviour of drag anchors and VLA's is to be documented through testing of prototype anchors in representative soil conditions.

Complementary analysis, where applicable, may be used.

For VLA's, the relations between achieved penetration (and related load), soil parameters, and ultimate capacity of the anchors are to be established and documented through these tests.

The anchor body is to be able to withstand the minimum expected holding power (ultimate capacity) computed as per Sec 3, [11.2]. This case is to be considered as 'load case 3' (accidental), with respect to the strength criteria of the Offshore Rules, Part B, Chapter 3.

6.2.8 Particular provisions - Suction piles

Geotechnical capacity of suction piles may be established by analysis, with due consideration for the potential modes of failure under the combination of the vertical load, horizontal load, and overturning moment.

In strength evaluation, due attention is to be given to the buckling resistance of the anchor body with respect to the under-pressures generated by suction effects, at installation, in service, or for retrieval.

Additional requirements and detailed methodology are given in NI 605 Geotechnical and Foundation Design.

6.2.9 Particular provisions - Anchor piles

The design of long (soft) anchor piles may be documented in accordance with recognised procedures, such as those specified in NI 605, where:

- the pull-out capacity (axial load) and the strength under lateral load can be evaluated separately
- the strength of the pile under lateral load is assessed considering factored loads (e.g. as per NI 605), with load factors taken as per Sec 3, Tab 6.

In strength evaluation, attention is to be paid to loads generated during installation and retrieval.

Additional requirements and detailed methodology are given in NI 605 Geotechnical and Foundation Design.

6.3 Manufacturing

6.3.1 Manufacturing

Manufacturing of anchoring devices is to be performed under Survey of the Society, in accordance with the relevant requirements of:

- the Offshore Rules, Part B, Chapter 3
- the Rules on Materials and Welding, Ch 2, Sec 3 and Ch 2, Sec 4
- NR426 Construction Survey of Steel Structures of Offshore Units and Installations.

6.3.2 Structural categories and design temperature

For the selection of materials, and the definition of fabrication and NDT requirements, the following elements are to be considered as belonging to the following structural categories (as defined in the Offshore Rules, Pt B, Ch 3, Sec 2):

- pad-eye, shank, and adjacent structure are to be considered as 'special category' elements
- the other parts of the anchor body are to be considered as 'first category' elements.

A design service temperature of 4°C is generally to be considered for anchoring devices in deep waters. In the other cases, the design temperature is to be specified.

7 Items at the unit-side end

7.1 General

7.1.1 Scope

Article [7] covers the items intended to guide and secure the anchoring lines at their end on board units, such as:

- fairleads or bending shoes
- stoppers
- supporting structures for connection of the above items to the unit hull.

Note 1: The foundations of these items into the hull (or turret, as applicable) are covered by the main Class of the unit (see also [7.2.5]).

Note 2: For winches, windlasses and other deck appliances, see [1.2.3].

7.1.2 Designation

The items are to be defined by the nature and nominal dimensions of the line segment they are intended to support, and the related minimum breaking strength.

7.1.3 Approval

The items are generally approved for the particular application for which they are specifically designed.

The standard items may be type-approved by the Society on the basis of the requirements of Article [7] and the relevant Sections of the Rules and related documents.

7.2 Design

7.2.1 Design documentation to be submitted

As a minimum, the following documents or information are to be submitted for review, as applicable to the type of item:

- drawings of arrangement, construction, and mechanical components, with the detailed design of all the parts made by, or supplied through, the manufacturer
- design loads and other relevant design conditions
- detailed structural drawings
- specification of materials
- strength and fatigue evaluations
- documentation on mechanical components
- documentation on interface loads
- interface drawings
- corrosion protection drawings and calculations.

7.2.2 Design conditions

The items are to be designed to withstand the mooring line they are intended to support, when loaded to:

- a design breaking strength equal to the minimum breaking strength of the weakeast segment of the line plus the weight of the line segments located between the upper end of the weakest segment of the line and the fairlead
- the design tension T_D in the line, for each mooring system condition: intact, damaged, transient, as relevant.

Note 1: For type approval, T_D is to be taken as the design breaking strength divided by the minimum value of safety factor as specified in Sec 3.

For items supporting the suspended part of the line, due attention is to be given to the range of orientation of the line load resulting from tolerances in system geometry, unit offset and unit motions, in addition to those resulting from possible configurations or predicted by mooring analysis.

7.2.3 Materials

Materials are to conform to the relevant Sections of the Offshore Rules and of the Rules on Materials and Welding (offshore grades), taking into account the design temperature and the structural categories, as defined in [7.3.2].

7.2.4 Strength

Strength is to be documented by appropriate calculations, in accordance with the provisions of App 3.

The items are to be designed to withstand the loads specified in [7.2.2].

The App 3 gives the strength criteria.

The parts supporting mechanical components are to have, under the highest design tension T_D , deformations within such limits that they do not impair the integrity of mechanical components.

7.2.5 Interface with unit structure

Loads and load distribution at the interface with the unit structure are to be documented.

Interface arrangement and weld details are to be specified, in a manner consistent with the arrangement of unit underdeck structure, in order to ensure suitable structural continuity. Attention is to be given to thickness transitions between materials of different strengths.

7.2.6 Fatigue

Resistance to fatigue of the items and of the interface connections is to be documented.

The data referenced in [5.2.4] may be used as a guidance for the purpose of type approval.

For a particular project, the achieved fatigue life is to be documented and in accordance with the relevant requirements of Sec 3.

Possible detrimental interaction with the mooring line is to be assessed and taken into account for the design of the upper segment of the line, as well as for the design of the item itself.

In this respect, attention is to be given to :

- minimise out-of-plane bending in chain
- locked-in modes that may arise due to friction between the suspended part of the line and the unit body.

7.2.7 Mechanical components

The mechanical components are to be of a suitable type with respect to the functional requirements (e.g. low friction properties) and durability in marine environment/seawater.

The mechanical components are to be able to withstand the internal loads induced by the design breaking strength in the line, and to operate under the highest design tension T_D in the line.

The parts requiring replacement are to be identified, and the criteria specified.

7.2.8 Protection

Protection against corrosion and wear is to be provided by adequate means.

For the submerged items, consideration may be given to a complementary cathodic protection (when electrical bonding is provided to benefit from hull cathodic protection system), or an independent protection.

7.3 Manufacturing and testing

7.3.1 Manufacturing

Manufacturing of the items is to be performed in accordance with the relevant requirements of:

- the Offshore Rules, Part B, Chapter 3
- the Rules on Materials and Welding, Ch 2, Sec 3 and Ch 2, Sec 4
- NR426 Construction Survey of Steel Structures of Offshore Units and Installations.

7.3.2 Structural categories and design temperature

For the selection of materials, and the definition of fabrication and NDT requirements:

- principal load bearing items and adjacent structure are to be considered as 'special category' elements
- the other parts of the item body may be considered as 'first category' elements
- the design temperature is to be specified, and taken not higher than the design air temperature for the unit. The (near-surface) seawater design temperature may be however considered for the permanently submerged parts.

7.3.3 Testing and installation on board

The installation on board of items is to be performed under survey of the Society.

Interface welds are to be considered as 'special category' elements (100% NDT).

The NR426 (see Sec 1, [4.2.2]) gives specific recommandations for surveys of such steel structures.

Functional testing is to be performed in workshop, as far as practicable, and, after installation on board, following an agreed program.

7.3.4 Testing of chain stoppers

Chain stoppers are to be proof load tested to evaluate their proper functioning under load from chain, and to ensure the absence of any defect by inspection after proof load test.

Proof load test may be dispensed, providing that:

- no main load bearing structure is working in tension (exception is to be made for parts of the structure close to contact area)
- non-linear analysis is performed as per App 3 to demonstrate that failure in way of local high stress is not foreseeable.

Break load testing is not required for chain stoppers.

8 Ancillary components

8.1 General

8.1.1 Article [8] is addressing ancillary components such as buoys, sinkers and their connections, that are permanent parts of the mooring system (see Sec 1, [2.4.1]).

Attention is to be paid to the following potential issues:

- wear
- degradation
- local fatigue.

8.1.2 Drawings, design calculation notes and material specifications are to be submitted. Based on this documentation, additional calculations and tests may be required.

Manufacturing and testing are to fulfill the requirements of the Rules on Materials and Welding and the Offshore Rules (see Sec 1, [4.2.1], items a) and b)).

8.1.3 Design criteria, materials, surveys during manufacturing and testing, as applicable, are to be carried out to the satisfaction of the Society.

8.2 Clump weights

8.2.1 Clump weights may be added on mooring lines in order to improve the restoring capacity of the mooring system. Clump weights are usually installed near the line touchdown point.

9 Monitoring system

9.1 Load monitoring system

9.1.1 For permanent mooring, such as fibre rope moorings (usually in deep-water), and other cases where checking of the line pre-tensions cannot be achieved by conventional methods, a permanent load monitoring device is to be fitted on each line, for verification of the line pre-tensions at the time of the periodical surveys.

