



**BUREAU
VERITAS**

Classification of Mooring Systems for Permanent Offshore Units

June 2004

**Guidance Note
NI 493 DTM R00 E**



MARINE DIVISION

GENERAL CONDITIONS

ARTICLE 1

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

The Society:

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

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

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

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

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

ARTICLE 2

2.1. - Classification is the appraisalment 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 appraisalment 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 appraisalment or cause to modify its scope.**

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

ARTICLE 3

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

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

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

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

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

ARTICLE 4

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

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

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

ARTICLE 5

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

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

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

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

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

ARTICLE 6

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

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

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

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

ARTICLE 7

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

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

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

ARTICLE 8

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

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

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

ARTICLE 9

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

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

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

ARTICLE 10

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

ARTICLE 11

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

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

ARTICLE 12

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

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

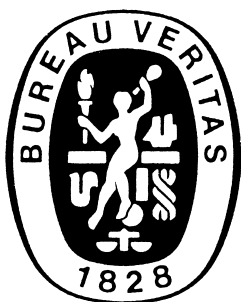
12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and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

ARTICLE 13

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

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

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



GUIDANCE NOTE NI 493

Classification of Mooring Systems for Permanent Offshore Units

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NI 493

Classification of Mooring Systems for Permanent Off-shore Units

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SECTION 1

GENERAL

1 Subject

1.1

1.1.1 The subject of this document is the mooring system (station keeping system) of floating offshore units that are permanent installations as defined in Chapter 1 of the Rules for the Classification of Offshore Units.

This document gives technical requirements, criteria and guidance on the design, construction and installation of mooring systems, as a complement to the above mentioned Rules and other publications of the Society, for the granting of the additional notation **POSA** to the unit.

1.2 Rules and related documents

1.2.1 Rules

- Rules for the Classification of Offshore Units (1998)

- NR 216 -1997: Rules and regulations for the classification of ships and offshore installations - Materials
- NR 467.D1 (February 2003): Rules for the Classification of Steel Ships – Part D “Materials and Welding”, Chapter 1, Chapter 2 and Section 2 of Chapter 5.

1.2.2 Guidance and Rule Notes

- NI 461: Quasi dynamic analysis of mooring systems
- NI 432: Certification of synthetic fibre ropes for mooring systems
- NR 426: Construction survey of steel structures of offshore units and installations
- NR 320: Approval and inspections at works of materials and equipment for the classification of ships and offshore units.

SECTION 2

CLASSIFICATION REQUIREMENTS

1 General

1.1 Context of classification

1.1.1 Within the context of the classification of a floating offshore unit as defined in the Rules for the Classification of Offshore Units, the **POSA** notation is addressing the station keeping capability of the unit, within the limits of applicability defined in [1.2] and [1.3].

1.1.2 For floating units such as FPU's, F(P)SO's, off-loading buoys (this list is not limitative), that are considered as "permanent installations", the station keeping capability is deemed a Safety Critical element and the compliance to **POSA** notation is a Classification Requirement.

1.1.3 General provisions

The general provisions of Chapter 1 of the Rules for the Classification of Offshore Units, where the principles, conditions, and other aspects of the Classification process are defined, are fully applicable, as relevant.

1.1.4 Maintenance of Class

Conditions for the maintenance of Class, as defined in Chapter 2 of the Rules for the Classification of Offshore Units, also apply to **POSA**, with specific requirements as given in section 2-12.3 of the Rules for the Classification of Offshore Units (see also [3] hereafter).

1.2 Applicability of POSA notation

1.2.1 The **POSA** notation covers, in general terms, the station keeping system of a free-floating body by means of a principally passive system.

This notation covers all the possible types of anchoring patterns (such as spread mooring, internal or external turret, etc.), line make up, and materials (such as chain, wires, fibre ropes, in catenary or taut configuration, etc.).

The **POSA** notation does not cover however a Tension Leg Platform, that is not deemed a free-floating body, nor its tendons system.

The **POSA** notation also covers Thruster Assisted mooring (see [1.3.1]). However, Dynamic Positioning is not covered by **POSA** but by other notations.

1.3 Limits of POSA notation and interfaces with Class

1.3.1 The **POSA** notation covers all the outboard elements of a mooring system, namely:

- anchors, whatever type (drag anchors, piles, suction piles, etc.),
- all the components of load bearing lines, including line segments and connecting devices,
- all the ancillary components, such as buoys, sinkers, and their attachment to the main lines, excluding those that are used solely at time of deployment of the mooring system.

1.3.2 **POSA** notation also covers:

- fairleads and stoppers on the vessel (in whole, i.e. including vessel-side female support parts),
- any associated monitoring and control systems.

1.3.3 For permanent installations, the **POSA** notation does not cover windlass, winches, sheaves, used for deployment of the system or for occasional handling of lines during vessel operation, nor associated monitoring and control systems (separate certification may be performed on request).

However, the foundations of these items into hull or on the turret are considered as part of the vessel hull and covered by the Main Class of the Vessel.

Note 1: During the classification process, organization of classification activities will take due account of the respective scopes of Contractors, in case the limits of Contractors' scope differ from those above.

Equipment and systems related to Thruster assistance, if any, shall be separately covered under the classification Mark for Machinery, as a condition for the granting of **POSA** notation.

For other configurations that are not explicitly addressed hereabove, the limits of **POSA** notation will be specified on a case by case basis.

2 Scope of activities for POSA notation

2.1 General

2.1.1 As for other Disciplines or Systems, Classification activities will span over all phases of a project:

- design of the mooring system and of principal components (engineering): proposed design and related documentation are reviewed by the Society,
- detailed design, manufacturing, and testing of all components (procurement): detailed design is reviewed, and Surveys are made of the manufacturing and testing,
- installation on vessel and deployment of the system at site (deemed equivalent to the construction of a structure): installation activities are Surveyed,
- in Service inspection, for the maintenance of Class.

2.2 Certificates

2.2.1 Upon satisfactory completion of the installation of the system and of all activities before, and of related Surveys by the Society, the **POSA** notation is granted and entered in the Initial Hull Classification Certificates of the Vessel.

2.3 Design

2.3.1 The design of the mooring system is to be performed on the basis of vessel data, operational data and environmental data, as specified in Section 4-1 of the Rules for the Classification of Offshore Units.

As a prerequisite to the activities of design assessment, the metocean and sea-bottom data are to be examined by the Society, following the provisions of Section 4-2 of the Rules for the Classification of Offshore Units. In accordance with the sub-section 4-2.1.2 of the same document, background data (metocean information, bathymetry and geotechnical survey reports) are also examined.

Model test specification is to be submitted to the Society for examination.

The mooring system is to be designed in accordance with the provisions and criteria specified in the present document, where guidance is also given on the methodology for the analysis.

Statements of design review are issued following the relevant procedures.

2.4 Components of mooring system

2.4.1 Line components

All the components of the mooring line are to be of the type and size defined in the documentation of the mooring system and are to be of adequate material and construction to meet the strength and durability properties identified therein. Specifications prepared by the designer of the system will be reviewed.

All components that are not purpose-designed for a specific system shall be type approved by Bureau Veritas and are to be manufactured and tested under Survey by Bureau Veritas.

The design, the materials and the construction of components that are purpose-designed for a specific system (e.g. suction piles), are to be in accordance with the provisions of Sec 4 and relevant provisions of the Rules for the Classification of Offshore Units.

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

The manufacturing of materials and sub-components, and the construction of components are to be performed under survey by the Society, according to an approved program.

Certificates will be delivered to each set of items, upon satisfactory completion of all related reviews and Surveys.

2.4.2 Load control system

For deep water moorings, taut systems, fibre rope moorings, and other cases where the verification of line pre-tensions cannot be achieved by conventional methods, a permanent load monitoring device shall be fitted on each line, for the control of line pre-tensions at the time of the installation and of periodical surveys.

System may include the transmission of an alarm in case of line failure, or capability for continuous recording over some time, e.g. for re-tensioning operations. Associated computer software shall be in accordance with applicable provisions of NI 425 "Recommendations on the quality of software on board".

2.5 Survey of installation and deployment

2.5.1 Installation on Vessel

The installation of vessel-side items (fairleads, stoppers, chainhawses, etc....) and on-board equipment and related systems is to be performed under Bureau Veritas Survey, in accordance with applicable provisions of the Rules for the Classification of Offshore Units (these activities will be usually carried out within the frame of Vessel Classification Surveys).

Survey will cover quality of construction work (particularly through weld NDT) and functional tests of mechanical equipment. Load tests are normally not required but, if performed, will be attended.

2.5.2 Deployment at site (installation)

Survey of installation is performed on the basis of general provisions of the Rules for the Classification of Offshore Units, and particularly those of Section 5-6 "Construction survey".

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

Installation tolerances are to be specified in the installation procedures, and duly taken into account in design calculations.

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

- installation of anchors,
- deployment of mooring lines,
- test loading of anchor and lines (see Sec 3, [9.4]),
- connection to Vessel and tensioning,
- post-installation inspection of the system (by divers and/or ROV Survey).

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

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

Surveys will include attendance of operations at site by the Bureau Veritas Surveyor, following an agreed program.

The Bureau Veritas Surveyor will review records and other documentation of the installation operations, prior to the delivery of a Certificate.

Note 1: Survey by the Society is by no way intended to substitute to Installator's duty to fully document installation of the mooring system.

3 In service surveys

3.1

3.1.1 In service surveys are to be performed in accordance with the requirements of Chapter 2 of the Rules for the Classification of Offshore Units "Maintenance of Class", in particular the section 2-12.3 which gives requirements for the attribution of **POSA** notation.

Specific provisions applicable to Fibre Rope mooring lines are given in NI 432.

SECTION 3

DESIGN OF MOORING SYSTEM

Symbols

- T_p : Peak period of the wave spectrum, in s
 T_0 : Largest natural period of the system for motions in the horizontal plane, in s.

