OFFSHORE STANDARD
DNV-OS-E301

POSITION MOORING

OCTOBER 2004

Since issued in print (October 2004), this booklet has been amended, latest in April 2007.
See the reference to “Amendments and Corrections” on the next page.

DET NORSKE VERITAS

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

DNV Offshore Codes consist of a three level hierarchy of documents:

— *Offshore Service Specifications.* Provide principles and procedures of DNV classification, certification, verification and consultancy services.
— *Offshore Standards.* Provide technical provisions and acceptance criteria for general use by the offshore industry as well as the technical basis for DNV offshore services.
— *Recommended Practices.* Provide proven technology and sound engineering practice as well as guidance for the higher level Offshore Service Specifications and Offshore Standards.

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B) Materials Technology

C) Structures

D) Systems

E) Special Facilities

F) Pipelines and Risers

G) Asset Operation

H) Marine Operations

J) Wind Turbines

Amendments and Corrections

This document is valid until superseded by a new revision. Minor amendments and corrections will be published in a separate document normally updated twice per year (April and October).

For a complete listing of the changes, see the “Amendments and Corrections” document located at:
http://webshop.dnv.com/global/, under category “Offshore Codes”.

The electronic web-versions of the DNV Offshore Codes will be regularly updated to include these amendments and corrections.

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Main changes

- **General**

The present edition supersedes the June 2001 edition.

- **Main changes**

— Reference to DNV-RP-C203 Fatigue Strength Analysis of Offshore Steel has been included. Reference to BS 7035 has been deleted (Ch.1, Sec.1).
— Harris wind spectrum has been deleted and more information regarding squalls is included, (Ch.2 Sec.1)
— Design with respect to Vortex Induced Motions (VIM) is included (Ch.2 Sec.1).
— For floating production/storage units and offshore loading buoys analysis which include the effect of anchor line dynamics shall always be carried out regardless of water depth, (Ch.2 Sec.2).
— Definitions regarding operation in Consequence Class 1 and 2 has been updated (Ch.2 Sec.2). Main changes are:

    — The mooring system of units designed for production and or injection of oil, water and or gas through a system of flexible, steel catenary or rigid risers shall be designed according to Consequence Class 2, when the unit is not designed for emergency disconnection.
    — The mooring system of semi-submersibles accommodation units in standby position of at least 150 m can be designed according to Consequence Class 1.

— E. Operational States have been deleted (Ch.2 Sec.2).
— Updated requirements regarding corrosion allowance for chain on the Norwegian Continental Shelf, (Ch.2 Sec.2 Table E1, perilously Table F1)
— Guidance Note regarding stress concentration factors for chain in fairleads with 5 and 7 pockets has been deleted (Ch.2 Sec.2).
— Requirements for structural design and material for anchors and load attachment points (padeyes) included. Design requirements for long term mooring are separated from mobile mooring (Ch.2 Sec.4).
— Updated requirements for anchor shackles to be applied in long term mooring (Ch.2 Sec.4).
— The text regarding windlasses winches and chain stoppers have been reorganised (Ch.2 Sec.4).
— Requirements regarding skew loads caused by bearing friction in the design of fairleads have been included (Ch.2 Sec.4).
— Proof testing of anchors has been moved from Ch.2 Sec.5 to Ch.3 sec.1
— Requirements for testing of chain stoppers have been included (Ch.2 Sec.5).
— A table giving requirements for certification of material has been included in Ch.2 Sec.2.
— Requirements for anchors used on mobile mooring have been included and updated (Ch.3 Sec.2).

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CHAPTER 1

INTRODUCTION

CONTENTS PAGE

SECTION 1
GENERAL

A. General

A 100 Introduction

101 This offshore standard contains criteria, technical requirements and guidelines on design and construction of position mooring systems.

102 The standard is applicable for column-stabilised units, ship-shaped units, loading buoys and deep draught floaters (DDF) or other floating bodies relying on catenery mooring, semi-taut and taut leg mooring system.

A 200 Objectives

201 The objective of this standard shall give a uniform level of safety for mooring systems, consisting of chain, steel wire ropes and fibre ropes.

202 The standard has been written in order to:

— give a uniform level of safety for mooring systems, consisting of chain, steel wire ropes and fibre ropes
— serve as a reference document in contractual matters between purchaser and contractor
— serve as a guideline for designers, purchasers and contractors
— specify procedures and requirements for mooring systems subject to DNV certification and classification services.

A 300 Scope and application

301 The standard is applicable to all types of floating offshore units, including loading buoys, and covers the following mooring system components:

— stud chain
— studless chain
— Kenter shackles, D-shackles with dimension according to ISO 1704
— LTM shackles
— purpose built connection elements, such as triplates
— buoyancy and weight elements
— steel wire ropes
— fibre ropes
— windlass, winch and stopper
— fairleads
— anchors.

B. Normative References

B 100 General

101 The standards in Table B1 include provisions, which through reference in this text constitute provisions of this standard.

Table B1 DNV offshore service specifications, offshore standards and rules

Reference	*Title*
DNV-OS-B101	Metallic Materials
DNV-OS-C101	Design of Offshore Steel Structures, General (LRFD method)
DNV-OS-D101	Marine and Machinery Systems and Equipment
DNV-OS-C401	Fabrication and Testing of Offshore Structures
DNV-OS-D201	Electrical Installations
DNV-OS-D202	Instrumentation and Telecommunication Systems
	Rules for Classification of Ships
	Rules for Planning and Execution of Marine Operations, Part 2: Operation Specific Requirements

C. Informative References

C 100 General

101 The documents in Table C1 and Table C2 include acceptable methods for fulfilling the requirements in the standard. Other recognised codes and standards may be applied provided it is shown that they meet or exceed the level of safety of the actual standard.