The control system may include the transmission of line failure detection system, or the capability for continuous recording over some time, e.g. for re-tensioning operations. The associated computer software is to be in accordance with the applicable provisions of NI 425 (see Sec 1, [4.2.2]).

SECTION 5 MOBILE MOORING

1 General

1.1 Application

1.1.1 The purpose of this Section is to provide Class requirements with a view to the assignment of the notation **POSA MU** to a mobile offshore unit.

1.1.2 The notation **POSA MU** covers the station-keeping system of mobile units, such as surface and column-stabilized MODUs, in compliance with the IMO MODU Code requirements related to anchoring arrangements. The mooring systems are to be capable of being retrieved for regular inspections out of the water.

1.2 Applicability and limits

1.2.1 The notation **POSA MU** covers the station-keeping systems of spread mooring type, which are principally passive systems.

This notation covers also:

- all the possible types of anchoring patterns, line make-up, and materials
- the thruster-assisted mooring, if any.

1.2.2 The notation **POSA MU** covers all the outboard elements of the mooring system (see Sec 1, [2.4.1]).

1.2.3 The notation **POSA MU** covers also:

- the fairlead stoppers on the unit (in whole, i.e. including unit-side female support parts)
- any associated monitoring and control systems
- the deck appliances (winches and windlasses).

1.3 In-service surveys

1.3.1 The surveys of the mooring system of units granted with the notation **POSA MU** are to comply with the provisions of Sec 2.

1.3.2 Mooring components are to be inspected on board as per Sec 2. Registrations of component usage are to be kept on board and made available to the Surveyor for review at each annual survey.

1.4 General requirements

1.4.1 The design of the mooring system is to be in accordance with the provisions of the notation **POSA**. Deviations from these provisions and additional requirements due to the mobile unit specificities are detailed in the present Section.

2 Design

2.1 Environment

2.1.1 Mobile units may have different areas of operations. The design metocean data are to be provided by the party applying for the classification. These assumptions are to be listed in the Design Criteria Statement (see NR445, Part A).

The site assessment is to be conducted by the party applying for the classification in order to ascertain that the actual conditions met at the contemplated operating site remain on the side of safety when compared to the design data and assumptions, particularly those listed in the Design Criteria Statement.

The ISO 19905 gives specific requirements regarding site-specific assessment of mobile offshore units.

2.1.2 As specified in Sec 3, [10.4.2], the extreme metocean conditions may be considered as corresponding to a return period N equal to five times the duration of the operation, provided N is never taken less than 5 years.

For the mooring systems in the vicinity of other structures, N is not to be taken less than 10 years.

2.2 Design loads

2.2.1 As specified in Chapter 2 of the IMO MODU Code, the environmental loading to be considered is depending on the intended areas of operation and is to include, as applicable: wind, waves, current, ice, seabed conditions, temperature, fouling and earthquake.

2.2.2 In the loading calculation, consideration is to be given to the interaction of waves and current. The resultant velocity to be used is to be calculated from the superimposition of current velocity and wave particle velocity.

2.3 Fatigue

2.3.1 For mooring systems installed on the same location for a duration greater than two years, Fatigue assessments are to be icluded in the site assessment in accordance with the criteria of Sec 3, [11.4]. The results are to be made available for the Surveyor.

3 Components of mooring lines

3.1 General requirements

3.1.1 The components of a mobile mooring which cannot be inspected or retrieved are to be considered as permanent mooring components.

3.2 Chains and standard fittings

3.2.1 Grade of materials for chains and standard fittings is specified in NR216, Ch 4, Sec 1.

For temporary mooring systems, the use of ORQ grade may also be considered.

3.3 Deck appliances (winches and windlasses)

3.3.1 According to the IMO MODU Code, two independent power-operated brakes are to be provided for each windlass. Each of these brakes are to be able to withstand a static load in the mooring line at least equal to 50% of its minimum breaking load.

3.3.2 In case of loss of windlass power, these two power-operated brakes are both to be automatically activated. Together, they are to be capable of withstanding at least 50% of the total static braking capacity of the windlass.

3.3.3 Each windlass is to be designed to comply with the following requirements:

- to provide adequate dynamic braking capacity in order to control normal combinations of loads from the anchor, the mooring line and the anchor handling vessel during the deployment of the anchors at the maximum design unwinding speed of the windlass
- to be controlled from a position allowing for a good visibility of the operation
- to provide means, at the windlass control position, to monitor mooring line tension, power load and mooring line unwinding length.

3.4 Items at the unit-side end

3.4.1 Items at the unit-side end, such as fairlead and sheaves, are to be designed to withstand the line when loaded to the minimum breaking load of the mooring line.

3.4.2 The strength criteria of the items are to be documented by appropriate calculations, in accordance with the provisions of App 3.

3.4.3 Loads and load distribution at the interface with the unit structure are to be documented.

Interface arrangement is to be designed in a manner consistent with arrangement of the underneath unit structure, in order to ensure a suitable continuity. Welding details are to be specified. Attention is to be given to the thickness transitions between the materials of different strengths.

3.5 Anchoring devices

3.5.1 Suitable anchor stowage arrangements are to be provided to prevent a move of the anchors into a seaway during the transit phase.

3.5.2 For the mobile units, ordinary anchors and high holding power anchors may be considered. Refer to the Ship Rules, Pt B, Ch 9, Sec 4., for more details

4 Installation and service conditions

4.1 General requirements

4.1.1 Means are to be provided for display and automatic recording of cable tensions, wind speed and wind direction.

5 Thruster assisted mooring (TAM)

5.1 General

5.1.1 Thrusters may be part of the station-keeping system providing that a thruster assist system has been properly defined and designed.

Dynamic positioning systems used as a sole means of position keeping, as described in the Ship Rules, Pt E, Ch 10, Sec 6, are not addressed in this Article [5].

The ISO 19901-7 gives specific recommendations for the design of thruster assisted moorings.

5.1.2 The thruster system may be used to assist the mooring system, for the purpose of:

- reducing the environmental loads
- controlling the unit's heading
- adding damping to the low frequency motions.

5.1.3 TAM systems may be controlled by an automatic or a manual system. This specificity is to be taken into account in the design process.

5.2 Conditions of analysis

5.2.1 Conditions of intact and damaged TAM systems to be considered for the analysis are given in Tab 1.

Table 1 : Conditions of analysis

Conditions of analysis	Mooring system conditions	Thruster assist system conditions
Intact	Intact	Intact
Damaged	Damaged	Intact
Damaged	Intact	Damaged

5.2.2 The thruster allocation used in the analysis is to reflect the on-board allocation algorithm.

5.2.3 The simulations are to be consistent with the operating conditions.

5.3 Allowable thrust

5.3.1 Available thrust

When a thruster assist system is used, it is necessary to evaluate the allowable thrust that may be used for the mooring analysis.

The first step is to determine the available thrust taking into consideration:

- efficiency of the thrusters
- losses due to the unit motions, current, thruster/hull and thruster/thruster interference effects, and
- any directional restrictions.

A guidance for evaluation of the available thrust is given in document API RP 2SK (see Sec 1, [4.2.6], item a)).

5.3.2 Worst thruster system failure

The available thrust calculated as per [5.3.1] is to account for the worst thruster system failure.

This worst failure is to be determined by a failure mode and effects analysis (FMEA) and is to include failure of any mooring line, failure of any single thruster, or stop of thrusters occurring in the event of the most serious failure in the power system.

5.3.3 Allowable thrust for automatic thruster control systems

For automatic thruster control systems, the allowable thrust may be determined as follows:

- for the intact thruster condition, the allowable thrust is equal to the available thrust (see [5.3.1]) or the effective bollard pull when the thruster system is operating normally
- for the damaged thruster condition, the allowable thrust is equal to the available thrust after accounting for the worst thruster system failure as determined by a FMEA (see [5.3.2]).

5.3.4 Allowable thrust for manual thruster control systems

For manual thruster control systems, the allowable thrust is equal to the value determined as per [5.3.3], multiplied by a reduction factor taken equal to 0,7.

5.3.5 The allowable thrust used in the mooring analysis is to be verified during thruster system sea trials.

5.4 Analysis for thruster assisted mooring

5.4.1 The analysis for thruster assisted mooring systems is to be properly conducted by a time-domain system dynamic analysis.

As defined in Sec 3, [3.3], the quasi-dynamic or coupled quasi-dynamic methods may be used, providing compliance with the different assumptions. The thruster responses are to be added to the different loads of the system and calculated at each time step of the simulation.

More information about the time-domain system dynamic method is given in document API RP 2SK.

5.4.2 A simple mean load reduction method may also be used as a simplified approach. Reference is made to document API RP 2SK for guidelines on this method.

5.5 System requirements

5.5.1 Functional requirements

The thruster system, and thruster control and monitoring are to comply with Pt E, Ch 10, Sec 6, [4.4] to Pt E, Ch 10, Sec 6, [4.6] of the Ship Rules.

The power system and monitoring of the power production and propulsion are to comply with Pt E, Ch 10, Sec 6, [4.2] and Pt E, Ch 10, Sec 6, [4.3] of the Ship Rules.