1 General

1.1 Subject

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

The present Section is updating and complementing document NI 461 "Quasi-dynamic mooring analysis" and includes:

- recommended methodology for mooring analysis
- design criteria.

Alternative methodologies will be given consideration, on a case by case basis, provided they are demonstrated to provide a Safety Level equivalent to that resulting from the application of the present document.

1.2 References

1.2.1 Rules and related documents

- Rules for the Classification of Offshore Units (1998)
- NI 461: Bureau Veritas Recommended practice: "Quasi-dynamic mooring analysis" NI 461 -1995
- NI 432: Certification of synthetic fibre ropes for mooring systems (1997).

1.2.2 Other Industry documents

- API RP2SK: API "Recommended practice for design and analysis of Station Keeping systems for floating structures", RP 2SK, 1997
- ISO / DIS 19901-7: "Stationkeeping systems for floating offshore structures and mobile offshore units".

1.2.3 Papers

- (1) L. Leblanc, J.L. Isnard, H. Wilczynski: "A complete and consistent methodology for the assessment of mooring systems", OTC 7709, May 1995
- (2) M. François & al: "Statistics of extreme and fatigue loads in deep water moorings", OMAE01-2162, June 2001
- (3) X. B. Chen: "Approximation on the quadratic transfer function of low-frequency loads", 7th International BOSS conference, 1994

- (4) M. Le Boulluec & al: "Recent advances on the slow-drift damping of offshore structures", 7th International BOSS conference, 1994
- (5) M. François, P. Davies: "Fibre rope deep water mooring: a practical model for the analysis of polyester mooring systems" Rio Offshore 2000
- (6) Clark, P.J., Malenica, S., and Molin, B., 1993, "An heuristic approach to wave drift damping", Applied Ocean Research, 15, 0141-1187/93, p. 53-55
- (7) B. Molin (1994): "Second-order hydrodynamics applied to moored structures – A state-of-the-art survey" Ship Technology Res. Vol. 41.

1.3 Methodology

1.3.1 A methodology for analysis of mooring systems, the "Quasi-dynamic analysis", has been developed by Bureau Veritas, and presented in (1) (paper reference in [1.2.3]). Details of the methodology and related criteria are given in document NI 461 "Quasi-dynamic mooring analysis".

Since then, this methodology has been expanded in order to reflect progress of knowledge in the disciplines related to mooring analysis, and to address the analysis of mooring in deep waters, that were initially not covered.

The present document is updating and complementing NI 461 in this respect, and should be read in conjunction with it.

Background information is presented in paper (2) quoted in [1.2.3].

Note 1: Unless otherwise specified, documents quoted in [1.2.2] are for general reference and may complement, but not replace, the requirements of the present document.

1.4 Review of design

1.4.1 For the granting of the notation **POSA** to a Floating Offshore Unit, proposed design and supporting documentation will be reviewed, including, but not limited to:

- metocean data, soil data, and background information (see Section 4-2 of the Rules for the Classification of Offshore Units)
- proposed mooring arrangement and methodology for analysis
- reports of design analysis
- final arrangement proposed.

Verification will be generally performed by independent analysis, following the methodology of this document.

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

2 Methods of evaluation

2.1 Objective

2.1.1 The objective of analysis is to obtain information on vessel motions, the resulting excursions and line tensions, under some specified metocean conditions, that are 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 fatigue.

2.1.2 Available methods

The available methods of analysis vary by the approach taken to evaluate:

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

Model Tests are another possible source of information, as discussed below.

Guidance and criteria in the present document are made with reference to the Quasi-dynamic and the Quasi-dynamic / Dynamic line response methods, as defined below.

2.2 Quasi-static analysis

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

This method is often used at an initial planning stage, but is not deemed acceptable for system design nor for Class assessment.

2.3 Quasi-dynamic analysis

2.3.1 In a Quasi-dynamic analysis, that is described in (1) (see paper reference in [1.2.3]) and in NI 461, the dynamic vessel response is computed using a mixed time-domain/frequency domain analysis, taking into account quasi-static line response. Then, the line tensions are evaluated from the quasi-static line response to the fairlead motion.

This method is generally considered as the most adequate for moorings in shallow and moderate water depths, in the conditions specified in Section 1 of NI 461 and within the present Section.

2.4 Dynamic line response

2.4.1 In a Quasi-dynamic / Dynamic line response analysis, the dynamic vessel 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 applicable to deep water moorings, or very harsh metocean conditions, where the criteria of acceptability of Quasi-dynamic analysis are not met, and, in all cases, to fatigue analysis.

2.5 Other methods of analysis

2.5.1 Other methods of analysis, such as uncoupled frequency domain, may be considered for design, but will not be the basis of Class acceptance.

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

2.6 Model tests

2.6.1 Tunnel (or basin) tests are to be performed in order to obtain load coefficients for wind and current loads on the vessel.

Model tests in the Basin shall be carried out for the validation of the overall behavior of the system and the calibration of analyses.

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

Model tests however will not be generally deemed sufficient to fully document a design, due to 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 that can be addressed within a testing program.

Note 1: These tests, that are considered as a source of information for design, do not form part of physical testing activities during manufacturing and construction, and Surveyor attendance is generally not required.

3 Environment and actions

3.1 Environment

3.1.1 Waves

Waves are defined by the parameters of a wave energy spectrum. In some areas, it will be 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 modelling of waves by elementary Airy wave components, using the technique of random frequency and random phase, the number nf of elementary Airy wave components (in each spectrum) is not to be taken less than:

$$nf \geq 100$$

nor less than:

$$nf \geq 30 \cdot \sqrt{T_0/T_p}$$

provided the range of circular frequency ($\Delta\omega = \omega_M - \omega_m$) does not exceed $15/T_p$ (otherwise, nf is to be increased accordingly).

3.1.2 Wind

A description by a constant speed $V_{10\text{-min}}$ may be used for initial evaluations or when the natural period T_0 is not very large (typically less than 240 s).

Otherwise, e.g. in deep waters, a description by an appropriate wind spectrum should be used.

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

$$f_m = 2,7 \cdot 10^{-4}$$

The upper frequency and the number of frequencies are to be selected so that:

$$\Delta f < 0,1 / T_0$$

Strong and sudden winds (squalls) occurring in equatorial areas are to be modelled by representative time series of wind speed and direction.

3.1.3 Current

A description of near-surface current by a constant speed is normally sufficient. The current may be averaged over the vessel draft.

Sudden changes (local surface currents, loop currents) occurring in some 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

Consideration should be given to the use of "full QTF" (Quadratic Transfer Function, see paper (3) quoted in [1.2.3]), in the case where the Newman approximation might not be sufficient (as a guidance: when slow drift natural period is less than 150 s, or in very shallow waters).

3.2.2 Wind and current loads

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.

Note 1: Data in OCIMF are relevant for tankers, and not applicable to different hull shapes or arrangement of superstructure.

At initial design stage, load coefficients may be obtained from analytical expressions (e.g. extended Duchemin Formula) or other heuristic expression, provided all three components of force are taken into account (i.e.: along-flow (drag) force, cross flow force, and yaw moment). Reduction to the in-line component, as in A5 of API 2SK, is not considered adequate in this respect.

3.2.3 Riser loads

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

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

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

The mean static load, that is depending upon the instantaneous low frequency position of the vessel, 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 paper (2) quoted in [1.2.3]).

3.2.4 Damping

- a) Data in 2.5.7 of NI 461 are to be used, unless more accurate data is available from model test, or fully coupled analysis calibrated by model tests, to assist in the calibration of the slow-drift damping coefficients.

For vessel moored by only surface lines, as a vessel on a single point mooring or a shuttle tanker moored to a FPSO, the values from formula in 2.5.7 of NI 461 for tanker should be multiplied by a factor 0,37.

- b) A direct assessment of damping terms requires that main contributing terms are separately evaluated:
 - viscous damping on the hull is accounted for by the relative velocity formulation of the equations of manoeuvrability
 - wave drift damping may be obtained from the drift forces and its derivatives. Reference can be made to the formulation in papers (5) and (6) (see reference in [1.2.3]). In these papers the quadratic transfer function matrix is modified taking into account the slow drift velocity, the current speed and the instantaneous heading
 - damping due to lines (risers and mooring lines) may be estimated from line Dynamic calculations, or inferred from a fully coupled analysis.

3.2.5 Wave frequency motions

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

The effect of suspended load of the mooring lines and of risers (vertical and horizontal components), around the mean vessel position, is to 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.

4 Line response

4.1 Quasi-static line response

4.1.1 General

The quasi-static line response is based on the equations of the elastic catenary, which are developed in NI 461.

The elasticity properties of different materials are given in [4.1.2] to [4.1.5].

4.1.2 Chains

Data on Young modulus for stud chain are given in 2.2.3.2 of NI 461.

Young modulus for studless chain is 10 to 20% lower.

4.1.3 Wire ropes

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

4.1.4 Fibre rope mooring lines

A polynomial fit of the break load test load-elongation curve is not appropriate.

A model for the load-elongation characteristics of polyester deep water mooring lines is given in paper (5) (see reference in [1.2.3]).

4.1.5 Hawsers

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

4.2 Dynamic line analysis

4.2.1 The Dynamic line response is obtained from a finite element model of the line, using cable elements.

Table 1 : Hydrodynamic coefficients

	D _{eff}	CD _N (1) (3)	CA _N (1)	CA _L (1)	m _N
Chain	1,8 d	0,8	1	0,5	1,13 m
Wire rope	D	0,7	1	0	1,20 m
Fibre rope (2)			1,2	0,2	2,60 m
(1) Suffix N is for Normal (transversal) direction Suffix L is for Longitudinal (tangential) direction					
(2) For fibre rope, CA _N and CA _L are inclusive of entrapped water.					
(3) CD are specified as lower bound, to avoid unconservative over-estimate of damping effects.					

a) Hydrodynamic drag coefficient CD and inertia coefficient CA may be taken as shown in Tab 1.