Table C1 DNV Recommended Practices, Classification Notes, Guidelines and Standards for Certification

Reference	*Title*
DNV-RP-C103	Column Stabilised Units
DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
DNV-RP-E301:	Design and Installation of Fluke Anchors in Clay
DNV-RP-E302:	Design and Installation of Drag-in Plate Anchors in Clay
Classification Note: 30.5	Environmental Conditions and Environmental Loads
Certification Note No.: 2.5	Certification of Offshore Mooring Steel Wire Ropes
Certification Note No.: 2.6	Certification of Offshore Mooring Chain
Standard for Certification No.: 2.13	Standard for Certification of Offshore Mooring Fibre Ropes
Guideline No. 17	Plan Approval Documentation Types – Definitions

Table C2 Other References

Reference	*Title*
API RP 2A	Recommended Practice for Planning, Designing and Construction of Fixed Offshore Platforms
API RP 2SK	Recommended Practice for Design and Analysis of Station-keeping Systems for Floating Structures,
API RP 2SM:	Recommended Practice for Design, Analysis, and Testing of Synthetic Fibre Ropes in Offshore Applications
BS 3226	Specification for thimbles for natural fibre ropes, 1960
CI 1505-98	Test Method for Yarn-on-Yarn Abrasion (draft)
ISO 1704:	Shipbuilding – Stud link anchor chains
ISO 2232	Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes - Specifications
ISO 3178	Steel wire ropes for general purposes – Term of acceptance
ISO/TR 13637	Petroleum and natural gas industries – Mooring of mobile offshore drilling units (MODUS) – Design and analysis

ISO 13819-1:	Offshore structures Part 1: General requirements
NORSOK M-001	Material selection
NORSOK N-003:	Actions and Action Effects
OCIMF:	Guidelines for the purchasing and testing of SPM hawsers, First Edition - 2000
OCIMF:	Prediction of Wind and Current Loads on VLCCs. 2nd Edition 1994

D. Definitions

D 100 Verbal forms

101 *Shall:* Indicates a mandatory requirement to be followed for fulfilment or compliance with the present standard. Deviations are not permitted unless formally and rigorously justified, and accepted by all relevant contracting parties.

102 *Should:* Indicates a recommendation that a certain course of action is preferred or particularly suitable. Alternative courses of action are allowable under the standard where agreed between contracting parties, but shall be justified and documented.

103 *May:* Indicates a permission, or an opinion, which is permitted as a part of conformance with the standard.

104 *Can:* Requirements with can are conditional and indicate a possibility to the user of the standard.

D 200 Terms

201 *ALS:* An accidental limit state to ensure that the mooring system has adequate capacity to withstand the failure of one mooring line or one thruster or thruster system failure for unknown reasons.

202 *CALM Buoy:* Catenary anchor leg mooring. The CALM system consists of a buoy that supports a number of catenary chain legs.

203 *Classification note (CN):* The classification notes cover proven technology and solutions which are found to represent good practice by DNV, and which represent one alternative for satisfying the requirements stipulated in DNV rules or other codes and standards cited by DNV. The classification notes will in the same manner be applicable for fulfilling the requirements in the DNV offshore standards.

204 *Collinear environment:* Wind, waves and current are acting from the same direction.

205 *Creep:* Continuing elongation with time under tension. May be recoverable (primary creep) or non-recoverable (secondary creep).

206 *Creep rupture:* Breakage after a time under tension.

207 *Design brief:* An agreed document where owners requirements in excess of this standard should be given.

208 *Drift stiffness (intermediate stiffness):* Range of stiffness between minimum (post installation) and maximum (storm) stiffness. Depends on prior history and applied cyclic loading.

209 *Emergency mooring:* Anchoring in bad weather condition during transit movements of the unit, and which is capable of keeping the unit from uncontrolled drift.

210 *FLS:* A fatigue limit state to ensure that the individual mooring lines have adequate capacity to withstand cyclic loading.

211 *Horizontal low frequency motion:* Horizontal resonant oscillatory motion of a moored unit induced by oscillatory wind and second order wave loads.

212 *Long term mooring:* Mooring of a unit at the same location for more than 5 years.

213 *Marine growth:* Caused by soft (bacteria, algae, sponges, sea quirts and hydroids) and hard fouling (goose, barnacles, mussels and tubeworms).

214 *Mobile mooring:* Anchoring at a specific location for a period less than 5 years.

215 *Net thrust capacity:* Thrust capacity after all types of loss in thrust capacity are considered.

216 *Offshore standard:* The DNV offshore standards are documents which present the principles and technical requirements for design of offshore structures. The standards are offered as DNV's interpretation of engineering practice for general use by the offshore industry for achieving safe structures.

217 *Plate anchor:* Anchors that are intended to resist applied loads by orientating the plate approximately normal to the load after having been embedded.

218 *Position mooring:* Mooring of a unit at an offshore location.

219 *Post installation stiffness:* Stiffness immediately after installation.

220 *Recommended practice (RP):* The recommended practice publications cover proven technology and solutions which have been found by DNV to represent good practice, and which represent one alternative to satisfy the requirements stipulated in the DNV offshore standards or other codes and standards cited by DNV.