5.5.2 Position reference system and sensors

The position reference system is to comply with the recommendations of the Ship Rules, Pt E, Ch 10, Sec 6, [5], with the following deviations:

- for manual TAM systems, only one reference system is required
- for automatic TAM systems, at least two independent reference systems are required.

The sensors and monitoring are to comply with the requirements of the Ship Rules, Pt E, Ch 10, Sec 6, [5.5].

5.6 Sea trials

5.6.1 For TAM systems, sea trials are to be performed in order to test the propulsion system.

5.6.2 Prior to the mooring trials, a comprehensive list of the tests intended to be carried out by the builder, including procedures and planning of the tests, is to be submitted to the Society and the Surveyor.

5.6.3 The mooring trials are to be carried out during the construction, in the presence of, and to the satisfaction of, the attending Surveyor.

5.6.4 Mooring system

The mooring system is to be tested during the mooring trials under working conditions, to demonstrate satisfactory operation.

5.6.5 Thruster assisted mooring

For thruster assisted mooring, the trials are to be conducted according to the requirements of the Ship Rules, Pt C, Ch 1, Sec 15.

5.6.6 Control systems

Tests of control and monitoring systems are to be performed during the mooring trials.

Where relevant, the following control systems are to be tested by measurements:

- line tensions
- wind speed and direction
- wave elevation
- unit position
- line unwinding length.

Means of communication between locations which are critical for the mooring operations are to be tested.

It is also to be checked that all the control stations provide a good visibility of the mooring operations.

6 Mooring equipment tests

6.1 Mooring equipment

6.1.1 The mooring equipment is to be tested on board under working conditions.

The test program is to include:

- test for braking
- test for clutch functioning
- test for lowering and hoisting of chain/cable and anchor
- test for the proper riding of the chain/cable through the other mooring components
- verification of proper storage of the chain/cable and anchor
- verification of proper alignments and arrangements of mooring components (winches, fairleads, ...).
- test for mooring handling equipments

7 Operating manual

7.1 General

7.1.1 The operating manual defines the operational characteristics and capabilities of the mooring system in accordance with the Offshore Rules and the IMO MODU CODE.

7.1.2 The site assessment is to be inclued in the operating manual.

7.1.3 The Offshore Rules, Pt A, Ch 1, Sec 4 give the requirement to be included in the operating manual.

SECTION 6 MOORING AT A JETTY

1 General

1.1 Application

1.1.1 The purpose of this Section is to provide Class requirements with a view to the assignment of the notation **POSA JETTY** to an offshore unit moored at a jetty.

1.2 Applicability and limits

1.2.1 The notation **POSA JETTY** covers the station keeping capability of a unit moored at a jetty, a quay, or to a spud pile system within the limits of applicability defined in this Section.

1.2.2 As a minimum, the notation **POSA JETTY** covers the following items:

- all the components of the load bearing lines, including the connecting devices
- the fairleads, rollers, bitts and winches, and their foundations, used for connecting the mooring lines on board the unit
- the quick release hook for disconnectable systems
- any associated monitoring and control systems.

1.2.3 The scope of the notation **POSA JETTY** may also cover the jetty, including the devices connecting the mooring lines, and its foundations. In case the jetty is covered by this notation, it is to be explicitly written in the Design Criteria Statement.

1.3 In-service surveys

1.3.1 The surveys of the mooring system for units granted with the notation **POSA JETTY** are to comply with the provisions of Sec 2.

1.4 General requirements

1.4.1 The design of the mooring system is to be in accordance with the provisions of the notation **POSA**, as specified in Sec 3 and Sec 4. Deviations from these provisions and additional requirements due to the jetty mooring specificities are detailed in the present Section.

2 Design

2.1 Environment

2.1.1 The metocean data to be considered are the conditions at the unit location.

For permanent mooring systems (no disconnection expected during the service life), the extreme metocean conditions to be considered at the unit location are those corresponding to a return period N of 100 years, as described in Sec 3, [10].

For disconnectable mooring systems, the design metocean data are to be provided by the party applying for the classification. In addition, the disconnection procedures are to be submitted to the Society for review. Such procedures are to include:

- description of the load monitoring system
- alarm levels for disconnection decision and alarm types (visual, audible)
- locations of the load monitoring devices.

The disconnection procedures are to be included in the operation manual.

2.1.2 Attention is to be paid to the water level variations due to the tides.

2.2 Design loads

2.2.1 Description of the environmental loads is given in Sec 3, [3].

2.2.2 For calculation of the wave drift load, the influence of the jetty or of any other structure is to be considered in the calculation of the Quadratic Transfer Functions (QTF).

In case of interaction with another unit or floating structure, as in side-by-side configuration, the potential influence is to be considered in the calculation of QTF.

2.2.3 Where applicable, the loads due to the waves from passing ships are to be taken into account.

2.3 Fatigue

2.3.1 Generally, hawsers and accessories are periodically renewed, given the conditions of use, ambient temperatures, daily UV exposures, etc

The service life of hawsers is to be specified in the operating manual.

For the mooring lines and mooring components having a service life greater than 2 years, a fatigue analysis is to be performed.

The foundations of mooring fittings subjected to cycling loads are to be verified in fatigue.

2.4 Side-by-side configuration

2.4.1 When transfer operations may be done between the unit and another one in side-by-side position, such configurations are to be analyzed.

2.5 Berth area

2.5.1 The berth area is to be such that it allows a sufficient depth for the unit under-keel clearance at any states of the tide.

2.5.2 The case of emergency departure is to be taken into account for determination of the sufficient depth at any states of the tide.

2.6 Dolphins system

2.6.1 For this type of system, the unit is moored at a set of piles with the help of brackets and fenders.

2.6.2 Stiffness of soil, piles and fenders is to be taken into account in the mooring calculations.

2.6.3 For such systems, the gap between the unit and the fenders is to be taken into account in the calculations as it usually induces non-linear stiffness of the piles and fenders system, and may induce damping.

2.6.4 Attention is to be paid to the type of analysis to be used for the mooring calculations. A quasi-dynamic analysis with no coupling between low and wave frequencies may not be sufficient, given the non-linear stiffness of the piles (see Sec 3, [2.3.2]).

When selecting the type of analysis to be used, the compliance with the different assumptions is to be clearly demonstrated.

3 Mooring arrangements

3.1 Mooring lines

3.1.1 The mooring line design is to be in accordance with the requirements of Sec 3 and Sec 4.

3.1.2 Regarding the methods of evaluation to be used for the design, a great care is to be paid to the compliance with the required assumptions. In particular, the uncoupled quasi-dynamic analysis may not be sufficient when the mooring system natural period is less than five times the zero-up crossing period of the wave (see Sec 3, [2.3.2]).

The different methods, and the means to ensure their validity, are fully described in Sec 3, [2].

3.1.3 Hawsers and accessories are to be in accordance with the requirements of NI432 and NR216 (see Sec 1, [4.2]).

3.1.4 In this Article, the minimum breaking load (MBL) to be used for hawsers is the certified new wet breaking load.

3.1.5 The tension data in each mooring line are to be continuously monitored and available on board the unit by appropriate means. The load monitoring system is to be approved by the Society.

3.2 Release mooring hooks

3.2.1 When quick release mooring hooks are provided, gravity-based release mechanisms are not acceptable.

3.2.2 In case a remote release system is provided, the failure of a single component or of electrical power is not to result in the release of the mooring hooks.

3.2.3 Release mooring hooks are to be designed to be able to move in both vertical and horizontal planes.

3.2.4 Release mooring hooks are to be designed to release independently of each other.

3.2.5 The safe working load (SWL) of a quick release hook is defined as being equal to 60% of the minimum breaking load (MBL) of the mooring line.

3.2.6 The quick release hooks are to be capable of releasing the mooring lines, whether slack or under full SWL.

3.2.7 Release mooring hooks are to be tested to the following loads:

- proof load test: at 1,25 times the SWL
- release test: at the SWL.

3.2.8 Release mooring hooks are to be designed to withstand the mooring lines when loaded to the SWL and to the proof load.

3.2.9 The hook strength is to be documented by appropriate calculations, in accordance with the provisions of App 3.

Release mooring hooks are to be designed to withstand the loads specified in [3.2.7], and the allowable stress factor α to be considered for the strength criteria is as follows:

- for the safe working load ("static"): α = 0,6
- for the proof load ("testing"): α = 0,9

3.2.10 The SWL of the quick release hooks, expressed in tonnes, is to be clearly marked on each hook by weld bead outline, in such a location that it is always easily readable by the unit operators during any operation of the hook.

3.3 Winches

3.3.1 On-board winches may be of different drive type (hydraulic, electric, or steam) and of different control type (automatic or manual tensioning).

In the scope of the notation **POSA JETTY**, the winches are supposed to operate in brake mode. Drive components are not covered by the notation **POSA JETTY**.

This sub-article gives specific strength requirements.

Note 1: Additional guidance regarding the winch design is provided in the OCIMF guidelines mentioned in Sec 1, [4.2.6], item m).

3.3.2 Rated pull

The rated pull is the pull that the mooring winch is able to develop at the rated speed on the outer layer.