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

- nominal chain diameter d, for chains
- rope outside diameter D, for wire rope and fibre rope.

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

b) Length of elements ℓ_i in finite element model should not exceed, for each segment of line:

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

where:

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

m_N may be obtained from Tab 1 based on the (in air) mass per unit length m of the line segment

F_{mean} : Mean line tension, in kN.

Note 2: A smaller length of elements is generally necessary in the touchdown area.

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

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

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

4.3 Characterization of the line response

4.3.1 When the Quasi-dynamic line response has been obtained, a test-run of Dynamic response shall be performed, in order to characterize the Dynamic response, and evaluate, or confirm, if the Quasi-dynamic response can be used for the evaluation of extreme loads.

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

Such evaluation may be omitted for chain moorings in moderate water depths (less than 150 m), if all the other conditions specified in NI 461 are met, and accordingly the safety factors for Quasi-dynamic analysis are used.

4.4 Dynamic line response

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

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

Three to five windows are to be selected, based on the maxima of dT_{qs}/dt , or of T_{qs} if relevant (see App 1).

Alternatively, when the correlation of T_{dyn} with dT_{qs}/dt is clearly established, an option is to analyse only one window corresponding to the expected maximum.

4.4.2 The maximum tension for the simulation is then taken as the maximum over the several windows, or the maximum in the selected one-window, as relevant.

5 Design tensions

5.1 Intact condition

5.1.1 The design tension of a line in intact condition, for a specified set of vessel and metocean conditions, is defined from the mean and the standard deviation of the n maxima T_k , each obtained from n simulations, using different “seeds”, i.e. different sets of elementary waves and wind components. Each simulation is to be at least of 3 hours.

The maxima are either the maxima of the Quasi-dynamic tension, or the maxima of the Dynamic tension, obtained as defined in [4.4] above.

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

$$T_D = T_M + a T_S$$

where:

- T_M is the mean of T_k :

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

- T_S is the $(n - 1)$ standard deviation, given by:

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

- a is a factor, given in Tab 2, as a function of the type of analysis actually performed, and the number of simulations

Table 2 : “a” factor

Method of analysis	Number of simulations n:			
	5	10	15	≥ 20
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 numbers, a can be obtained by interpolation with n				
Note 2: For $n=5$, $1,8 \cdot T_S$ is the same as $2,0 \cdot T_\sigma$ in NI 461.				

5.2 Damaged condition

5.2.1 The design tension of a line in damaged condition is obtained by the same method as the “intact” tension, considering a system with any one line removed, or a thruster failure as specified in 2.7.4.1 of NI 461.

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

5.3 Line failure (transient) condition

5.3.1 The design tension of a line in a failure (transient) condition is obtained, as specified in 2.7.3 and 2.7.4 of NI 461, as the average over a set of possible failure instants, of the maximum transient tension (see also [8.6]).

5.4 Design tension in line components

5.4.1 The tensions at different locations along the lines, as required for sizing of line components, are to be obtained by the same method as defined in [5.1] to [5.3].

When Quasi-dynamic analysis is performed, design tension 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 offset and vertical position, that are governing for different locations along the line.

5.5 Minimum tension

5.5.1 When required (fibre rope mooring), the minimum tension T_{Dm} is to be obtained from line Dynamic analysis, by the same method as maximum tension, as:

$$T_{Dm} = T_M - a T_S$$

6 Fatigue analysis

6.1 Tension range

6.1.1 The distributions of tension ranges are to be obtained from line Dynamic analyses, with a minimum duration of 20 to 30 min each. Both windward and leeward lines shall be analysed.

Further guidance for analysis may be found in paper (2) quoted in [1.2.3].

6.2 Fatigue damage

6.2.1 The fatigue damage, in each segment or component of the lines, is calculated by the Miner sum, taking into account the fatigue capacity, as given in [7.3] below.

From the fatigue damage D calculated for a reference duration of exposure L_{ref} , the fatigue life FL , i.e. the duration of exposure for which the cumulative damage (Miner sum) would be equal to 1, is obtained as:

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

7 Strength of line

7.1 General

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

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

7.2 Breaking strength of line components

7.2.1 The reference load for the evaluation of safety factor is the minimum breaking strength (MBS) of the mooring line component (see Sec 4).

7.2.2 Strength reduction resulting from corrosion and wear, where applicable, is to be taken into account.

A current practice for chains is to use the breaking strength of the chain of the same grade, with a diameter reduced by the specified corrosion (or wear) allowance.

7.3 Fatigue endurance

7.3.1 General

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

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

$$N \cdot R^m = K$$

where:

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

7.3.2 Chain

For chain, the reference load is to be taken as the minimum breaking strength of an element of the same diameter but in QR3 quality, for both QR3 and higher grades.

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

$$m = 3,36$$

$$K = 370$$

Note 1: see also Sec 4, [2.5.1].

This T-N curve may be assumed to be also applicable to standard end links and to properly designed D shackles (see API RP 2SK).

The fatigue endurance of Kenter and Baldt connecting links is about 25% of that of common link (i.e. $K = 90$).

The fatigue strength of studless chain is lower: $K = 170$ may be considered.

7.3.3 Wire rope

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

- for six/multi-strand wire rope:
 - $m = 4,09$
 - $K = 231$
- for spiral strand wire rope:
 - $m = 5,05$
 - $K = 166$

Note 1: These data are for a mean load of 30% of rope minimum breaking strength. Fatigue endurance at higher mean load is lower (see references in [1.2.2]). This should be given consideration where applicable.

7.3.4 Polyester fibre rope

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

$$m = 5,05$$

$$K = 830$$

Note 1: Other published curves, with 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 will generally have significantly lower fatigue strength than the rope itself.

8 Selection of design conditions

8.1 General

8.1.1 A given set of time domain simulations provides a design tension that is a short-term extreme over the duration of the simulations (3 hours), and for the condition analysed.

The design tension for each line (or component) is taken as the maximum of T_D over the possible combinations of metocean parameters and configurations of the system.

8.1.2 The intact, transient, and damaged cases are separately analysed (for transient condition, see [8.6]).

8.2 System configuration

8.2.1 A set of representative configurations of the system shall be selected for analysis, so as to cover all intended situations of operations of the vessel, and to ensure that the conditions that are the most onerous for the mooring system have been examined.

This may include:

- variation of vessel draft, in relation with operations (e.g. a Storage vessel) or weather considerations (operating/survival draft)
- connected/disconnected situations, with e.g. an export tanker, or between adjacent vessels (multi-vessel systems)
- other relevant conditions.

For the analysis of a vessel in the offloading conditions, further guidance is given in paper OTC14311 by Morandini & al.

8.3 Metocean conditions

8.3.1 Metocean data

The metocean data (see Section 4-2 of the Rules for the Classification of Offshore Units) are described by the distributions of the intensity of each element as a function of the return period (marginal distribution of independent all-direction extremes), and by associated parameters (e.g. spectral shape and peak period, for waves).

Directional data may be used under the condition specified in the Rules for the Classification of Offshore Units, and if consistent with all-direction data, understanding that the intensity defined for one direction applies to any direction in the sector around that direction.

8.3.2 Design conditions

The metocean conditions for a N-year return period (see [8.4] to [8.6]) are to be defined as combinations of the direction and intensity of waves, wind, current and associated parameters.

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

- wave (swell) governed conditions
- current governed conditions
- etc.

More detailed information is given in App 2.

8.3.3 Combinations of intensity and direction

For each set, one parameter is to be taken with intensity corresponding to the N-year return period.

Other parameters are to be taken as “associated values”, with an intensity that will generally correspond to a lower return period, depending on the degree of correlation of extremes, and the relative direction, but not less than one year in principle.

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

8.3.4 Associated parameters

Associated parameters are generally defined by a value that is generally a best estimate / most likely value.

For the spectral peak (or zero-crossing) period, a range is to be considered. A range of $\pm 15\%$ around the specified value is recommended.

H_s / T_p (or T_z) response contours (inverse FORM approach) may be used instead, when available, and shall be preferred when the response is found very sensitive to the wave period. Contours shall be defined, having a plateau not less than a 10% range on period. The contour to the relevant return period shall be scanned for the most onerous H_s / T_p combination.

Similar approach as for period may be applicable to other parameters, when relevant.

8.3.5 Scanning

- In principle, scanning shall be performed over 360° for each governing parameter. The scanning interval may be reduced, depending on symmetry(ies) of the mooring system (same lines over a flat bottom), of the vessel (including load coefficients, e.g. for wind), and the required accuracy (envelope or results in individual lines). Such reduction will generally preclude the use of directional data.
- In principle, scanning shall be performed, for each of the other elements, over a large enough interval to provide the evidence that maximum response have been caught. Generally, the relative direction between any two elements need not exceed 150° . A scanning interval of 15° will be generally sufficient to catch maximum

response, taking into account the directional variations of intensities.

- The scanning technique may be adjusted following the type of mooring (e.g. spread or turret), and the relative contribution to the total tension of wind / current / wave slow drift / wave frequency motions, as evidenced by test runs (see also App 1) and split accordingly in appropriate steps.

8.4 Extreme metocean conditions

8.4.1 For a permanent installation, the extreme metocean conditions are to be taken as the conditions with return period N of 100 years.

8.5 Operating conditions

8.5.1 The limiting conditions for particular operations (e.g. offloading, maintenance) shall be specified as either an envelope of possible combinations of elements, or as discrete set of conditions.

In the latter case, the acceptable envelope shall be determined at a later stage, for incorporation in the vessel operating criteria.

When the limiting conditions are infrequent, such as one year conditions or above, combinations of metocean parameters shall be considered as per [8.3], taking into account the specified return period.

For more frequently occurring conditions, the directions of elements will be assumed as independent, unless otherwise specified in the above criteria.

In both cases, the range of wave period is to be selected based on a 100-year contour, unless otherwise specified in criteria.