221 *Redundancy:* The ability of a component or system to maintain or restore its function when a failure of a member or connection has occurred. Redundancy can be achieved for instance by strengthening or introducing alternative load paths.

222 *Splash zone:* The extension of the splash zone is from 4 m below still water level to 5 m above still water level.

223 *Storm stiffness:* Is defined as the maximum stiffness of the mooring lines, which is predicted when the mooring system is subject to a maximum design storm.

224 *Temporary mooring:* Anchoring in sheltered waters or harbours exposed to moderate environmental loads.

225 *ULS:* An ultimate limit state to ensure that the individual mooring lines have adequate strength to withstand the load effects imposed by extreme environmental actions.

226 *Unit:* is a general term for an offshore installation such as ship-shaped, column-stabilised, self-elevating, tension leg or deep draught floater.

227 *Wave frequency motion:* This motion is induced by first order wave loads in the frequency range of the incoming waves.

E. Abbreviations and Symbols

E 100 Abbreviations

101 Abbreviations as shown in Table E1 are used in this standard.

Table E1 Abbreviations

Abbreviations	*In full*
API	American Petroleum Institute
ALS	accidental limit state
BS	British Standards
CI	The Cordage Institute
DIA	vertical design inlet angle
DNV	Det Norske Veritas
DWR	design working rank
FLS	fatigue limit state

IACS	International Association of Classification Societies
IMO	International Maritime Organization
ISO	International Organisation for Standardisation
NMD	Norwegian Maritime Directorate
NPD	Norwegian Petroleum Directorate
OCIMF	Oil Companies International Marine Forum
ULS	ultimate limit state

E 200 Symbols

201 *Latin characters*

a_D	Intercept parameter of the S-N curve
C_D	Drag coefficient.
	Stud chain: 2.6 with respect to diameter
	Studless chain: 2.4 with respect to diameter
	Six strand wire rope: 1.8
	Spiral stand wire rope without sheathing: 1.6
C_{D0}	The initial hull drag coefficient, including strakes, but without VIV
D	Cylinder diameter
	Spiral strand wire rope with sheathing: 1.2
d_c	Characteristic accumulated fatigue damage during the design life
d_{CSi}	The fatigue damage in one environmental state calculated by the combined spectrum method
d_d	Winch drum diameter
d_{DNBi}	The fatigue damage in one environmental state calculated by the dual narrow-banded approach
d_F	Accumulated fatigue damage ratio between the lesser and more heavily loaded of two adjacent lines
d_i	Fatigue damage in one environmental state
DIA	Design inlet angle
d_{NBi}	Fatigue damage in one environmental state, based on a narrow banded assumption
D_{nom}	Nominal chain or wire diameter
d_p	Diameter of the anchor shackle pin
d_s	The diameter of the anchor shackle
d_w	Nominal wire diameter
DWR	Design working range
$E[S_i^m]$	Expected value of the nominal stress range raised to the power of m in environmental state i
FC	Fibre core
f	Average breaking load of one wire in kN
f_1	Material factor
F_D	Towing design load
f_m	Method factor
f_n	Natural frequency of the transverse rigid body mode
f_s	Vortex shedding frequency
$f_{Si}(s)$	The probability density of nominal stress ranges of magnitude s in environmental state i
F_T	Towing force
f_{tow}	Towing design load factor
F_X	Mean environmental surge load
F_Y	Mean environmental sway load
IWRC	Independent wire rope core
h	Water depth
h_g	Depth of fairlead groove
H_s	Significant wave height
k	Restoring force coefficient (N/m)
k_1	Amplification factor for transverse VIV
k_l	Lay factor of steel wire ropes
$k_p(l)$	Correction factor evaluated for fatigue test set with *l* test specimens
K1	Stud links chain cable for bow anchors according to IACS, see DNV Rules for Classification of Ships Pt.3 Ch.3 Sec.5 E. Anchor chain cables
K2	Stud links chain cable for bow anchors according to IACS, see DNV Rules for Classification of Ships Pt.3 Ch.3 Sec.5 E. Anchor chain cables
K3	Stud links chain cable for bow anchors according to IACS, see DNV Rules for Classification of Ships Pt.3 Ch.3 Sec.5 E. Anchor chain cables
l	Number of fatigue test results
l_p	Free length of anchor shackle pin
L_{oa}	The length overall of a ship shaped unit
LTM	D-shackles where the locking device normally consists of a nut and a locking pin through the bolt
ma	The unit's mass included added mass
m	Slope parameter of the S-N curve
M_E	Maximum yaw motion between the target and the equilibrium heading
M_T	Yaw moment that can be generated by the thrusters
M_Z	Mean environmental yaw moment
n	The number of tests, not less than 5
n_i	Number of stress cycles in one environmental state
$n_c(s)$	Number of stress ranges of magnitude s that would lead to failure of the component
N_{LF}	Number of low frequency oscillations during the duration of a sea state
N_{WF}	Number of wave frequency oscillations during the duration of a sea state
P	Pitch diameter
P_i	Probability of occurrence of environmental state i
r_g	Radius of fairlead groove
R	The ratio of tension range to characteristic strength
R3	Chain quality according to IACS, see Standard for Certification 2.6
R3S	Chain quality according to IACS, see DNV Certification Note 2.6
R4	Chain quality according to IACS, see DNV Certification Note 2.6
s	Stress range (double amplitude)
S_C	Characteristic strength of the mooring line segment
S^*_C	Reduced characteristic strength
S_{mbs}	Minimum breaking strength of a new component
S_t	Strouhal number
t	Total number of wires
T_{C-mean}	Characteristic mean line tension, due to pretension and mean environmental actions in the environmental state