The rated speed is the speed able to be maintained with the rated pull applied to the mooring line. The rated speed in combination with the rated pull determines the power requirement for the winch drive.

3.3.3 Brake holding load

The brake holding load is to be taken equal to 60% of the line MBL.

3.3.4 Winch components

Winch frames, foundations, drums, shafts, bearings and brakes are to be designed to withstand the line when loaded at the design loads defined in Tab 1.

Strength of the winch components is to be documented by appropriate calculations, in accordance with the provisions of App 3.

The basic allowable stress factors to be considered (see the Offshore Rules, Pt B, Ch 3, Sec 3) are defined in Tab 1.

Table 1 : Design loads and strength criteria

Mooring winch components	Design loads	Allowable stress factor α
Frames and foundations	MBL	0,8
Drums, shafts and bearings	MBL	0,8
Brakes	80% of MBL	0,8

3.3.5 Marking of winch

The MBL of the mooring line, expressed in tonnes, is to be clearly marked on each winch by weld bead outline, in such a location that it is always easily readable by the unit operators during any operation of the winch.

3.4 Mooring fittings

3.4.1 Fittings, such as fairleads, bitts or bollards (list not exhaustive), may also be part of the mooring system.

Design specifications and documentation of these fittings, if any, are to be submitted to the Society for review.

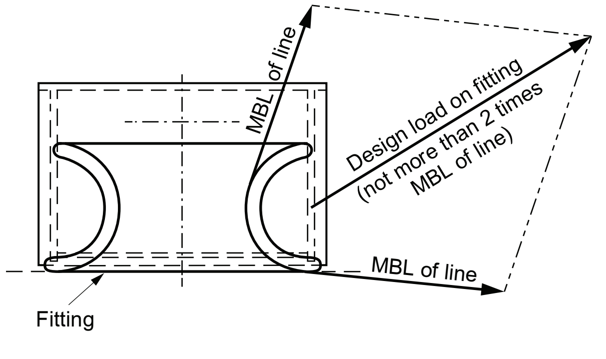
3.4.2 The fittings are to be designed to withstand a load corresponding to the mooring line MBL, taking account of the mooring line entry and exit directions, as defined in Fig 1.

In case several mooring line arrangements are possible for a fitting, the one leading to the maximum resultant load on the fitting is to be considered.

Fitting strength is to be documented by appropriate calculations, in accordance with the provisions of App 3.

Note 1: Additional guidance regarding strength of the mooring fittings is provided in the OCIMF guidelines mentioned in Sec 1, [4.2.6], item m).

Figure 1 : Example of mooring component arrangement



3.4.3 Each mooring fitting is to be marked with the MBL of the mooring line.

3.5 Fenders

3.5.1 The fenders are to offer a sufficient surface area to avoid damaging both the jetty and the moored unit.

4 Design requirements for jetty

4.1 General

4.1.1 The jetty may be part of the scope of the notation **POSA JETTY**.

4.1.2 The design of the jetty structure is to comply with the Offshore Rules, Part B.

The design of the jetty foundations is to comply with the requirements of NI 605 (see Sec 1, [4.2.2], item d)).

5 Operating manual

5.1 Information to be included

5.1.1 Disconnection procedures

Disconnection procedures, if any, are to be included in the operating manual.

5.1.2 Environmental conditions

The limiting environmental conditions, in terms of operating conditions, and scenarios where disconnection decision is to be made are to be included in the operating manual.

The following environmental conditions are to be included, where relevant:

- wave height and period
- wind velocity
- current velocity
- minimum air and sea temperatures.

5.1.3 Hawsers

The design life of hawsers is to be documented in the operating manual.

Where relevant, the periodicity of the hawser inspections is to be documented in the operating manual.

5.1.4 Side-by-side operations

Where relevant, side-by-side procedures are to be fully documented in the operating manual.

The limit conditions for such operations are also to be included in the operating manual.

APPENDIX 1 CHARACTERISATION OF THE LINE RESPONSE

1 General

1.1 Test run

1.1.1 A characterisation of the line response is to be performed to obtain information on the respective contribution of the mean load, slow drift, and wave frequency motions to the line tension, the level of dynamic tensions, and to evaluate whether the quasi-dynamic analysis is sufficient. A relatively short run (from 10 to 15 min in real time) is generally sufficient.

The run conditions are to be taken as close as possible to those of the "wave governed" case leading to maximum quasi-dynamic tensions at fairlead, or at any other point of interest, in the governing (intact or damaged) situation.

1.1.2 The time series of the quasi-dynamic tension T_{qd} and the dynamic tension T_{dyn}, in N, is to be taken equal to:

$T_{qd} = T_{mean} + T_{lf} + T_{wfqd}$

$T_{dyn} = T_{mean} + T_{lf} + T_{wfdyn}$

where:

T_{mean} : Mean tension, in N

T_{lf} : Low frequency tension variation, in N

T_{wfqd}, T_{wfdyn} : Quasi-dynamic and dynamic wave frequency variations, respectively, corresponding to the difference between the total signal and the previous terms, in N.

T_{lf}, T_{wfqd} and T_{wfdyn} may be characterised by their standard deviation, respectively σ_{lf}, σ_{wfqd} and σ_{wfdyn}.

1.2 Characterisation

1.2.1 T_{mean} and T_{lf} are to be checked for consistency between dynamic and static response analyses.

1.2.2 Significance of the dynamic tension may be assessed from the following dynamic amplification factor DAF:

$DAF = \sigma_{wfdyn} / \sigma_{wfqd}$

Note 1: Ratio between the total (maximum) tensions T_{maxdyn}/T_{maxqd} from time domain simulation is not a proper indication, and cannot be considered as a DAF.

1.2.3 The quasi-dynamic analysis is sufficient, if one the following conditions is satisfied:

a) $\sigma_{lf} > \frac{1,9\ DAF\ \sigma_{wfqd}}{3,2 - \log T_0}$

where:

DAF : Coefficient defined in [1.2.2]. DAF is to be taken not less than 1

T_0 : Largest natural period defined in Sec 3, Symbols.

In that case, the low frequency part of the tension is governing over the wave frequency part.

b) $1,75\ (M + 1,8\ S) > 1,67\ (M' + 0,7\ S')$

and, if the analysed case is a damaged condition:

$M + 1,8\ S > M' + 0,7\ S'$

where:

M, S : Mean and (n − 1) standard deviations of the maximum tension over 5 simulations, in the same conditions

M', S' : Estimators of the same quantities in case of a dynamic simulation, taken equal to:

$S' = DAF \cdot S$

$M' = M + B\ (DAF - 1)$

with:

$B = M - (T_{mean} + 2\ \sigma_{lf})$

1.2.4 In case a) of [1.2.3], and on condition that DAF is undoubtedly below 1, the safety factors for the dynamic analysis may be used with the results of the quasi-dynamic analysis.

1.2.5 When the line dynamic is prevailing, plots of T_{dyn} versus T_{qd} and T_{dyn} versus dT_{qd}/dt are to indicate with which of these T_{dyn} is correlated, as needed for the selection of windows in the dynamic analysis.

1.2.6 For scanning through the combination of the unit conditions and metocean parameters, the following tension criteria (based on API RP 2SK, see Sec 1, [4.2.6], and the above data) may be used, with the results of a single quasi-dynamic simulation for each combination:

a) when low frequency is prevailing over wave frequency for the tension variations:

$T_{AL} = T_{mean} + (4,9 - 0,9 \log T_0)\ \sigma_{lfqd} + 2\ \sigma_{wfqd}$

b) otherwise:

$T_{AW} = T_{mean} + 2\ \sigma_{lfqd} + 3,7\ DAF\ \sigma_{wfqd}$

APPENDIX 2 COMBINATION OF METOCEAN PARAMETERS

Symbols

H : Waves

S : Swell

W : Wind sea

V : Wind

C : Current

H-V, C-V : Relative directions between waves and wind, and between (near) surface current and wind, respectively. Relative headings are between incoming directions and are taken positive, viewed from above, when clockwise in the northern hemisphere, and when anti-clockwise in the southern hemisphere

RP : Return period

N : Specified return period: n = log(N)

RP_0 : Reference return period: $r_0 = \log(RP_0)$ (see [3.3])

nXd : Number of exceedance per year: nXd = 1/RP

r : Reduction factor (see [3.3])

pe(X) : Probability of exceedance of X: pe(X) = p(x > X)

p_{asi} : pe for associated independent parameters.

1 General

1.1 Scope

1.1.1 This Appendix defines the combinations of metocean parameters to be considered as design metocean conditions for a mooring system (station-keeping, offshore tandem or side-by-side mooring, ….).

The criteria herein may be considered as minimum requirements, for guidance, and may be adjusted when more accurate data are available for the site under consideration.

1.1.2 These criteria are also applicable to heading analysis and sea-keeping analysis in extreme conditions (short term approach). In such cases, it is most often necessary to consider intermediate combinations between those defined herein.

Note 1: The approach is that the possible metocean design conditions for a N-year return period form a response contour, in the sense of the Inverse First Order Reliability Method (I-FORM), so that the N-year response is the maximum response over all the possible design points.