8.5.2 For operations not requiring particular conditions, the operating metocean conditions, when needing consideration, are to be taken as the metocean conditions with one year return period conditions.

8.6 Transient conditions

8.6.1 A transient analysis is to be performed in the following cases:

- a) When the vessel is moored in close proximity to a fixed installation, or another floating structure.
In this case, analysis may be however limited to the critical lines (line type I in 3.2.1.1 of NI 461).
- b) For operating conditions with specified metocean limiting conditions as defined in [8.5.1] above (e.g. offloading).

In this case, analysis may however be omitted in case of a system with large redundancy, as demonstrated by analysis in damaged condition for the same operating situation being far from critical.

In other cases, transient analysis can generally be omitted.

9 Criteria

9.1 Line tension

9.1.1 Maximum line tension

The minimum Safety Factors for line components are specified below, as a function of the condition analysed, the type of analysis, and other factors as indicated in the notes of Tab 3.

Note 1: This table is not applicable to hawsers. The relevant safety factors can be found in NR 494 "Rules for the Classification of Off-shore Loading and Offloading Buoys".

Table 3 : Minimum safety factors for line components

Minimum safety factors line components (1) (2)	Method of analysis (6)	
	Quasi-dynamic	Dynamic
Condition of system		
Intact (4)	1,75	1,67
Damaged (4)	1,25	1,25
Transient (3) (5)	1,25	1,20
<p>(1) Base factors are for line type II (see NI 461) i.e. not including the case of structures in close proximity. See notes (4) and (5) below.</p> <p>(2) For fibre ropes, an increase of the safety factor in the rope itself (i.e. not including other parts of the line) by 10% for polyester ropes, and 20% for other materials, is recommended.</p> <p>(3) Following methodology in NI 461, and when required.</p> <p>(4) Safety Factor to be increased by 25%, for line type I.</p> <p>(5) Safety Factor to be increased by 40%, for the most loaded line, following the breakage of a line type I.</p> <p>(6) The Safety Factor for Dynamic analysis may also be used with the results of a Quasi-dynamic analysis, after the Society agreement, when the characterization of the line response has provided a firm evidence of a dynamic amplification factor (DAF) below 1,0 in all relevant conditions (see App 1).</p>		

9.1.2 Minimum line tension

For deep-water fibre rope mooring, the following minimum tensions may be considered, in lieu of a more refined analysis:

- Polyester: 2% of rope minimum breaking strength, in intact condition (5% may be used as guidance, for quasi-static analysis of the intact system)
- HMPE: 5% of rope minimum breaking strength, in intact condition (criteria subject to possible relaxation, with progress of knowledge on this material)
- Aramid: 10% of rope minimum breaking strength, in both intact and damaged conditions
- Other fibres: same as Aramid, unless otherwise documented.

9.2 Anchors

9.2.1 Drag anchors

The minimum safety factors for drag anchors are specified in Tab 4.

The factors given in Tab 4 apply only in the case of no uplift at the anchor.

Alternatively, the criteria in App 4 may be applied.

Table 4 : Minimum safety factors for drag anchors

Minimum safety factors anchors (1)	Method of analysis (5)	
	Quasi-dynamic	Dynamic
Condition of system		
Intact (3)	1,60	1,50
Damaged (3)	1,15	1,05
Transient (2) (4)	1,15	1,05
<p>(1) Base factors are for line type II (see NI 461) i.e. not including structures in close proximity. See notes (3) and (4) below.</p> <p>(2) Following methodology in NI 461, and when required.</p> <p>(3) Safety Factor to be increased by 25%, for line type I.</p> <p>(4) Safety Factor to be increased by 40%, for the most loaded line, following the breakage of a line type I.</p> <p>(5) The Safety Factor for Dynamic analysis may also be used with the results of a Quasi-dynamic analysis, after Society agreement, when the characterization of the line response has provided a firm evidence of a dynamic amplification factor (DAF) below 1,0 in all relevant conditions (see App 1).</p>		

9.2.2 Anchor piles

For long (soft) piles, the safety factors given in Tab 4 also apply 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 horizontal. Otherwise the required pull out capacity is to be increased by a factor K_α equal to $(1 + 0,33 \sin^2 \alpha)$.

The factors given in Tab 4 also apply to lateral strength assessment (see Sec 4, [6.2.8]).

9.2.3 Suction anchors and vertical load anchors

The partial factor verification format in App 4.

9.3 Fatigue

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

The Safety Factor is defined as the ratio between calculated fatigue life and design service life of the system (as defined in Ch 5, Section 5-3.1.2.2 of the Rules for the Classification of Offshore Units).

9.3.2 The minimum safety factors, for each line component are:

- 6, for all line segments under T-T fatigue loading and other components of the lines
- 10, for anchors and buried parts
- 3, for on vessel-end items.

Note 1: The factor 6 is taking into account the difficulty of an efficient inspection of mooring systems in most cases.

Note 2: The minimum safety factor of 3 is also applicable to top segments at support points (see Sec 4, [2.5.2] and Sec 4, [7.2.6]), when the effect of out of plane bending or other local actions is taken into account, in addition to T-T fatigue loading.

Higher safety factors may be applied, if specified by the Owner.

9.4 Test loading of anchor and lines

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

- a) Drag anchors: 80% of the design tension T_D at fairlead, in intact conditions
- b) Vertically loaded anchor (VLA): as required to achieve target penetration and related holding capacity
- c) Anchor piles and suction piles: as for the line, as specified below.

9.4.2 The load for the test loading of lines is to be taken not less than the following, depending on the type of the line:

- a) Steel lines: the specified pretension, with some increase (10% minimum is recommended) in order to ensure correct setting of the assembly
- b) Fibre rope (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.

SECTION 4 COMPONENTS OF MOORING LINES

1 General

1.1 Subject

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 the **POSA** notation to a floating unit.

1.2 Scope

1.2.1 The components under consideration in this Section include:

- a) main line components, such as:
 - chain cables and standard fittings
 - steel wire ropes and terminations
 - fibre ropes
- b) non-standard fittings and connectors
- c) anchors
- d) items at the on-vessel end, such as fairleads and stoppers
- e) ancillary components (buoys, sinkers, ...).

1.2.2 Deck appliances (winches and windlasses) are excluded from the scope of this Guidance Note. Winches or windlasses that are used as stoppers will be given special consideration.

1.2.3 The compliance with the requirements of this Section are mandatory for the assignment of the **POSA** notation.

1.3 General requirements

1.3.1 General

The present [1.3] gives general requirements for all mooring components. The particular requirements for each type of mooring components are given in [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 following Rules and related documents, as applicable to particular items, depending on its

type of construction (such as forged or cast or fabricated, etc.):

- NR 216: Rules and Regulations for the Classification of Ships and Offshore Installations - Materials
- Chapter 5 of the Rules for the Classification of Offshore Units
- NR 426: Construction survey of steel structures of offshore units and installations
- Other Rules and publications of the Society, as applicable.

1.3.3 Designation

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

1.3.4 Manufacturing, testing and certification

The manufacturing and testing of the components of a mooring system are to be performed following the applicable provisions of Rules, and under Survey by the Society.

When load tests are performed, a Surveyor of the Society shall witness these tests.

1.3.5 Type approval

When specified in [2] to [8], items are to be type approved by the Society according to the requirements of the present Section.

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

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

For a particular project, once an item is holding a type approval:

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

2 Chains and standard fittings

2.1 General

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

2.1.2 Rules and related documents

- NR 216: Rules and Regulations for the Classification of Ships and Offshore Installations – Materials – Section 10-4.

2.1.3 Standards

- ISO 1704: “Stud-link anchor chains”.

2.2 Designation

2.2.1 Chain and accessories shall be specified by their Minimum Breaking Strength and grade, or by nominal diameter and grade.

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

2.2.2 The specified nominal diameter / MBS shall include an adequate margin for corrosion and wear over the intended service life (see Sec 3, [7.2]).

2.3 Design

2.3.1 Design documentation to be submitted

Drawings giving the detailed design of chain and accessories shall be submitted for review at the time of approval.

2.3.2 Dimensions

The dimensions of stud chains and standard fittings shall be as per the Rules (NR 216), (typical designs). Alternatively, reference may be made to ISO 1704.

For studless chains, dimensions shall be in accordance with the Manufacturer's specification.

2.3.3 Materials

Chains and standard fittings shall be made of materials in grade QR3, or QR3S, or QR4, as specified in the Rules (NR 216, Section 10-4).

The use of ORQ grade is generally not permitted within the framework of the POSA notation.

Grades higher than QR4 will be given special consideration.

2.4 Manufacturing and testing

2.4.1 Manufacturing

Chains and standard fittings shall be manufactured according to the criteria specified in the Rules (NR 216, Section 10-4).

Chains and standard fittings shall be manufactured only by Manufacturers approved by the Society for the intended product.

2.4.2 Load Tests

The chain cables and their fittings are to be tested and examined as required in Section 10-4 of NR 216.

Each chain link or standard fitting shall be tested at a proof load PL depending on the required Breaking Strength MBS and the specified material grade, as per the Rules. The ratio of proof load to Minimum Breaking Strength is given for reference in Tab 1.

Table 1 : Ratio PL / MBS

Type of chain	QR3	QR3S	QR4
Stud-link	0,66	0,72	0,79
Studless	0,66	0,70	0,70

Break load tests shall be carried out in the conditions specified in the Rules.

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

2.5 Installation and service conditions

2.5.1 The deployment of lines shall be performed in such a way as to avoid jamming on the bottom, and accumulation of twist, that may result in damage to the chain itself or to other components, when the line is tensioned.

2.5.2 Attention is drawn to the fact that the fatigue performance of studlink chain might be significantly decreased in the case of loose studs. The T-N curve given in Sec 3, [7.3.2] applies to links with tight studs.