$T_{C\text{-}dyn}$	Characteristic dynamic line tension induced by low-frequency and wave-frequency loads in the environmental state
T_D	Design life time of the mooring line component in seconds
$T_{Design\text{-}L}$	Total design tension calculated in the operational limiting environment
$T_{Design\text{-}100}$	Total design tension in an environmental condition with a return period of 100 year
T_i	Duration of the environmental state
T_X	Thrust component in surge
T_Y	Thrust component in sway
T_p	Peak wave period
T_z	Zero up-crossing wave period
$T_{WF\text{-}max}$	Maximum wave frequency tension
$T_{QS}(.)$	Quasi-static line tension function
$U_{1\ hour,\ 10m}$	Mean wind speed over a 1 hour period 10 m above sea level
V	Current speed
V_C	Surface current speed
$V_{C_{Wind}}$	Wind generated current speed
V_r	Reduced velocity
$X_{LF\text{-}sig}$	Horizontal significant low frequency motion
$X_{LF\text{-}max}$	Maximum horizontal low frequency motion
X_{mean}	Horizontal excursion caused by the mean environmental loads relative to the still water location of the unit
X_V	The horizontal distance between the unit and an installation
$X_{WF\text{-}sig}$	Horizontal significant wave frequency motion
$X_{WF\text{-}max}$	Maximum horizontal wave frequency motion

202 *Greek characters*

δ_s	The coefficient of variation of the breaking strength of the component
δ_w	Bandwidth parameter
ΔT_{growth}	Marine growth surface thickness
γ	Arc of support of a steel wire rope in a fairlead
γ_F	Fatigue safety factor
γ_L	Additional safety factor for operational states
γ_{mean}	Partial safety factor on mean tension
γ_{dyn}	Partial safety factor on dynamic tension
λ_L, λ_W	Normalised variances of the low and wave frequency stress process
κ	Correction for 3-D effects
μ	2.0 for chain, 1.0 for wire rope
μ_s	The mean value of breaking strength of the component
ν_i	The mean up-crossing rate (hertz) of the stress process in environmental state i
ν_{yi}	The mean-up-crossing rate (hertz) for the combined stress process in environmental state i
σ_b	Specified minimum tensile strength of the material
σ_e	Nominal equivalent stress
σ_f	Specified minimum upper yield strength of the material
ρ_{growth}	Density of marine growth
ρ_i	Correction factor based on the two frequency bands that are present in the tension process
$\rho_{seawater}$	Density of seawater
σ_{Li}	Standard deviation of low frequency stress range in one environmental state
σ_{Si}	Standard deviation of the stress process
$\sigma_{X\text{-}LF}$	The standard deviation of horizontal, low frequency motion of the upper terminal point in the mean mooring line direction
$\sigma_{X\text{-}WF}$	The standard deviation of horizontal, wave frequency motion of the upper terminal point in the mean mooring line direction
$\sigma_{T\text{-}WF}$	The standard deviation of the wave-frequency component of line tension
σ_{yi}	Standard deviation of the stress process including both wave and low frequency components
σ_{Wi}	Standard deviation of wave frequency stress range in one environmental state

F. Documentation

F 100 General

101 When preparing documentation in accordance with this standard a design brief document shall be prepared and used as basis for the design documentation, stating all project specification, standards and functional requirements.

102 The design documentation shall include drawings and calculations for the limit states. The type and extent of the documentation shall be evaluated on an individual basis.

F 200 Design documentation

201 The following general design documentation of the mooring system is required:

- number of lines
- type of line segments
- dimensions
- material specifications
- weight in air and seawater
- line length from fairlead to anchor point of individual segments
- additional line length kept onboard
- characteristic strength
- anchor pattern
- anchor type
- horizontal distance between fairleads and anchor point and/or initial pretensions
- position of buoyancy elements, and net buoyancy
- position of weight elements, and weight in air and seawater
- position and type of connection elements, such as Kenter shackles, D-shackles, and triplates
- windlass, winch and stopper design
- anchor design including anchor size, weight and material specifications.

202 The following documentation of environmental data used as basis for the design is required:

a) Combinations of significant wave heights and peak periods along the 100-year contour line for a specified location. Directionality may be considered if sufficient data exist to develop contour lines for from 0° to 360° with a maximum spacing of 45°.

b) 1 hour mean wind speed with a return period of 100 year, and wind gust spectrum Directionality may be considered if sufficient data exist to develop wind speeds with 100 year return periods for directions from 0° to 360° with a maximum spacing of 45°.

c) Surface and subsurface current speed with a return period of 10 years. Directionality may be considered if sufficient data exist to develop current speeds with 10 year return periods for directions from 0° to 360°, with a maximum spacing of 45°.

d) Current profile.

e) Water depths.

f) Soil conditions.

g) Marine growth, thickness and specific weight.

h) Wave spectrum.

i) Wave energy distribution: Long crested sea. Wind generated waves may be considered short crested described by a cosine to the power 4 wave directionality function.