The N-year contour is notionally an hyper-surface in a multi-variate space. It is limited here to a set of discrete combinations, with generally one governing element, the others being 'associated values'.

The true contour (or a subset of it) is to be considered when supported by adequate data, and where needed.

See document in Sec 1, [4.3.1], item j).

2 Metocean data

2.1 Metocean conditions and design data

2.1.1 The metocean conditions at a given site are generally based on site measurements, or may be derived from satellite data or by hindcasting, duly validated by site measurements.

Processing of such a database is to provide metocean design data (extremes). The statistical techniques used to choose these values are to be documented, to the satisfaction of the Society.

The database processing is also to provide adequate joint statistics regarding the parameters.

2.2 Intensity and direction

2.2.1 The metocean data are normally available as the intensity of each element (wind speed, current speed, wave -or wave system- significant height), in function of the return period (independent extremes in all directions).

2.2.2 When available, directional data (i.e. different values per sectors of incoming -geographical- direction) may be used, provided they are consistent with all-direction data, as detailed hereafter.

Directional data are derived from joint (or conditional) distributions of intensity and incoming sector. Inconsistent variations between adjacent (small) sectors are to be removed by appropriate means, and values are to be properly "rescaled" as defined below (see document in Sec 1, [4.3.1], item j)).

Given:

X^* : The all-direction extreme value of an intensity variable X at a given return period

$pe(X, \Delta\Theta_k)$: The joint probability of exceedance of X in sector $\Delta\Theta_k$

$\Delta\Theta^*$: The most probable sector for exceedance of X^*,

thus:

$pe(X^*, \Delta\Theta^*) \geq pe(X^*, \Delta\Theta_k)$

$\Delta\Theta^*$ is also the incoming sector of the maximum of the directional values X_k (at the same return period).

Then the values X_k at the same return period in each sector $\Delta\Theta_k$ are to be such that:

- in sector $\Delta\Theta^*$:

  $X_k = X^*$, i.e. the maximum (over all sectors $\Delta\Theta_k$) of X_k is taken equal to the all-direction extreme value X^* at the same return period
- in other sectors:

  X_k is to be taken such that $pe(X_k, \Delta\Theta_k) = pe(X^*, \Delta\Theta^*)$, or lower.

Besides, $X_k = 0$ when $p(\Delta\Theta_k)$, the probability of incoming direction being in sector $\Delta\Theta_k$ is such that:

$p(\Delta\Theta_k) \leq pe(X^*, \Delta\Theta^*)$

Note 1: $p(\Delta\Theta_k) = pe(0, \Delta\Theta_k)$

2.2.3 For frequent values of intensities (see [3.3.5]), when needed, the all-direction value can be obtained from the observed (marginal) distribution of the considered parameter. Directional values can be then derived following the same method as above.

Note 1: The intensity for intermediate return periods between those quoted in the specification may be obtained by linear interpolation of intensity as a function of the (decimal) log of return period (i.e. of the factor r defined in [3.3]), or by fitting the data to an adequate extremal distribution.

Note 2: When RP is less than one year, it is more representative to quote:

- the number of exceedance, per year: nXd = 1 / RP, or
- the probability of exceedance, in % of time (based on 3-hour sea states): pe = 100 nXd / 2922

The intensity for a specified pe may be then obtained by linear interpolation of intensity as a function of the (decimal) log of pe, on the observed distribution.

Note 3: When the intensity is defined for a discrete set of incoming directions, the same value applies to any other direction within the sector around each specified direction.

2.3 Sea states

2.3.1 A Sea state may be described by:

- a wave spectrum (unimodal sea state), or
- the sum of several wave spectra (for multimodal -and generally multidirectional- sea states).

Each spectrum is defined by its significant wave height H_S, in m, the period T_P (or T_Z), in s, and additional parameters as relevant for the specified spectral shape (e.g. the peakness factor γ for a JONSWAP spectrum).

The significant wave height H_S is to be selected as per [3.3].

2.3.2 Associated parameters are generally available as a best estimate/most likely value.

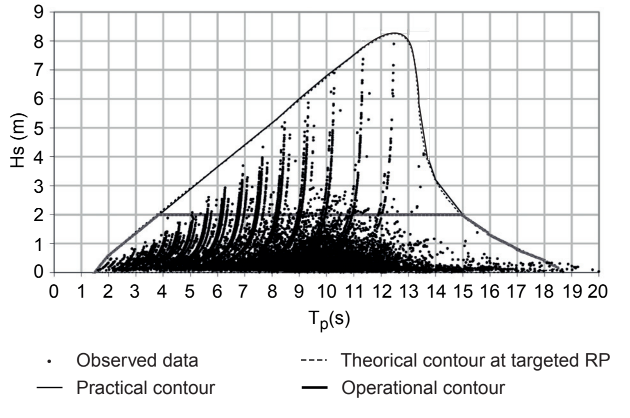
For the spectral peak (or zero-crossing) period T_P (or T_Z), when waves (or the sea state component under consideration) are quoted as the governing parameter, a range is to be considered around the specified value, as a minimum. A range of ± 15% (around the specified value) is to be considered. However, the minimum period may be adjusted, based on considerations of minimum steepness at considered site.

2.3.3 H_S/T_P (or H_S/T_Z) response contours (inverse FORM approach, e.g. see document in Sec 1, [4.3.1], item j)) may be used when available, and are to be preferred when the response is found very sensitive to wave period.

Contours are to be defined, covering a range of return periods. Where relevant and possible, directional contours (i.e. different H_S/T_P contours for different sectors) are to be defined.

The contour having its maximum at the specified H_S is to be selected, and scanned as being the most onerous H_S/T_P combination (i.e. the combination leading to the maximum response). However, it is recommended to take a plateau (i.e. no reduction of H_S) over not less than ± 10% around the specified period. See Fig 1.

Figure 1 : H_S/T_P contour (for illustration)



2.3.4 For spectral peakness parameter, when waves (or sea state component) are quoted as the governing parameter, a range of values is to be considered, unless (depending on the available data), a relation with e.g. steepness (or other relevant parameter) can be documented. In the other cases, the specified (mean) value may be used.

2.4 Wind

2.4.1 The design wind speed V is to be selected as per [3.3].

Sustained winds are specified by the 10-minute or 1-hour average speed (see Sec 3, [3.1] and Sec 3, [3.2]), typically at 10 m above the sea level.

2.4.2 Squall winds are defined from records of wind speed and direction with time.

For input to analysis, the record is adjusted as follows:

a) The wind speed record V(t) is rescaled to get the design 1-minute mean speed.

Note 1: The rescaling factor is thus equal to: $V_{1'}$ specified / $V_{1'}$ max

where:

$V_{1'}$ max : Taken equal to:

- the maximum velocity in the record, if time step of record is 1 minute, or
- the maximum over the record of the calculated 1-minute average speed (sliding average), if time step of record is smaller.

For cases where $T_0 < 1$ min, the 3-second gust speed squall is to be considered (See Sec 3, [3.1.3]).

b) The wind direction record D(t) is shifted by the difference between a reference direction D_r in the record (usually taken as the direction at time of V max) and the reference direction D_s specified for each simulation, thus preserving the variation of wind direction with time, together with the variation of wind speed.

Note 2: That is to write: $D_c(t) = D(t) - D_r + D_s$

2.5 Current

2.5.1 The design current speed C is to be selected as per [3.3].

2.5.2 Actions on floaters

When a current profile is specified, an average speed may be considered for the actions on floaters.

Note 1: Pending more accurate evaluations, the average current speed may be taken as the average over a depth of:

- 1,3 times the unit draft for ship- and barge-shaped units
- 1,1 times the unit draft for semi-submersible units.

2.5.3 Actions on risers and mooring lines

In shallow and medium water depths, the relevant current profile is to be considered.

In deep waters, surface currents and currents over the water column are generally uncorrelated and are to be considered in separate sets of design conditions.

3 Metocean design conditions

3.1 Principles

3.1.1 The design metocean conditions for a specified N-year return period are defined as combinations of direction and intensity of waves, wind and current, and of associated parameters.

Depending on the climatic conditions at site, several sets are defined. In each set, one of the elements is generally governing.

For each set, the intensity of the elements is to be selected with values depending on:

- the degree of correlation of the extremes, both in intensity and in direction, that are also depending on the climatic conditions at site
- the relative directions between the elements.

Note 1: This is intended to take into account that extreme values of element intensities may not all result from the same meteorological conditions, nor from the same storm event, nor at the same time within the same event, so are not to happen simultaneously, nor necessarily with the same incoming direction.

The criteria to select intensities are defined in Articles [4], [5] and [6], for different types of climatic conditions.

These criteria are given for guidance and may need adjustments when more accurate data are available for the site under consideration.

Note 2: For a given site, several climatic conditions may be applicable, depending on the season.

3.2 Directions

3.2.1 All the relevant combinations of direction of the governing element (or an element taken as reference) and the relative directions between the elements are to be investigated by appropriate scanning.

In principle, scanning is to be performed over 360° for the governing (or a reference) element.

For each of the other elements, scanning is to be performed over an interval large enough to provide the evidence that a maximum response has been caught. Generally, the relative direction between any two elements need not exceed 120°.