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

3 Steel wire ropes

3.1 General

3.1.1 Scope

The present [3] covers steel wire ropes intended for mooring lines and associated termination fittings.

3.1.2 Standards

Reference may be made to the following standards:

- API Spec 9A: “Wire ropes”
- ISO 2232:1990: “Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes – Specifications”
- API Recommended Practice 2SK.

3.2 Designation

3.2.1 Steel wire ropes shall be specified by their Minimum Breaking Strength, and by the type of construction and nominal diameter.

3.2.2 The specified nominal diameter / MBS shall include, where applicable, a margin for additional corrosion and wear allowance (see [3.3.3]).

3.3 Design of steel wire rope

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
- specification of wires
- specification of other materials (galvanic coating, compound, sheathing)
- calculation of wire rope static strength
- documentation of 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 the present document include:

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

3.3.3 Protection

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

- wire galvanisation, or equivalent
- stranding compound.

Complementary protection by one or several adequate means shall be provided as necessary, considering service conditions and 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, [7.3.3] are valid only when a suitable corrosion protection is provided.

3.3.4 Strength

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

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

Termination shall be designed in accordance with the requirements given in [5].

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

Terminations shall provide an effective electrical isolation between the wire rope and the rest of the mooring line.

Termination fittings shall be fitted with cathodic protection, to a level consistent with that 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 proposed witness points for the Surveyor
- process monitoring and recording (including traceability)
- acceptance criteria
- steel rod raw material certificates
- sheathing procedure
- procedure for connection of terminations to rope,
- individual wires records
- manufacturing documentation of termination (see [5.3.1] below)
- records of connection of terminations to rope
- rope sample test procedures
- rope sample load test reports.

3.5.2 Testing

A break load test shall be carried out on a sample of the wire rope and its terminations, taken off the production under Survey.

The sample shall withstand the specified MBS.

3.6 Installation and service conditions

3.6.1 The deployment of lines shall be performed in such a way as to avoid:

- damage by over-bending or chaffing over obstacles
- over-bending in free span, by maintaining a suitable minimum tension
- excessive bending at terminations: Bending restrictors shall be provided as necessary
- accumulation of twist, particularly in case of a non-torque compliant structure
- any damage to sheathing (when provided).

3.6.2 The use of wire rope is generally not allowed in the touchdown area.

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

Attention is also to be given to the risks of bending fatigue of rope 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 line at these locations.

4 Fibre ropes

4.1 General

4.1.1 Scope

The present [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 Section 3 of NR 494 "Rules for the Classification of Offshore Loading and Offloading Buoys".

4.1.2 Rules and related documents

- NI 432: "Certification of synthetic fibre ropes for mooring systems".

4.1.3 Designation

Fibre ropes shall be specified by a Minimum Breaking Strength, and the type of material.

4.1.4 Approval

Fibre ropes are to be Type Approved by the Society according to the requirements of NI 432.

Note 1: type approval is based on full size testing of a prototype rope, of the specified MBS.

Termination thimbles other than steel roller thimbles (spools) shall be in accordance with the requirements of [5].

4.2 Design

4.2.1 Fibre rope shall be identical to the approved rope.

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

4.2.2 The service conditions of the fibre rope shall be as specified in NI 432

No contact with the seabed is allowed at any stage (installation and operation).

4.3 Manufacturing and testing

4.3.1 Manufacturing and testing of fibre rope shall be performed in accordance with the requirements of NI 432, under Survey by the Society.

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

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

4.4 Installation and service conditions

4.4.1 The deployment of lines shall be performed in such a way as to avoid damage by chaffing, cutting, or over-bending over obstacles, as well as contamination by solid or by

liquid projections. Any contact with the seabed shall be avoided.

Seizing of line, or of ancillary installation devices on line shall be performed by soft rope seizing only.

To avoid the risks of local over-bending, lines shall be deployed under a low tension, with a suitable minimum tension being maintained.

The accumulation of twist shall be avoided.

4.4.2 The service conditions of the fibre rope shall be as specified in NI 432.

No contact with the seabed is allowed in any condition of operation.

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

5 Non standard fittings

5.1 General

5.1.1 Scope

The present [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 (e.g. for connection to a fibre rope thimble)
- tri-plates
- connectors (for underwater connection)
- termination fittings for wire ropes
- termination thimbles (special type) for fibre ropes (see [4]).

5.1.2 Rules and related documents

The present [5] primarily addresses fittings that are made of cast steel, forged steel, or machined from steel plates, for which reference is made to:

- NR 216: Rules and Regulations for the Classification of Ships and Offshore Installations – Materials – Section 10-4.

5.1.3 Designation

Fittings shall be specified by a 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 attached elements shall be also specified.

5.1.4 Type Approval

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

Fittings that are purpose-designed for a specific system shall be approved following the requirements of the present [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 fittings and all 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, shall be made of materials meeting the requirements of one of the following Rules grades: QR3, or QR3S, or QR4.

Where applicable, steel with yield and tensile strength lower than QR3 may be used, provided other mechanical properties of grade QR3, in table 10-4b of NR 216, are met.

The specification of material shall also include reference to a recognised material Standard, with details of chemical composition and heat treatments.

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

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

5.2.3 Strength

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

Note 1: Elasto-plastic analysis is generally required when a verification by a break load test is not performed (see [5.3]).

5.2.4 Fatigue

The Resistance to fatigue shall be documented.

The fatigue resistance shall be established with reference to data for line components (see Sec 3, [7.3]) and, as a rule, shall be not lower than the fatigue resistance of a chain of the same breaking strength in grade QR3, except as follows:

- the fatigue resistance of wire rope termination fitting should be not lower than that a wire rope (six strand or spiral strand, as applicable)
- for detachable links, the fatigue resistance shall be at least that of a Kenter link.

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

5.2.5 Protection

Protection against corrosion and wear shall be provided by adequate means.

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

Electrical isolation of connectors shall be provided as applicable.

5.2.6 Functional requirements

Designer shall ensure that all detachable parts are adequately locked in position by passive means.

Connectors shall maintain a positive stability under a low tension, and shall be fitted with a locking system.

Note 1: Where applicable, a minimum tension shall be specified, and the device shall not be allowed for use on sea bottom nor in touch down area.

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 Bureau Veritas witness points
- fabrication and testing procedures and records.

5.3.2 Break load tests

Proof and break load tests shall be carried out on a prototype item, as per Rules.

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

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

For large items, where load test might not be achievable, the test may be dispensed, with prior agreement with the Society, subject to adequate documentation of strength, by analysis.

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

5.3.3 Proof load tests

Each item shall be tested at a proof load depending on the required Breaking Strength and the specified material grade, as given for studless chain in Tab 1.

For large items, 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

The present [6] covers anchoring devices such as:

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

The present [6] does not address conventional (ship type) drag anchors, that are designed, manufactured and tested in accordance with the relevant provisions of the Rules for the Classification of Steel Ships. Such type of anchor is not normally used in permanent moorings.

Other types of anchoring devices will be given special consideration, on a case by case basis.

6.1.2 Designation

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

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

6.1.3 Approval

Drag anchors and VLA's shall be type approved by the Society on the basis of the present document.

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

Note 2: Other type 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 of conditions at testing site (see [6.2.7])
- documentation of site conditions (see Chapter 4 of the Rules for the Classification of Offshore Units), including the study of possible geo-hazards
- design loads at anchor lug, with details of derivation from loads in line at sea-bottom
- loads/design conditions at time of installation
- drawings, with the detailed design of all 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 shall be documented (see [6.2.7] to [6.2.9] below). The effects of cyclic loading shall be assessed.

Behaviour during installation and related loads shall also 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 shall be provided, and the geotechnical ultimate capacity of proposed device shall satisfy the requirements of Sec 3, [9.2].

Note 1: For most types of anchoring devices, the full design geotechnical capacity may be not 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 shall conform to the relevant sections of the Rules for the Classification of Offshore Units and NR 216 (off-

shore grades), taking into account design temperature and structural categories, as defined in [6.3.2].

6.2.4 Strength

The strength shall be documented by appropriate calculations, in accordance with the provisions of App 3.

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

The anchor body shall be able to withstand the ultimate capacity of the anchoring device, with deformations within such limits as not to impair anchor geotechnical capacity (see [6.2.9] however).

6.2.5 Fatigue

The resistance to fatigue shall be documented.

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

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

6.2.6 Protection

Protection against corrosion shall be provided by adequate means.

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

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

6.2.7 Particular provisions - Drag anchors and VLA's

The geotechnical behaviour of drag anchors and VLA's is to be documented by testing of a prototype anchor in representative soil conditions.

Complementary analysis, where applicable, may be used.

The relations between achieved penetration (and related load), soil parameters, and ultimate capacity of the anchors are to be established and documented by these tests.

6.2.8 Particular provisions - Suction piles

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

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

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 API Recommended Practice RP2A, where:

- the pull-out capacity (axial load) and the strength under lateral load can be evaluated separately
- the strength of pile under lateral load is assessed considering factored loads (e.g. as per API RP2A-LRFD), with load factors taken as per Sec 3, Tab 4.

6.3 Manufacturing

6.3.1 Manufacturing

The manufacturing of anchoring devices shall be performed under Survey by the Society, in accordance with the relevant requirements of:

- Chapter 5 of the Rules for the Classification of Offshore Units
- Chapters 5 and 6 of NR216
- NR 426: Construction survey of steel structures of off-shore 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 categories of construction (as defined in Section 5-2 of the Rules for the Classification of Offshore Units) shall be considered:

- pad-eye, shank, and adjacent structure shall be considered as "Special Category elements"
- the rest of Anchor body, shall be considered as "First Category" elements
- a design temperature of 4°C shall be generally considered for anchoring devices in deep waters. In other cases, the design temperature shall be specified.

6.4 Installation

6.4.1 The installation at site of anchoring devices shall be performed under Survey by the Society (see Sec 2, [2.5]).

Installation procedures for anchor setting and pre-loading shall be submitted in advance for review by the Society.