203 The following drawings and documentation of mooring design and mooring design capacities are required:

a) The accuracy of computer program applied for calculation of the unit's response shall be quantified by comparison with relevant model test results.

b) The accuracy of the model test results applied in the design shall be quantified.

c) Wind and current loads based on coefficients from wind tunnel tests, model basin tests or theoretical calculations according to recognised theories, see Ch.2 Sec.1 C101 and C201.

d) Transfer functions (RAOs) of motion in six degree of freedom.

e) Wave drift force coefficients, see Ch.2 Sec.1 C400. Viscous effect shall be considered together with the current effect on the wave drift forces.

f) Wave frequency motions for selected sea states, see Ch.2 Sec.1 B201.

g) Wind and wave induced low frequency motions, see Ch.2 Sec.2 B104 and B200.

h) Mean offset caused by wind, current and waves.

i) Mooring line tensions in ULS and ALS limit states, see Ch.2 Sec.2 B400 and B500.

j) Fatigue calculations of mooring line segments and accessories, see Ch.2 Sec.2 G.

k) Windlass and winch lifting capacity, static and dynamic braking capacity, see Ch.2 Sec.4 K.

l) Structural strength calculation of main components of windlass or winch such as cable lifter or drum, couplings, shafts, brakes, gears and frame bases.

m) Strength calculation of anchors except for type approved drag anchors.

n) Holding capacity of the anchors.

o) Necessary installation tension for drag embedment anchors.

p) Structural strength calculations of fairlead, see Ch.2 Sec.4 L.

204 Additional documentation required for fibre ropes used as mooring systems:

a) Basic rope information:

— fibre rope type
— material
— reel/rope diameter ratio
— sheathing type
— end termination.

b) Rope properties:

— characteristic strength
— fatigue strength
— residual breaking strength
— creep properties
— axial stiffness under static and dynamic load
— heat build up under dynamic loading
— torque and twist behaviour
— resistance to chemical attack in the offshore environment.

More information is found in Ch.2 Sec.5 F for synthetic fibre ropes.

205 Additional documentation required for thruster assisted mooring systems:

a) System schematics for remote thrust control system.

b) System schematics for automatic thrust control system.

c) Power distribution schematics for thrust system.

d) Test program for sea trials regarding thruster assistance.

e) Net available thrust output showing which effects have been considered to derive the net thrust relative to nominal thrust output.

206 If the thruster assistance is subject to redundancy requirements, the redundancy is to be documented by one of the following methods:

a) Failure mode and effect analysis (FMEA), covering all relevant sub-systems. Special attention should be taken in case emergency shut down systems are installed.

b) A test program covering failure situations and thereby demonstrating redundancy. The test program has to be carried out during thruster assistance sea trials.

207 Additional documentation required for long term mooring:

a) Fatigue calculation of mooring lines and connecting elements using site specific data.

b) Line tensions with and without marine growth shall be considered.

c) Corrosion allowance shall be included in design.

d) When fluke anchors or plate anchors are used calculations of anchor resistance for ULS and ALS, see guidance in DNV-RP-E301 and DNV-RP-E302.

OFFSHORE STANDARD
DNV-OS-E301

POSITION MOORING

CHAPTER 2

TECHNICAL PROVISIONS

CONTENTS PAGE

DET NORSKE VERITAS

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SECTION 1
ENVIRONMENTAL CONDITIONS AND LOADS

A. General

A 100 Objective

101 This section describes the environmental data to be used in the mooring system analyses.

A 200 Application

201 The environmental loads to be applied in mooring line response calculations should be based on wind and wave conditions with a 100-year return period, applied together with current with a 10-year return period.

202 An alternative for regions with multiple design events (i.e. hurricanes and loop currents for Gulf of Mexico, and swell and local squalls for West Africa) is:

— The environmental condition represented by wind and current with a return period of 100-year in combination with a sea state with a 10-year return period should also be considered. See B403.

203 The specified combinations of environmental loads and headings should cover conditions at a wide variety of locations, because they have been calibrated for both the Norwegian Sea and the Gulf of Mexico. However, some locations may experience environmental processes of a different nature, which are not fully covered by the present specification; e.g. angles between wind, wave or current effects that are due to local geography, or extreme wind waves together with significant swell in a different direction. In such cases, a conservative choice of characteristic environment should be made for the ULS and ALS, aiming for a return period of no less than 100 years for the combined environmental event. The combination of environmental loads that leads to the largest line tensions should be selected, at this environmental return period.

204 Reliability analysis can be applied as a more precise alternative, if sufficient environmental data is available to develop joint probability distributions for the environmental loads.

B. Environmental Conditions

B 100 General

101 The load effects are based on the predicted tensions in the mooring lines, normally obtained by calculations. The analysis of the line tensions shall take into account the motion of the floating unit induced by environmental loads, and the response of the mooring lines to these motions. The characteristic load effects are obtained for stationary, environmental states. Each stationary environmental state may be specified in terms of:

— significant wave height (H_s)
— peak wave period (T_p)
— wave spectrum (Jonswap or double-peaked)
— wave energy spreading function (long crested waves or a cosine to the power of 4)
— main wave direction
— mean wind speed, over a 1 hour averaging period 10 m above sea level ($U_{1\ hour,\ 10\ m}$)
— wind spectrum function
— wind direction
— surface current speed (V_C)
— current profile over depth
— current direction.

The same environmental conditions should be considered for the ULS and ALS, while a wider range of environmental conditions must be considered for the FLS.

B 200 Waves

201 Sea states with return periods of 100 years shall be used. The wave conditions shall include a set of combinations of significant wave height and peak period along the 100-year contour, as defined by inverse FORM technique, /1/. The joint probability distribution of significant wave height and peak wave periods at the mooring system site is necessary to establish the contour line.

202 If this joint distribution is not available, then the range of combinations may be based on a contour line for the North Atlantic, see 204.