A scanning step of 15° is generally sufficient to catch a maximum response, taking into account the directional variations of intensities.

Note 1: The scanning interval may be reduced, depending on the symmetry(ies) of the mooring system (same lines over a flat bottom) and of the unit (including load coefficients, e.g. for wind), and taking into account the required accuracy (envelope or results in individual lines). Such a reduction, however, is to preclude the use of directional data.

Note 2: Depending on the type of mooring (e.g. spread or turret), considerations of, e.g., the relative contribution of the elements to the total mooring force or to the line tension (as evidenced by test runs, see also App 1) may be used to optimise the scanning effort and organise it in appropriate steps, but are not to replace such scanning.

3.2.2 Directional sectors are defined for the following conditions: extratropical, equatorial and tropical storm.

Due to physical phenomena (Coriolis effect, …), some sectors could be unsymmetrical. These sectors, defined for Northern hemisphere in this Rule Note, are to be inverted in case of study in Southern hemisphere areas.

3.3 Intensities

3.3.1 The intensity of the elements is specified from [3.3.2] to [3.3.6], except otherwise noted, by the return period RP of the value to be used.

3.3.2 Combination of metocean parameters for extratropical and equatorial conditions

For a design return period N of the combination of the extreme metocean parameters as defined in Sec 3, [10.4], the return period RP of the metocean parameters to be used in the combination is to be calculated as follows:

$$RP = N10^{r_n}$$

where:

N : Design return period of the combination of the metocean parameters: n = log(N)

$$r_n = \frac{(n+3)\cdot(r+r_0-2)}{5}$$

r : Reduction factor, function of the relative directions between the elements:

- for extratropical conditions, r is defined in Tab 1, Tab 2 and [4.4]
- for equatorial conditions, r = 0

$r_0 = \log(RP_0)$

with:

RP_0 : Reference return period to be taken into account in the combination for the considered metocean zone (extratropical, equatorial) and the governing conditions, and defined in Tab 1, Tab 2 and Tab 3.

When the design return period N is equal to 100 years, the formula of RP may be simplified as follows:

$RP = RP_0\ 10^r$

3.3.3 Combination of metocean parameters for tropical storm conditions

For tropical storm conditions, the provisions of [6.3] and Tab 4 are to be applied.

3.3.4 For tropical cyclonic conditions (see Article [6]), a reduction factor on the N-year value is specified instead of the above formulae.

3.3.5 Frequent values of intensities are specified by the following probability of exceedance:

$pe(X) = p_{asi}$

p_{asi} = 11% may be considered in the combinations (corresponding to $RP = 10^{-2,5}$ in [3.3.2]).

Then, r = 0 in any combinations.

Note 1: Other value is to be used if defined in the Company's specifications (e.g. p_{asi} = 5% for West Africa).

3.3.6 When directional data are used, intensity for each element is taken as the intensity in the geographical sector where that element is lying.

3.4 Operating conditions

3.4.1 The limiting operating conditions may be specified in different ways (see Sec 3, [10.5]).

3.4.2 When the limiting conditions for specific operations are infrequent, they can be defined by a return period (not less than one year). Then the combinations of metocean parameters are defined in the same way as (extreme) design conditions, taking into account the specified return period.

3.4.3 More frequently occurring conditions are specified by limiting values on some measurable parameters.

Then the combinations of metocean parameters are to be established, based on:

- a set of combinations, as applicable to the specific climatic conditions, with however, except those between wind and wind sea, no restriction on the relative direction between elements
- intensities taken, for each element in a combination, as the lowest of the explicitly specified limiting value, and the value in the N-year design (extreme) combination (with no restriction for relative direction, see [3.3.2], except factor r_v for wind and wind sea, where applicable).
- a range of wave period, selected based on a N-year contour, unless otherwise specified in criteria.

Note 1: The same acceptance criteria as for extreme conditions are applicable to operating conditions. Thus, notionally, the contour for operating conditions is defined by applying to the N-year design (extreme) contour the limiting criteria that are explicitly specified (e.g. the combined H_S of the sea state). See Fig 1

4 Extratropical conditions

4.1 Applicability

4.1.1 The combinations in [4.2] to [4.5] are applicable to areas where metocean conditions are driven by extratropical storms during the whole year (e.g. North sea, Mediterranean sea, …) or at some seasons (e.g. winter storms in tropical areas), in which:

- wind driven seas and wind driven current are governing over other components
- sea states are described by an unimodal spectrum and, most often, the strongest sea states are unimodal wind seas.

Some swell is however often present and, in some areas (North West Europe, South West Atlantic, …), a bimodal description is more appropriate: see [4.5].

4.2 Typical design conditions

4.2.1 Three typical conditions may be defined, as follows:

- wave governed, with the following relative headings:

  H-V between –45° and +60°, and

  C-V between –60° and +60°
- wind governed, with the following relative headings:

  H-V between –45° and +60°, and

  C-V between –60° and +60°
- current governed, with the following relative headings:

  H-V between –30° and +45°, and

  C-V between –60° and +90°.

Note 1: In a mooring analysis, the wind governed condition may be omitted in most cases, subject to documentation, to the satisfaction of the Society.

4.3 Selection of return periods

4.3.1 Data for the selections of return periods as per [3.3] are given in Tab 1, for N = 100 years.

However, when directional wave data are used, and unless swell is modelled as per [4.5], a minimum value of H_S is to be considered to account for occurrence of swell: see [4.4.3].

Table 1 : Extratropical conditions - Reduction factor r and return period RP_0 for N = 100 years

Type of combination	Waves H		Wind V		Current C	
	RP_0, in years	r	RP_0, in years	r	RP_0, in years	r
H governed	100	$r_v + r_c$	50	$r_v + r_c$	10	0,8 r_c
V governed	50	$r_v + r_c$	100	$r_v + r_c$	10	0,8 r_c
C governed	10	0,8 $(r_v + r_c)$	10	0,8 $(r_v + r_c)$	100	r_c

4.4 Reduction factors

4.4.1 Reduction factor r_v

The reduction factor r_v is given by (see Fig 2):

$$r_v = 1 + \frac{H\text{-}V}{15} \quad \text{when } -45° \leq H\text{-}V < -15°$$

$$r_v = 0 \quad \text{when } -15° \leq H\text{-}V \leq +30°$$

$$r_v = 2 - \frac{H\text{-}V}{15} \quad \text{when } +30° < H\text{-}V \leq +60°$$

4.4.2 Reduction factor r_c

The reduction factor r_c is given by (see Fig 2):

$$r_c = 0 \quad \text{when } |C\text{-}V| \leq 45°$$

$$r_c = 1 - \frac{|C\text{-}V|}{45} \quad \text{when } 45° < |C\text{-}V| \leq 90°$$

4.4.3 Notes

- Contours of r_v and r_c may be adjusted when adequate data of joint occurrence are available.
- When a value of current quoted as "simultaneous" (with wind or waves) is defined in the Site specification, the values of C in a combination (wind and wave governed conditions) may be taken as the lowest between the specified value (without reduction for relative direction) and the value obtained by the above criteria for that specific combination.
- When directional data are used, and to account for the possible occurrence of some swell that is uncorrelated with wind, H_S in any direction are to be taken not less than the smallest directional values of H_S at the return period RP_0 (i.e. without reduction for relative direction) specified in Tab 1 for the subject combination (or another appropriate value).

4.5 Conditions with swell

4.5.1 Following combinations are to be added to those given in [4.2]:

- Swell governed, with the following relative headings between wind-sea W, wind and current:

  W-V between –30° and +45°, and

  C-V between –60° and +60°
- Swell with wind and wind sea, with the following relative headings:

  W-V between –45° and +60°, and

  C-V between –60° and +60°
- Swell and current, with the following relative headings:

  W-V between –30° and +45°, and

  C-V between –60° and +90°.

Note 1: Swell is assumed here to be independent of the other parameters, both in intensity and in direction, so any direction is to be considered over 360°, and no reduction is applicable (i.e. r = 0) for the relative direction between swell and other elements. However same direction as in [4.4] above are applicable to W, V and C combinations.

Note 2: In a mooring analysis, when swell intensity is significantly lower than wind seas, these conditions may be omitted in most cases, subject to documentation to the satisfaction of the Society.