Anchor and line test loading shall be performed as required in Sec 3, [9.4].

Installation records, with related analyses, as needed, shall provide evidence that target penetration/holding capacity have been achieved.

7 Items at the on-vessel end

7.1 General

7.1.1 Scope

The present [7] cover items at the on-vessel end, that are intended for guiding and securing anchoring lines to vessel, such as:

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

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

Note 2: For winches, windlasses and other deck appliances, see [1.2.2].

7.1.2 Designation

Items shall be specified by the nature and nominal dimensions of the line segment they are intended to support, and the related Minimum Breaking Strength.

Note 1: When the on-vessel end of the line includes an oversized upper segment, a design BS may be taken as the load at fairlead corresponding to the MBS of the next segment.

7.1.3 Approval

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

Standard items may be type approved by the Society on the basis of the requirements of the present [7] and 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 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 of mechanical components
- documentation of interface loads
- interface drawings
- corrosion protection drawings and calculations.

7.2.2 Design conditions

Items shall be designed to withstand the line segment they are intended to support, when loaded to:

- a Design Breaking Strength, equal to the Minimum Breaking Strength of the line segment (see however Note 1 below)
- the design tension T_D in line, in each condition of the mooring system (intact, damaged, transient, as relevant).

Note 1: When the on-vessel end of the line includes an oversized upper segment, the Design Breaking Strength may be taken as the load at fairlead corresponding to a load in the next segment equal to the MBS of that segment.

Note 2: For type approval, T_D is to be taken as the Design BS divided by the minimum required safety factor as specified in Sec 3.

For items supporting the free spanning line, due attention is to be given to the range of orientation of line load that will result from tolerances in system geometry, vessel offset and vessel motions, in addition to those resulting from possible configurations or predicted by mooring analysis.

For fatigue, due attention is to be given to cyclic loading resulting from angular variations of line load.

7.2.3 Materials

Materials shall conform to the relevant sections of the Rules for the Classification of Offshore Units and NR 216 (off-shore grades), taking into account design temperature and structural categories, as defined in [7.3.2].

7.2.4 Strength

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

Items shall be designed to withstand the loads specified in [7.2.2].

Parts supporting mechanical components shall have, under the highest design tension TD, deformations within such limits as not to impair the integrity of mechanical components.

7.2.5 Interface with vessel structure

Loads and load distribution at interface with vessel structure shall be documented.

Interface arrangement and weld details shall be specified, in a manner consistent with the arrangement of underneath vessel structure, in order to ensure suitable structural continuity. Attention is to be given to thickness transitions between materials of different strength.

7.2.6 Fatigue

The resistance to fatigue of items and interface connections shall be documented.

The data referenced in [5.2.5] may be used as guidance for the purpose of type approval.

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

Possible detrimental interaction with the mooring line shall 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, and to locked-in modes that may arise in relation with friction between parts within the load path between free spanning line and vessel body.

7.2.7 Mechanical components

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

Mechanical components shall be able to withstand internal loads induced by the Design Breaking Strength in the line, and operate under the highest design tension T_D in line.

Parts requiring replacement shall be identified, and criteria specified.

7.2.8 Protection

Protection against corrosion and wear shall be provided by adequate means.

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

7.3 Manufacturing and testing

7.3.1 Manufacturing

The manufacturing of items shall be performed in accordance with the relevant requirements of:

- Chapter 5 of the Rules for the Classification of Offshore Units
- Chapters 5 and 6 of NR 216
- NR 426 (welded construction).

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 shall be considered as "special category" elements
- the rest of the body of items may be considered as "first category" elements
- the design temperature shall be specified, and taken not higher than the design air temperature for the vessel. The (near-surface) seawater design may be however considered for permanently submerged parts.

7.3.3 Testing and on-board installation

The onboard installation of items shall be performed under Survey by the Society.

Interface welds shall be considered as "special category" elements (100% NDT).

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

8 Ancillary elements

8.1 General

8.1.1 The present [8] is addressing ancillary items such as buoys, sinkers and their connections, that are permanent parts of the mooring system (see Sec 2, [1.3.1]).

8.1.2 Ancillary items shall be designed, manufactured and tested according to the general principles set out in this Guidance Note.

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

8.2 Service conditions

8.2.1 The failure of any of these components to fulfil its function shall be considered in the design of the mooring system as a damaged case.

8.2.2 Dispositions shall exist in order to ensure the integrity of the mooring system at any time. These dispositions shall be submitted to the Society for review.

APPENDIX 1

CHARACTERISATION OF THE LINE RESPONSE

1

1.1 Test run

1.1.1 A characterisation of the line response is to be performed in order to obtain information on the respective contribution of mean load, slow drift, and wave frequency motions to the line tension, the level of dynamic tensions, and to evaluate if Quasi-Dynamic analysis can be sufficient. A relatively short run (10 to 15 mn real time) will be generally sufficient.

Conditions of run should be taken as close as possible to those of the “wave governed” case leading to maximum Quasi-Dynamic tensions at fairlead (or other point of interest) in the governing (intact or damaged) situation.

1.1.2 The time series of the quasi-dynamic tension T_{qs} and of the dynamic tension T_{dyn} are to be written as:

$$T_{qs} = T_{mean} + T_{lf} + T_{wfqs}$$

$$T_{dyn} = T_{mean} + T_{lf} + T_{wfdyn}$$

where:

T_{mean} : Mean tension

T_{lf} : Low frequency tension variation.

T_{wfqs} and T_{wfdyn} are respectively the Quasi-Dynamic and the dynamic wave frequency variations, thus obtained by difference between the total signal and the previous terms. T_{lf} , T_{wfqs} and T_{wfdyn} can be characterised by their standard deviation σ_{lf} , σ_{wfqs} 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 The significance of dynamic tension can be assessed from:

$$DAF = \sigma_{wfdyn} / \sigma_{wfqs}$$

Note 1: The ratio of total (maximum) tension $T_{max\ dyn} / T_{max\ qs}$ from time domain simulation is not a proper indication, and cannot be called a “DAF”

1.2.3 The Quasi-Dynamic analysis is sufficient, if one the following condition is satisfied:

a) based on the above tension criteria:

$$\sigma_{lf} > \frac{1,9 \text{ DAF } \sigma_{wfqs}}{3,2 - \log T_0}$$

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, [3.1.1].

In that case, the low frequency part of the tension is governing over the wave-frequency part.

b) or:

$$1,75 (M - 1,8 S) > 1,67 (M' + 0,7 S')$$

and, if the analysed case is a damaged condition:

$$M + 1,8 S > M' + 0,7 S'$$

where:

- M and S are the mean and the (n – 1) standard deviation of the maximum tension over 5 simulations, in the same conditions
- M' and S' are estimators of the same quantities in case of a dynamic simulation, that are obtained by:

$$S' = DAF \cdot S$$

$$B = M - (T_{mean} + 2 \sigma_{lf})$$

$$M' = M + B (DAF - 1)$$

1.2.4 In the case of [1.2.3] a) above, and only when DAF is undoubtedly below 1, the Safety factors for dynamic analysis may be used with the results of a Quasi Dynamic analysis.

1.2.5 When line dynamic is prevailing, plot of T_{dyn} versus T_{qs} and T_{dyn} versus dT_{qs} / dt will indicate to which of these T_{dyn} is correlated, as needed for the selection of windows for dynamic analysis.

1.2.6 For the scanning through combination of vessel conditions and metocean parameters, the following tension criteria (based on API 2SK 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 tension variations:

$$T_{AL} = T_{mean} + (4,9 - 0,9 \log T_0) \sigma_{lfqs} + 2 \sigma_{wfqs}$$

b) otherwise:

$$T_{AW} = T_{mean} + 2 \sigma_{lfqs} + 3,7 \text{ DAF } \sigma_{wfqs}$$

APPENDIX 2

COMBINATION OF INTENSITY AND DIRECTION OF METOCEAN PARAMETERS

1 General

1.1 Metocean conditions

1.1.1 The metocean conditions for a N-year return period ($N = 100$ for permanent installations) are to be defined as combinations of the direction and intensity of waves, wind, and current, and of associated parameters.

Depending on the climate, several sets are to be defined in which one of the parameter is governing. This is intended to take into account that extremes may not result all from the same meteorological conditions, or not all from the same storm event, nor at the same time within the same event.

1.1.2 For each set, the “governing” parameter is to be taken with an intensity corresponding to the N-year return period. Other parameters are to be taken as “associated value”, with an intensity that will generally correspond to a lower return period, depending on the degree of correlation of extremes, and the relative direction, but generally not less than one year.

Generally, the relative direction between any two elements needs not be taken more than 150° .

1.1.3 The following criteria are given for guidance and may need adjustment when more accurate data are available for the site under consideration.

1.1.4 Scanning shall be performed over a large enough interval to provide the evidence that maximum response have been caught. A scanning interval of 15° will be generally sufficient to catch maximum response.

1.2 Notations

1.2.1 The following notations are used in this Appendix:

H	: Waves
S	: Swell
W	: Wind sea
V	: Wind
C	: Current
H-V	: Relative direction between waves and wind
C-V	: Relative direction between (near) surface current and wind
RP	: Return period
RP_0	: Reference return period
r	: Reduction factor (see [1.3.1]).

Note 1: Relative headings are between travel directions and are taken positive when clockwise, viewed from above, in the Northern Hemisphere.

1.3 Return period

1.3.1 The return period RP is to be taken as follows:

- $RP = N$ for the governing element
- $RP = RP_0 \times 10^r$ for other elements.

Note 1: 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:

$$pe = 100 \ nXd / 3000$$

1.3.2 The metocean data are normally available as the intensity of each element, as a function of the return period (independent all-directions or directional extremes).

Note 1: The intensity for intermediate return periods may be obtained by linear interpolation of intensity as a function of the log of return period (i.e. of the factor r).