203 It is important to perform calculations for several sea states along the 100-year contour line to make sure that the mooring system is properly designed. Ship-shaped units are sensitive to low frequency motion, and consequently a sea state with a short peak period can be critical. How to choose sea states along the contour line is indicated in Fig.1. The same values for wind and current shall be applied together with all the sea states chosen along the 100-year contour.

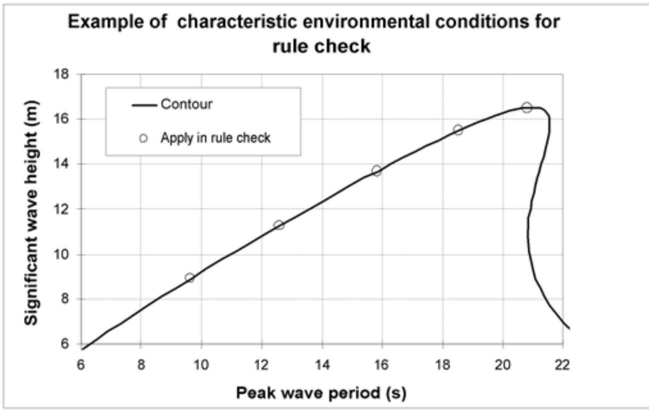
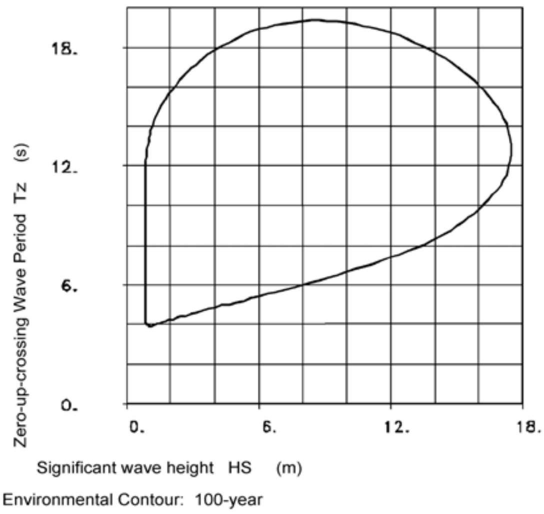


Figure 1
Selections of sea states along a 100-year contour line

204 For units intended for world wide operations a 100-year contour line for the North Atlantic may be applied, the contour line is given in the Guidance Note below. The contour line is based on the scatter diagram for the North Atlantic given in Classification Note 30.5. Typical sea states with a 100-year return period for different locations around the word is also given in the Guidance Note applicable for preliminary designs when detailed metocean data is not available.

Guidance note:



Typical sea states at different locations with a return period of 100 years are given below. Each sea state (3-hour duration) is characterised by maximum significant wave height and wave period (T_p or T_z):

Norwegian Sea (Haltenbanken)	H_s	=	16.5 m
	T_p	=	17.0 -19.0 s
Northern North Sea (Troll field)	H_s	=	15.0 m
	T_p	=	15.5 –17.5 s
North Sea (Greater Ekofisk area)	H_s	=	14.0 m
	T_p	=	15.0 – 17.0 s
Mediterranean			
- Libya (shallow water)	H_s	=	8.5 m
	T_p	=	14.0 s
- Egypt	H_s	=	12.1 m
	T_p	=	14.4 s
Gulf of Mexico (Hurricane)	H_s	=	11.9 m
	T_p	=	14.2 s
West Africa			
- Nigeria (swell)	H_s	=	3.6 m
	T_p	=	15.9 s
- Nigeria (squalls)	H_s	=	2.7 m
	T_p	=	7.6 s
- Gabon (wind generated)	H_s	=	2.0 m
	T_p	=	7.0 s
- Gabon (swell)	H_s	=	3.7 m
	T_p	=	15.5 s
- Ivory Coast (swell):	H_s	=	6.0 m
	T_p	=	13.0 s
- Angola (swell, shallow water)	H_s	=	4.1 m
	Tp	=	16.0 s
South America			
- Brazil (Campos Basin)	H_s	=	8.0 m
	T_p	=	13.0 s
Timor Sea			
- Non typhoon	H_s	=	4.8 m
	T_p	=	11.5 s
	T_z	=	8.3 s
- Typhoon	H_s	=	5.5 m
	T_p	=	10.1 s
	T_z	=	7.4 s
South China Sea			
- Non typhoon	H_s	=	7.3 m
	T_p	=	11.1 s
- Typhoon	H_s	=	13.6 m
	T_p	=	15.1 s

The following relation between the T_Z and the T_p can be applied:

$$T_z = T_p\left(\frac{5+\gamma_p}{11+\gamma_p}\right)^{1/2}$$

If no particular peakedness parameter γ_p, the following value may be applied:

$$\gamma_p = 5 \text{ for } \frac{T_p}{\sqrt{H_s}} \leq 3.6$$

$$\gamma_p = e^{5.75 - 1.15\frac{T_p}{\sqrt{H_s}}} \quad \text{for } 3.6 \leq \frac{T_p}{\sqrt{H_s}} < 5$$

$$\gamma_p = 1.0 \text{ for } 5 \leq \frac{T_p}{\sqrt{H_s}}$$

Further information is found in Classification Note 30.5.

If the peakedness parameter is not defined the following can be applied:

— North Sea or North Atlantic: γ_p = 3.3
— West Africa: γ_p = 1.5 ± 0.5
— Gulf of Mexico: γ_p = 1 for $H_s \leq 6.5$ m
γ_p = 2 for $H_s > 6.5$ m.