4.5.2 Data for the selections of return periods are given in Tab 2.

Figure 2 : Reduction factors r_v and r_c

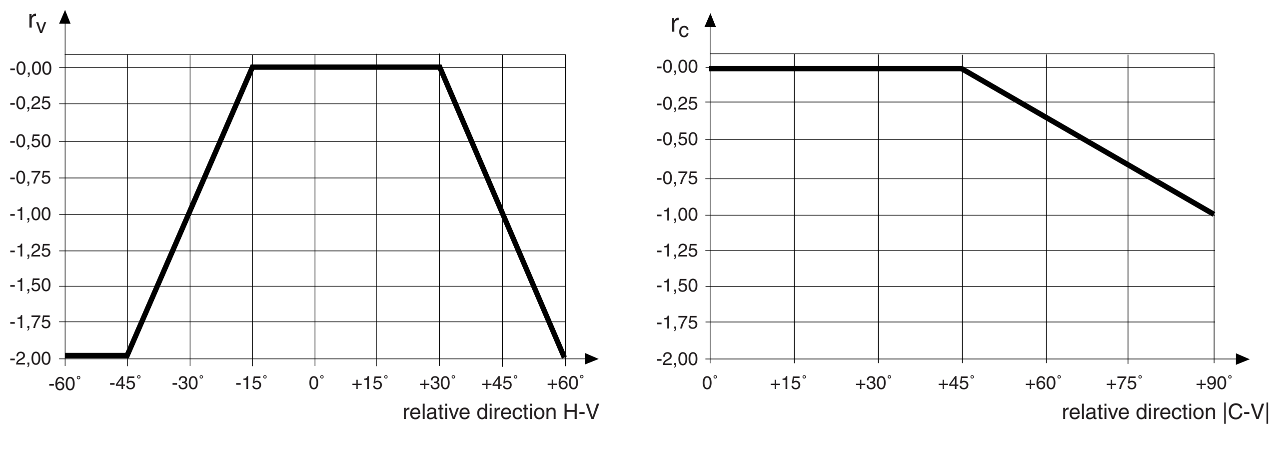


Table 2 : Extratropical conditions with swell - Reduction factor r and return period RP_0 for N = 100 years

Type of combination	Swell S		Waves W		Wind V		Current C	
	RP_0 (years) or pe	r	RP_0 (years) or pe	r	RP_0 (years) or pe	r	RP_0 (years) or pe	r
W governed	–	–	100	$r_v + r_c$	50	$r_v + r_c$	10	0,8 r_c
V governed	–	–	50	$r_v + r_c$	100	$r_v + r_c$	10	0,8 r_c
C governed	p_{asi}	–	10	0,8 $(r_v + r_c)$	10	0,8 $(r_v + r_c)$	100	r_c
S governed	100	0	p_{asi}	–	p_{asi}	–	p_{asi}	–
S and V + W	1	0	1	0,6 r_v	1	0,6 r_v	p_{asi}	–
S and C	1	0	p_{asi}	–	p_{asi}	–	1	0,6 r_c

5 Equatorial conditions

5.1 Applicability

5.1.1 Climate in equatorial conditions (e.g. West Africa) is characterised by long distance swells, local winds and currents, all three having distinct sources, thus being almost uncorrelated.

In addition, some distinct local events, typically not represented in the statistical distributions, are to be considered (see [5.2.3]).

5.2 Typical design conditions

5.2.1 Three base combinations may be defined as follows:

- swell governed
- wind governed
- current governed.

5.2.2 Three intermediate combinations are also to be considered:

- swell and wind
- swell and current
- current and wind.

Alternatively, these three combinations can be conservatively merged in a single one.

5.2.3 Additional combinations include:

- squall wind condition
- local current (e.g. surface current) condition.

5.3 Waves and wind

5.3.1 Waves are described in this sub-article as a combination of swell and wind-sea.

5.3.2 Swell is often a combination of several independent swell systems, but the strongest sea states usually show unimodal swell.

Then the swell governed condition could be separated in:

- a main swell governed condition (with unimodal swell)
- concomitant swells condition (multimodal).

5.3.3 Winds (other than squalls) are rather weak, and the higher frequency part of wave spectra, often denominated as "wind seas", is not well correlated with wind.

Note 1: However, for practicality, wind-sea is hereafter assumed correlated with wind.

5.4 Selection of return periods

5.4.1 Data for the selections of return periods are given in Tab 3, for N = 100 years.

In the combinations, the associated values of non governing parameters may be taken as a "frequent value" (see [3.3.4]).

Table 3 : Equatorial conditions
Return period RP_0 or pe (in years) for N = 100 years

Type of combination	Swell S	Waves W **(1)**	Wind V	Current C
S governed	100	–	p_{asi}	p_{asi}
V / W governed	p_{asi}	100	100	p_{asi}
C governed	p_{asi}	p_{asi}	p_{asi}	100
S and V / W	1	1	1	p_{asi}
S and C	1	p_{asi}	p_{asi}	1
C and V / W	p_{asi}	1	1	1
Squall wind	p_{asi}	p_{asi}	100 **(2)**	p_{asi}
Local current	p_{asi}	p_{asi}	p_{asi}	100 **(2)**

(1) If present. See [5.5.2].
(2) Following the relevant distribution.

5.5 Directions

5.5.1 Owing to lack of correlation, swell, wind (or squall) and current (or local current) are to be taken as acting together in any combination of directions, each over all possible directions, and no reduction factor r is applicable (i.e. r = 0 is to be taken in [3.3]).

5.5.2 The relative direction of wind-sea with wind may be assumed not to exceed 45°. In addition W = 0 (i.e. no wind sea) can be considered when its anticipated direction is falling in a sector in which no wind-sea was observed.

6 Tropical storm conditions

6.1 Applicability

6.1.1 Extreme conditions in areas affected by tropical storm (e.g. Gulf of Mexico, South East Asia, North West of Australia) are governed by occasionally passing hurricanes/typhoons, causing strong wind, waves and current, with rapid variations of both intensity and direction over a limited time.

In this case, associated values are better defined by a ratio to the specified extreme, and the wave direction is used for reference.

Directional data are to be used with caution. Their derivation needs special care.

6.2 Typical design conditions

6.2.1 Three typical conditions may be defined as follows:

- wave governed, with the following relative headings:
  V-H between –45° and +45°, and
  C-H between –30° and +30°
- wind governed, with the following relative headings:
  V-H between –45° and +45°, and
  C-H between –30° and +30°
- current governed, with the following relative headings:
  V-H between –45° and + 45°, and
  C-H between –120° and –60°.

Intermediate situations between the H governed and the C governed cases (with C-H between –30° and –60°) should be considered if needed.

Note 1: In a mooring analysis, the wind governed condition may be omitted in most cases, subject to documentation to the satisfaction of the Society.

6.2.2 In addition, conditions for winter/monsoon seasons, and those for local currents (e.g. eddy currents) are to be separately considered, as defined above, when relevant.

6.3 Data for the intensity of the elements

6.3.1 For each parameter (H, V or C), the intensity X may be taken as:

$$X = c_X \cdot X_N$$

where:

X_N : Intensity at the specified return period N

c_X : Reduction factor to account for both the degree of correlation and the relative direction between elements.

6.3.2 Data for factors c_H, c_V and c_C are given in Tab 4.

If needed, factors c_H, c_V and c_C for intermediate situations (C-H between –30° and –60°) may be obtained by interpolation between the H and C combinations.

Table 4 : Tropical storm conditions Intensity of the elements

Type of combination	Waves c_H	Wind c_V	Current c_C
H governed	1,0	0,9 q_v	0,5
V governed	0,9 q_v	1,0	0,5
C governed	0,7 q_v	0,6 q_v	1,0

6.3.3 Reduction factor q_v

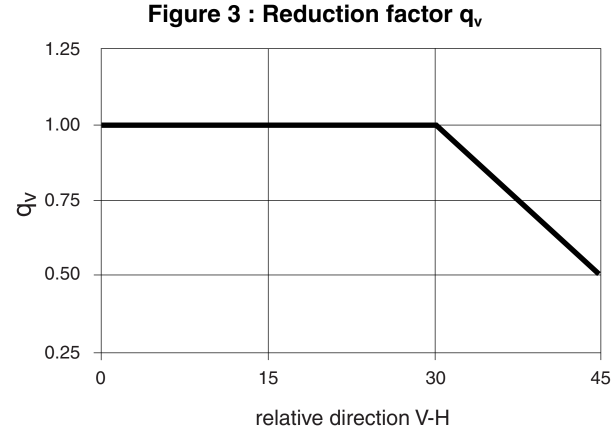
The reduction factor q_v is given by:

$q_v = 1$ when $|V\text{-}H| \leq 30°$

$q_v = 2 - \dfrac{|V\text{-}H|}{30}$ when $30° < |V\text{-}H| \leq 45°$

The reduction factor q_v is shown in Fig 3.

Figure 3 : Reduction factor q_v



APPENDIX 3 STRUCTURAL STRENGTH CRITERIA

1 General

1.1 Subject

1.1.1 This Appendix is applicable to the steel components of a mooring system such as:

- non standard connection and termination fittings
- anchors
- supporting structures in Unit hull or turret
- ancillary components.

1.1.2 Guidance is given on structural strength criteria, as a complement to the criteria specified in Offshore Rules, Part B, Chapter 2 and Chapter 3, and concerning:

- design loads
- assessment of strength based on non-linear analysis.

1.1.3 Fatigue strength and, where relevant, buckling strength are not addressed below and are to be duly considered following the applicable requirements of Offshore Rules and those of the present Note.

1.2 Design loads

1.2.1 As specified in Sec 4 and in Offshore Rules, Part B, Ch 2, Sec 3, [4.2], the reference load for design of steel components is the specified breaking strength that shall be considered as "load case 3" (accidental), with respect to the strength criteria of Offshore Rules, Part B, Chapter 3.