1.3.3 When directional data are used, intensity for any one element is taken as the intensity in the sector where that element is lying.

2 Extra-tropical areas

2.1 Applicability

2.1.1 The combinations in [2.2] to [2.4] below are applicable to areas with storm conditions in which wind driven seas and wind driven current are governing over other components.

2.2 Typical conditions

2.2.1 Two typical conditions may be defined, as follows:

- wave governed, with relative heading H-V between -60° and $+60^\circ$ and C-V between -60° and $+60^\circ$
- current governed, with relative heading H-V between -30° and $+30^\circ$ and C-V between -60° and $+90^\circ$.

2.3 Reduction factors

2.3.1 Reduction factor r_v

The reduction factor r_v is given by:

$$r_v = 0 \quad \text{when } |H-V| \leq 30^\circ$$

$$r_v = 1 - \frac{|H-V|}{22,5} \quad \text{when } 30^\circ < |H-V| < 60^\circ$$

$$r_v = -1,7 \quad \text{when } |H-V| \geq 60^\circ$$

The reduction factor r_v is shown in Fig 1.

2.3.2 Reduction factor r_c

The reduction factor r_c is given by:

$$r_c = 0 \quad \text{when } |C-V| \leq 45^\circ$$

$$r_c = 1 - \frac{|C-V|}{45} \quad \text{when } 45^\circ \leq |C-V| \leq 90^\circ$$

The reduction factor r_c is shown in Fig 1.

2.4 Selection of return periods

2.4.1 Data for the selections of return periods are given in Tab 1.

Table 1 : Return periods

Extra-tropical	Return periods of:					
	Waves H		Wind V		Current C	
Type of combination	RP ₀	r	RP ₀	r	RP ₀	r
H governed	100	0	50	r_v	10	r_c
C governed	10	r_v	10	r_v	100	0

3 Equatorial areas

3.1 Applicability

3.1.1 Climate in equatorial (West Africa) area is characterised by waves, local wind and current that have distinct sources, and therefore are almost uncorrelated.

Waves include a combination of long distance swell and wind seas.

3.2 Typical conditions

3.2.1 Four typical conditions may be defined as follows:

- swell governed
- wind sea governed
- wind governed
- current governed.

Besides, two additional conditions may be added to represent distinct local events, that are not represented in the statistical distributions:

- squall wind condition
- local current condition.

Owing to lack of correlation, swell, sea, wind and current are to be taken as acting together in any combination of directions, over 360° each.

3.3 Selection of return periods

3.3.1 Data for the selections of return periods are given in Tab 2.

No reduction factor r (see [1.3.1]) is applicable.

Table 2 : Return periods

Equatorial	Return periods (or pe) of:			
	Swell S	Waves W	Wind V	Current C
S governed	100	1	1	1
W governed	1	100	1	1
V governed	1	1	100	1
C governed	1	1	1	100
Squall wind	pe 5%	pe 5%	100	pe 5%
Local current	pe 5%	pe 5%	pe 5%	100

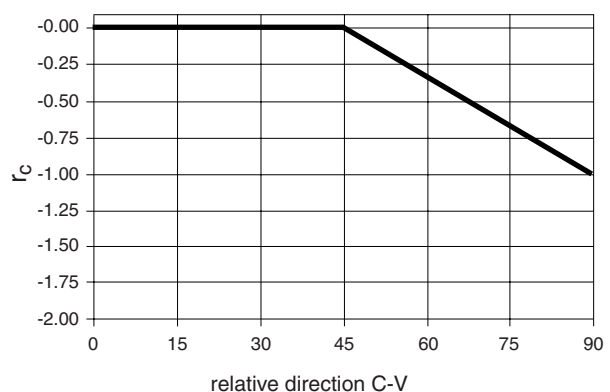
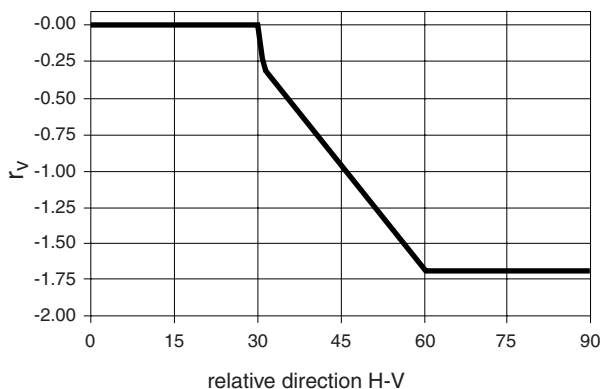
4 Tropical storm areas

4.1 Conditions

4.1.1 Extreme conditions in tropical storm areas are governed by occasionally passing hurricanes/typhoons, causing rapid variation of both intensity and direction of wind, waves, and current, over a limited time. Directional data should generally not be used.

In this case, associated values are better defined by a ratio to the specified 100 year extreme, and the wave direction is used for reference.

Figure 1 : Reduction factors r_v and r_c



Two typical conditions may be defined as follows:

- wave governed, with relative headings V-H between -45° and $+45^\circ$ and C-H between $+30^\circ$ and -30°
- current governed, with relative heading V-H between -45° and $+45^\circ$ and C-H between -60° and -120° .

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.

4.2 Reduction factors

4.2.1 Reduction factor q_v

The reduction factor q_v is given by:

$$q_v = 1 \quad \text{when } |V-H| \leq 30^\circ$$

$$q_v = 2 - \frac{|V-H|}{30} \quad \text{when } 30^\circ \leq |V-H| \leq 45^\circ$$

The reduction factor q_v is shown in Fig 2.

4.3 Data for the intensity of the elements

4.3.1 Data for intensity of elements are given in Tab 3.

If needed, the factors c_H , c_v and c_c for intermediate situations (C-H between -30° and -60°) may be obtained by interpolation between those of the H governed and the C governed case.

Figure 2 : Reduction factor q_v

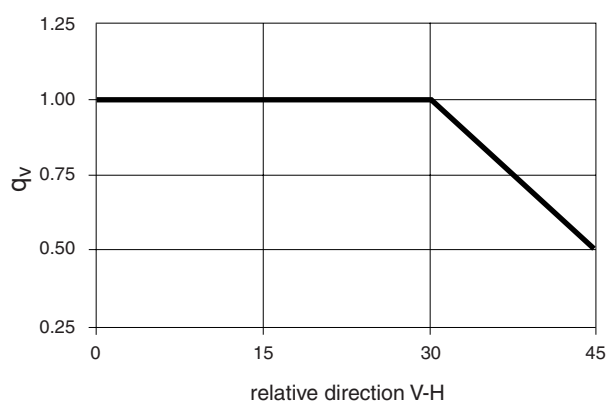


Table 3 : Intensity of the elements

Tropical storms	Waves $c_H = H / H_{100}$	Wind $c_v = V / V_{100}$	Current $c_c = C / C_{100}$
Type of combination			
H governed	1	0,9 q_v	0,5
C governed	0,7 q_v	0,6 q_v	1

APPENDIX 3

STRUCTURAL STRENGTH CRITERIA

1

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 vessel hull or turret
- ancillary components.

1.1.2 Guidance is given on structural strength criteria, as a complement to the criteria specified in Chapter 4 and 5 of the Rules for the Classification of Offshore Units, 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 the Rules for the Classification of Offshore Units and those of the present Guidance Note.

1.2 Design loads

1.2.1 As specified in 4-3.4.2 of the Rules for the Classification of Offshore Units, and in Sec 4, 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 the Chapter 5 of the Rules for the Classification of Offshore Units.

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 vessel or to the anchor, the angular variations resulting from tolerances in system geometry, vessel offset and vessel 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 vessel end, that may be subject to loads from several adjacent lines, combinations of loads may be derived from mooring analysis. In each of the con-

dition of the mooring system, load combinations shall be categorised as in [1.2.2] above.

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 Section 5-3 of the Rules for the Classification of Offshore Units are applicable.

1.3.2 The following criteria shall be satisfied:

$$\sigma_D \leq 1,1 \alpha R_f \quad \text{and} \quad \sigma_a \leq \alpha R_f$$

where:

- σ_D : Equivalent stress (as specified in Section 5-3.5.3 of the Rules for the Classification of Offshore Units), 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 Section 5-3.5.4.2 of the Rules for the Classification of Offshore Units, for the case considered (see [1.2.2])
- R_f : Reference stress (as specified in Section 5-3.5.2 of the Rules for the Classification of Offshore Units).

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 Elastic plastic design

1.4.1 In elastic-plastic analysis, a stress-strain relation is assumed as:

$$\sigma = E \varepsilon \quad \text{for} \quad |\sigma| \leq R_f, \quad |\varepsilon| \leq R_f / E$$

$$\sigma = R_f \quad \text{for} \quad |\varepsilon| \geq R_f / E$$

The load is applied by increment, until instability, or the onset of large deformations, or a maximum, is observed.

Contacts are to be modelled adequately.

The strength criterion is:

$$\frac{L_D}{\alpha} \leq L_P$$

where:

L_D : Design load

L_P : Load resulting in plastic failure

(analysis does not need to be continued beyond $1,05 L_D / \alpha$ if failure is not observed).

1.4.2 In some cases, the capacity of the structure can be assessed by assuming one or more plastic hinges at discrete locations, and failure is observed as an instability of the structure.

In such case, the strength criterion is, for all hinges:

$$\frac{F_D}{\alpha} \leq F_P$$

where:

F_D : Internal Force at a plastic hinge, under the design load

F_P : Capacity of the plastic hinge.

Note 1: F_D and F_P can be a single internal force component (e.g. a plastic moment), or a vector of several components (e.g. axial force and moment) acting together, taking into account a suitable interaction formula.

1.5 Design based on elasto-plastic analysis

1.5.1 In elasto-plastic analysis, the stress-strain relation corresponding to the actual type of material is considered.

This relation is to be re-scaled so that the yield stress, the ultimate stress, and the elongation at rupture are equal to the minimum guaranteed properties of the material.