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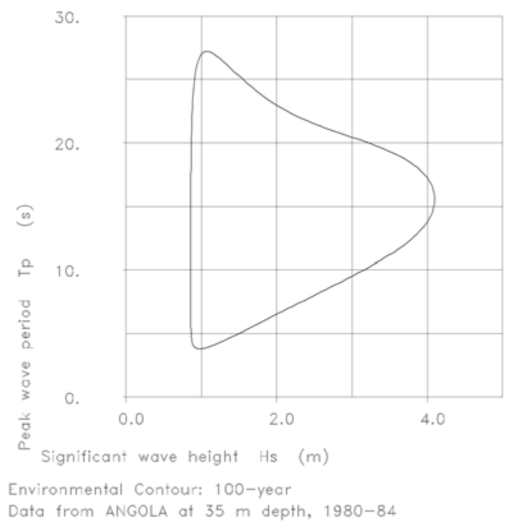
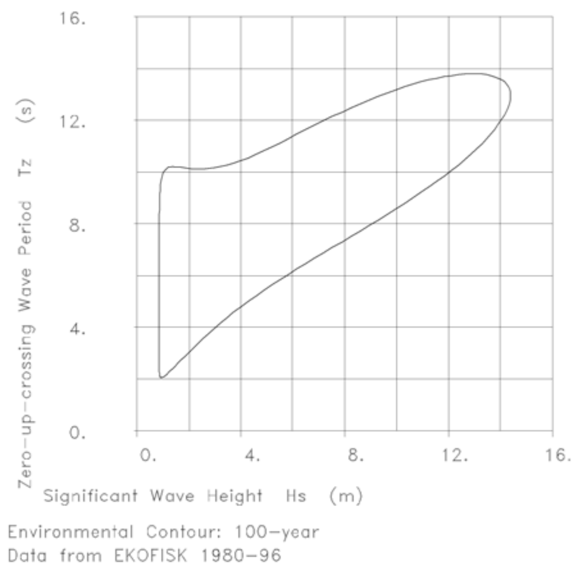
205 Examples of contour lines for different areas are given in the guidance note below.

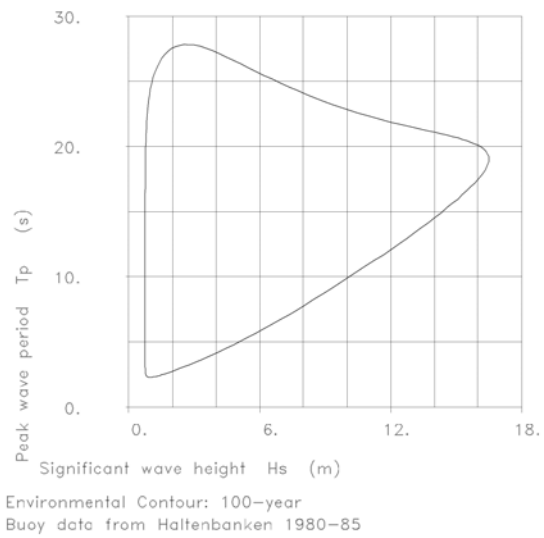
Guidance note:



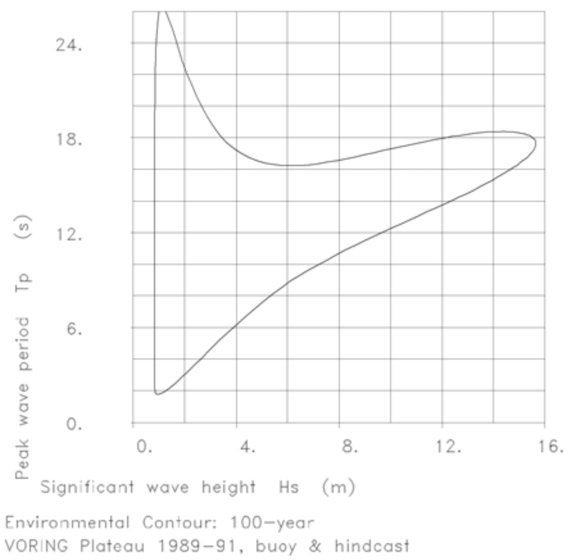
100-year contour line – Angola (swell)



100-year contour – Ekofisk (North Sea)



100-year contour – Haltenbanken (North Atlantic)



100-year contour – Vøring (North Atlantic)

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B 300 Wind

301 A mean wind speed 10 m above the water surface with a 100-year return period should be used, based on the marginal distribution of wind speeds at the specific locations.

302 Wind load shall be treated as a steady component in combination with a time varying component known as the gust, which generates low frequency motion. The time varying wind is described by a wind gust spectrum.

303 The following wind spectrum shall be applied dependent on location:

a) The NPD wind spectrum shall be applied for locations in the North Sea and North Atlantic. The formulation is given in NORSOK N-003.

b) The API wind spectrum may be used for locations outside the North Sea and North Atlantic. The formulation is given in API RP 2A.