1.2.2 In addition to the above requirements, the following design loads are to be considered, as necessary:

- design tension T_D , in the intact conditions of the mooring system, as a "load case 2" (design)
- design line tension T_D , in the damaged condition of the mooring system, also as a "load case 2" (design)
- design line tension T_D , in the transient (line failure) condition of the mooring system, as a "load case 3" (accidental).

1.2.3 The line of action of the design load is generally dictated by the geometry of the component.

1.2.4 For items fixed to the Unit or to the anchor, the angular variations resulting from tolerances in system geometry, Unit offset and Unit motions are to be duly considered. Suitable ranges of orientation are to be specified, with consideration of the loads induced in each part of the item.

1.2.5 For structures on the Unit end, that may be subject to loads from several adjacent lines, combinations of loads may be derived from mooring analysis. In each of the condition of the mooring system, load combinations are to be categorised as in [1.2.2].

Several combinations of line loads in each case may be needed to assess strength.

1.2.6 Other loads acting simultaneously as the line loads are to be considered where applicable (e.g. soil reactions, for anchors).

Generally, self weight is negligible and can be omitted.

1.3 Elastic design

1.3.1 When assessment of strength is based on elastic analysis, the strength criteria in Offshore Rules, Part B, Ch 3, Sec 3 are applicable.

1.3.2 The following criteria are to be satisfied:

$\sigma_C \leq 1{,}1\ \alpha\ R_f$ and $\sigma_a \leq \alpha\ R_f$

where:

σ_C : Equivalent stress (as specified in Part B, Ch 3, Sec 3, [5.3] of the Offshore Rules), under the design loads as defined in [1.2]

σ_a : Axial stress, under the same conditions (pure tension case)

α : Allowable stress factor, as defined in Offshore Rules, Pt B, Ch 3, Sec 3, [5.4.2], for the case considered (see [1.2.2])

R_f : Reference stress (as specified in Offshore Rules, Pt B, Ch 3, Sec 3 [5.2.1]).

1.3.3 In case of assembly with contact between several elements, non-linear contact analysis may be omitted, provided the distribution of stresses in the body of the element is not sensitive to the distribution of pressure over the contact area.

1.3.4 Local high compressive stresses in contact areas can be generally ignored, if the geometry ensure confinement of the area, so that shear failure is not foreseeable, and if the above condition is also satisfied.

1.4 Design Based on Elasto-plastic calculations

1.4.1 General

The evaluation of the structural strength of the component may be based on elasto-plastic calculations. These calculations are to be based on the actual hardening law (stress-strain relation) of the considered material.

Elasto-plastic calculation is to be performed on finite element analyses solvers qualified for elasto-plastic evaluation, accounting for the effects of contacts and large deformations.

Contacts between mooring line components are to be adequately modeled. The Finite element model is to consider the actual succession of components in the mooring line in order to ensure that the line loads are adequately transferred at contact areas to the mooring line component. In case of multi-purpose mooring line components, such as for type approval of mooring line component, the model has to analyze the most critical succession of components, to be agreed with the Society.

Strength analyses through elasto-plastic FEM calculation are not to be performed for welded structures, or limited to area away from welded area, except otherwise agreed by the Society.

1.4.2 Material stress-strain curve for elasto-plastic calculations

The material curve is to meet the minimum guaranties material properties in the component.

It has to be implemented in the elasto-plastic FEM calculation by considering the Cauchy true stresses and logarithmic (true) strain corresponding to the minimum guaranteed "engineering" material properties provided by the manufacturer.

$\sigma_{True} = \sigma_{eng} \times (1 + \varepsilon_{eng})$

$\varepsilon_{true} = \ln (1 + \varepsilon_{eng})$

The use of bilinear material curve, even if more conservative, may induce numerical divergences. Therefore, a Ramberg-Osgood (R-O) strain hardening law is recommended.

R-O curves describe a non linear relationship between stress and strain.

As a guidance, the R-O relationship and a generic representation Fig 1 of the stress-strain curve are presented below.

$$\varepsilon = \frac{\sigma}{E} + \alpha \times \left(\frac{\sigma_0}{E}\right)\left(\frac{\sigma}{\sigma_0}\right)^n$$

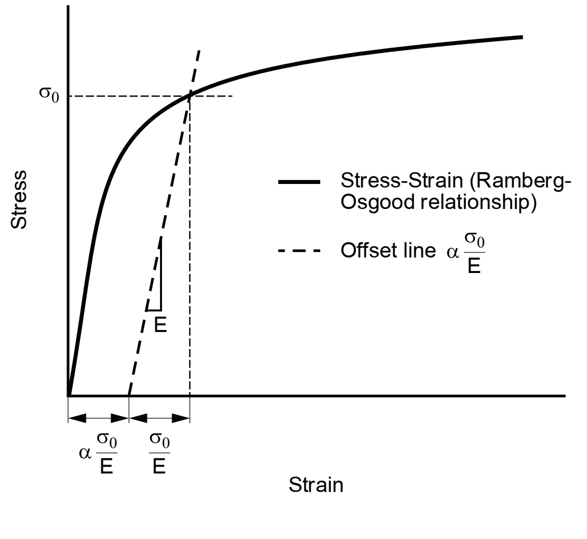
Where:

σ_0 : Reference stress (generally $\sigma_0 = \sigma_y$, yield stress)

E : Young's Modulus

α and n : Material constants.

Figure 1 : Representation of the stress-strain curve (Ramberg Osgood relationship)



The material hardening curve is to meet the following characteristics (or to be proven more conservative):

- the minimum required yield stress is met at 0,2% plastic strain
- the material is considered as linear below this limit
- the tensile stress is met at minimum guaranteed logarithmic (true) strain at tensile stress ε_m
- The material curve may be extended in the calculation for computional stability reasons, or in order to cope with meshing singularities in contact areas between components.

The minimum guaranteed logarithmic (true) strain at tensile stress ε_m is to be provided by the manufacturer, based on tensile tests of the same grade of material for equivalent component sizes.

Comparison of guaranteed minimum strain at tensile stress with FAT tensile tests results of components with equivalent material grades and size may be required by the Society.

The minimum guaranties material properties used in the calculation will have to be verified during the factory acceptance tests of the component, in particular the yield stress at 0,2%, the tensile stress and the corresponding strain level.

In absence of more detailed data, the logarithmic (true) strain at tensile stress ε_m may be evaluated as following, as a function of the elongation at break A in percent:

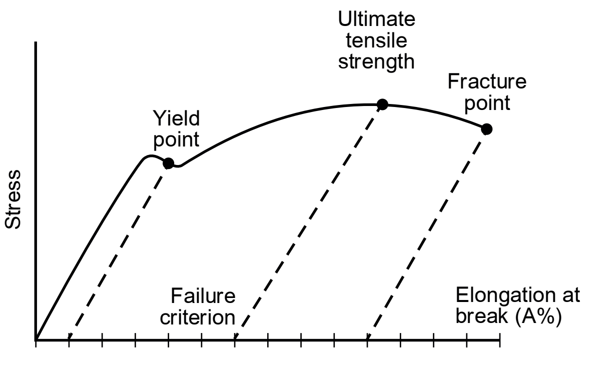
$\varepsilon_m = 0{,}5 \ln (1 + A)$

A example of stress-strain curve is given hereafter, see Fig 2

1.4.3 Design criterion

Due to the thickness of mooring line components, necking is not able to develop in large components, as it may develop in tensile test specimens. Due to this inability of the material to cope with tensile and shear loads, instability of the material will occur that will eventually result in the failure of the material. Due to the unpredictable behavior of the material after necking, the allowable equivalent strain is limited to the minimum guaranteed strain at tensile stress.

Figure 2 : Example stress-strain curve



For a mooring line component, the failure criterion can thus be defined:

- as a local equivalent plastic strain excessing the strain at tensile stress
- as the onset of large deformation of the component, imparing the functional requirements of the components
- as the excessive loads with regards to material toughness.

The load is to be applied by increment until the failure criterion is met. The failure criterion is not to be met for loads lower than the minimum required failure load in the elasto-plastic calculation, defined as following:

$$L_f = \frac{\beta L_d}{\alpha}$$

where:

L_d : Design load

L_f : Minimum required failure load

β : Factor to be taken equal to 1,05 for line components and 1,15 for on-vessel supporting structure and for anchoring pad-eyes

α : Allowable stress factor, ad defined in Offshore Rules, Pt B, Ch 3, Sec 3.

Note 1: The analysis may be stopped when the minimum required failure load Lf is met. It is however recommended to continue calculations till failure criterion or first computational instability in order to evaluate calculated breaking load and compare it with minimum breaking load.

1.4.4 Data to be provided for review

The following data are to be provided for the design review:

- The minimum guarantied material curve used in elastic-plastic calculations and the material tensile tests it is based upon
- Stress and plastic strain outputs at design load and at minimum required failure load, including graphical outputs with relevant cross sections and tabulated results. As a general matter, Von Mises stresses and equivalent plastic strain will be required. Additional stress and strain outputs may be required by the Society on a case by case basis
- Charts of stress, plastic strain, and deformations of relevant points of the model with load increment during elasto-plastic calculation.