Analysis is accounting for the effects of large deformations.

Contacts are to be modelled adequately.

The load is applied by increment, until a maximum, or the onset of large deformations, or excessive local strains, is observed.

The strength criterion is:

$$\frac{\beta L_D}{\alpha} \leq L_f$$

where:

L_D : Design load

L_f : Load resulting in plastic failure

β : Factor to be taken equal to:

- 1,05 for line components
- 1,15 for on-vessel supporting structure and for anchors

(analysis does not need to be continued beyond $\beta L_D / \alpha$ if failure is not observed).

APPENDIX 4 GEOTECHNICAL CAPACITY OF ANCHORING DEVICES (PARTIAL FACTOR FORMAT)

Symbols

T_D	: Design tension in line at lug, calculated according to Sec 3, [5]
T_P	: Line pretension (see [2.2.1])
F	: Force in line resulting from environmental actions at lug (see [2.2.3])
F_s	: Static force at lug (see [2.2.2])
α	: Angle of line at lug (see [2.1.3])
γ_p	: Partial load factor for line pretension (see [2.3.1])
γ_{fs}	: Partial load factor for static tension (see [2.3.2])
γ_F	: Partial load factor for tension given in Tab 2
C	: Ultimate capacity of the anchoring device (see [3])
P'	: Submerged deadweight of the anchoring device (see [3.2.1])
q	: Generic soil parameter (see [3.1])
ε	: Factor for suction effect (see [3.2.4])
γ_M	: Material factor (see [3.1.2])
A	: Model factor (see [4.1])
K_α	: Uplift factor (see [4.2]).

1 General

1.1 Scope of application

1.1.1 The present Appendix is addressing the geotechnical capability of anchoring devices for an offshore permanent mooring, and applies to such devices as suction anchors, drag anchors, VLA's, clumps and short piles.

1.1.2 The criteria in this Appendix are only valid for anchoring devices in adequately known soil profiles and in the absence of detrimental geo-hazard (see Sec 4, [6.2.2]).

1.1.3 Effects associated with creep and cyclic/repeated loading are to be investigated, if anticipated as detrimental.

1.2 Format

1.2.1 The criteria in this Appendix follow a limit state (partial factors) format, with distinct partial factors for actions and soil properties, and a set of global factors (model factor and safety factor) on the right side of the inequalities in [5].

1.2.2 The uncertainties on parameters not explicitly quoted in the following should be accounted for in an appropriate way, such as :

- a range is defined and the less favourable value is considered (e.g. for out of plane loading of the anchor)
- a suitable partial factor is considered, when a statistical description is possible (e.g. the rate of increase of shear strength with depth).

2 Actions

2.1 General

2.1.1 The actions at anchor lugs are to be evaluated for the possible combinations of metocean parameters and configuration of the system (see Sec 3, [8]), and for the following conditions of the mooring system:

- static (intact system)
- intact system
- damaged
- transient condition, when required (see Sec 3, [8.6]).

2.1.2 The actions at anchor lugs, in each of the design condition to be considered, are defined on the basis of:

- the angle α of line at lug
- the components of the design tension T_D at lug.

2.1.3 The angle α of line at lug is the angle of line with respect to horizontal.

2.2 Design tensions

2.2.1 Pre-tension

The line pretension T_P is the static tension in the mooring line at lug in the absence of environmental loads.

Note 1: T_P is including the effect of permanently applied loads such as tensions from risers or export lines attached to the floating body (see Sec 3, [3.2.3]).

2.2.2 Static condition

In the static condition, the static force at lug, noted F_s , is the environmental permanent force resulting from e.g. a persistent general circulation current, if any.

F_s is given by:

$$F_s = T_m - T_P$$

where:

T_m : Mean (static) line tension under permanent metocean actions.

In the absence of specific information, F_s may be taken equal to 0.

2.2.3 Dynamic forces

For each condition of the mooring system (intact, damaged, and transient condition when required) the force in line at lug F resulting from environmental actions only (i.e. excluding pretension) is evaluated for both extreme (100-year return period) and operating metocean conditions (1-year return period, if not otherwise specified: see Sec 3, [8.5] and Sec 3, [5]).

F is given by:

$$F = T_D - T_p$$

The notations in Tab 1 are used to describe corresponding forces and the associated load factors.

Table 1 : Dynamic force in line and associated load factor – Notations

Design condition	Condition of mooring system					
	Intact		Damage		Transient	
Extreme conditions	$\gamma_{Fe,i}$	$F_{e,i}$	$\gamma_{Fe,d}$	$F_{e,d}$	$\gamma_{Fe,t}$	$F_{e,t}$
Operating conditions	$\gamma_{Fo,i}$	$F_{o,i}$	$\gamma_{Fo,d}$	$F_{o,d}$	$\gamma_{Fo,t}$	$F_{o,t}$

2.3 Partial load factors

2.3.1 The partial load factor γ_p for line pretension is to be taken equal to 1,15.

2.3.2 The partial load factor γ_{fs} is to be taken equal to 1,25.

2.3.3 The partial load factor γ_f for dynamic forces is to be taken as per Tab 2 below.

Table 2 : Load factor γ_f

Design condition	Condition of mooring system		
	Intact	Damaged	Transient
Extreme conditions	$\gamma_{Fe,i} = 1,35$	$\gamma_{Fe,d} = 1,4$	$\gamma_{Fe,t} = 1,5$
Operating conditions	$\gamma_{Fo,i} = 1,25$	$\gamma_{Fo,d} = 1,3$	$\gamma_{Fo,t} = 1,4$
<p>Note 1: In intact and damage conditions, γ_f are for forces evaluated through dynamic analysis (see Sec 3, [2.4]).</p> <p>Note 2: The forces in transient conditions are usually evaluated through quasi-dynamic analysis (see Sec 3, [2.3]). If a dynamic analysis is performed, $\gamma_{Fe,t}$ and $\gamma_{Fo,t}$ may be taken as for damaged cases.</p>			

3 Capacity

3.1 Ultimate capacity

3.1.1 General

The ultimate capacity C of the anchoring device is defined as the ultimate capacity in the direction of the line at lug, as defined by angle α in [2.1.3] above, and is a function of soil strength parameters.

The evaluation of capacity is to account for any misverticality of the anchoring device.

The ultimate capacity C is to be evaluated considering the main soil parameter q (appropriate shear strength or $\tan \phi$) being divided by a material factor γ_M . The ultimate capacities are thus noted as $C (q / \gamma_M)$ in the criteria given in [5] below.

3.1.2 Material factor

The values of γ_M are given in Tab 3.

Table 3 : Material factor γ_M

Condition	γ_M (1)
Static	1,4
Intact (Extreme and Operating)	1,3
Damaged	
Transient	
(1) γ_M may be taken equal to 1,2 for sands.	

3.2 Components of ultimate capacity

3.2.1 Deadweight

The deadweight of the anchoring device P' is to be taken as the submerged weight in soil.

3.2.2 Ultimate capacity C_s and C_c

The ultimate capacity C is to be evaluated for both static (permanently applied load) and dynamic situations, and are noted respectively C_s and C_c .

For suction anchors or similar anchoring devices that may develop such phenomenon, C_s and C_c are the capacities not considering any suction effect.

3.2.3 Additional capacity C_a

For suction anchors or similar devices an additional ultimate capacity C_a , resulting from the development of in-service (normally passive) suction may be taken into account, in dynamic situation.

3.2.4 Factor for suction effect

C_a is to be factored by a factor ϵ , varying from 0 to 1.

The factor ϵ is depending on particular soil condition and device, and shall reflect :

- the confidence on the development of in-service suction (as proven by experience or through experiments, etc.)
- its anticipated mobilisation, specially under dynamic actions.

When the possibility of in-service suction is established, ϵ may be taken as the ratio of the double amplitude wave frequency load due to waves to the design tension in the situation considered, or may be derived by other appropriate method.

4 Other factors

4.1 Factor A

4.1.1 The factor A is a model factor. A is to be taken as 0,67.

For drag anchors, depending on experience on the type of anchor for the particular soil conditions and the possibility of gaining additional capacity when more deeper burying, the factor A may be taken as low as 0,55.

4.2 Uplift factor

4.2.1 The uplift factor K_α is to be taken as:

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

Where α is taken as defined in [2.1.3].

4.3 Safety factors

4.3.1 Basic minimum safety factors are specified in [5] below, on the right side of inequalities, for each relevant condition.

These factors are for anchoring devices of line type II (see NI 461).

In the case of a structure in close proximity, the safety factors for anchoring devices of line type I is to be increased in accordance with Sec 3, Tab 3 (see notes (3) and (4) of the table). A specific Risk Analysis may be considered to help in defining appropriate factors for a particular situation.

5 Criteria

5.1 General

5.1.1 The inequalities to be satisfied in each design condition are given in Tab 4 below.

The set of inequalities is to be simultaneously satisfied, however those for transient conditions need not be considered when transient analysis is not applicable (see Sec 3, [8.6])

Note 1: The criteria given in the present [5] are checking formats, not equilibrium equations.

Table 4 :

Condition of mooring system	Extreme conditions	Operating conditions
Static	$\frac{C_{CS}(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{FS} F_S} \geq 2,2AK_\alpha$	
Intact	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fe,i} F_{e,i}} \geq 1,15AK_\alpha$	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fo,i} F_{o,i}} \geq 1,45AK_\alpha$
Damaged	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fe,d} F_{e,d}} \geq 1,0AK_\alpha$	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fo,d} F_{o,d}} \geq 1,3AK_\alpha$
Transient	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fe,t} F_{e,t}} \geq 0,9AK_\alpha$	$\frac{C_C(q/\gamma_M) + \epsilon C_a(q/\gamma_M) + 0,9P' \sin \alpha}{\gamma_P T_P + \gamma_{Fo,t} F_{o,t}} \geq 1,15AK_\alpha$