304 The steady component of the wind speed is represented by a 1-hour average mean wind 10 m above sea level.

Guidance note:

Some typical 1 hour mean wind speeds with a return period of 100 years at different locations:

Norwegian Sea (Haltenbanken)	37.0 m/s
North Sea (Troll field)	40.5 m/s
North Sea (Greater Ekofisk area)	34.0 m/s
Mediterranean	
- Libya	25.3 m/s
- Egypt	25.1 m/s
Gulf of Mexico (Hurricane)	44.1 m/s
West Africa	
- Nigeria (combined with swell)	16.0 m/s
- Gabon (combined with swell)	16.6 m/s
- Gabon (squall)	24.1 m/s
- Ivory Coast (combined with swell)	16.0 m/s
- Ivory Coast (squall)	29.5 m/s
- Angola (squall)	21.8 m/s
South America	
- Brazil (Campos Basin)	35.0 m/s

Timor Sea	
- Non typhoon	16.6 m/s
- Typhoon	23.2 m/s
South China Sea	
- Non typhoon	28.6 m/s
- Typhoon	56.3 m/s

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305 The definition of wind speed as a function of time and height above sea level is given in Classification Note 30.5.

306 The Squall events should normally be analysed in the time domain using the time histories of squalls. The duration of squalls is approximately one hour. An example of a squall time series with respect to wind speed and direction is given in the guidance Note. The squalls directions may vary more than the Fig.3 in the guidance note indicate. Site specific data shall always be applied.

Guidance note:

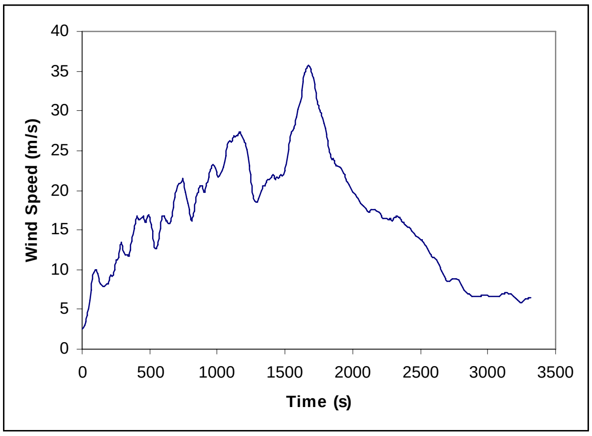

Figure 2
Squall time series with respect to wind speed

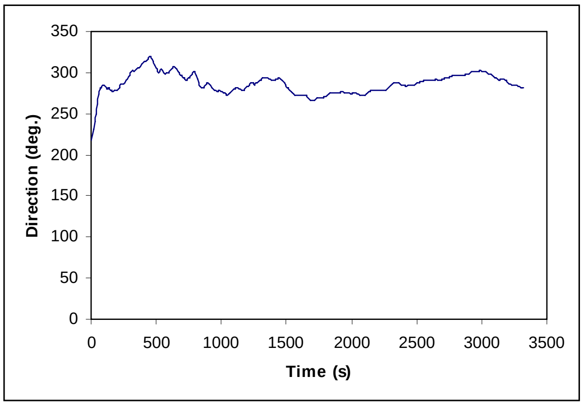

Figure 3
Squall time series with respect to direction

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B 400 Current

401 A surface current speed with a 10-year return period should be used, based on the marginal distribution of current speeds at the location.

402 The most common categories are:

- tidal currents (associated with astronomical tides)
- circulational currents (associated with oceanic circulation patterns)
- wind generated currents
- loop and eddy currents
- soliton currents

The vector sum of these currents is the total current, and the speed and direction of the current at specified depths are represented by a current profile. In certain geographical areas, current loads can be the governing design loads.

403 In areas where the current speed is high, and the sea states are represented with small wave heights e.g. West Africa, an environmental condition represented by 100 year wind and current speeds combined with a sea state with a return period of 10 year should be considered.

404 In open areas wind generated current velocities at the still water level may be taken as follows, if statistical data is not available:

$$V_{C_{Wind}} = 0.015 \cdot U_{1hour,\ 10m}$$

Guidance note:
Some typical surface current speeds with a return period of 10 years at different location:

Norwegian Sea (Haltenbanken)	0.90 m/s
North Sea (Troll)	1.50 m/s
North Sea (Greater Ekofisk area)	0.55 m/s
Mediterranean	
- Libya	1.00 m/s
- Egypt	0.78 m/s
Gulf of Mexico (Hurricane)	1.98 m/s
West Africa	
- Nigeria	1.1 m/s
- Gabon	0.91 m/s
- Ivory Coast	0.90 m/s 1)
- Angola	1.85 m/s 2)
South America	
- Brazil (Campos Basin)	1.60 m/s
Timor Sea	
- Non typhoon	1.10 m/s
- Typhoon	1.90 m/s
South China Sea	
- Non typhoon	0.85 m/s
- Typhoon	2.05 m/s
1) Ocean current going to east	
2) Ocean current going to 347.5° approximately parallel to the coast	

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405 The current's influence on the wave drift forces shall be taken into account.

B 500 Direction of wind, waves and current relative to the unit

501 For column-stabilised units and ships, which are directionally fixed, the loads from wind, waves and current are assumed acting in the same direction.

502 For units with symmetrical anchor pattern, at least head, quartering and beam load directions should be analysed in addition to the case where wind, current and waves are acting in the direction of an anchoring line.

503 A directional distribution of wind, waves and current may be applied if available.

504 For offset calculation use the direction that is intermediate to two neighbour lines in addition to the directions specified in 501.

505 For units with non-symmetrical anchor pattern all directions from 0° to 360° with a maximum spacing of 45° should be investigated. At least one case where the wind, current and waves are acting in the direction of an anchoring line shall be included. A directional distribution of wind, waves and current may be applied if available.

506 For weather vaneing units such as turret moored production or storage vessels dependant on heading control, site specific data regarding the direction spread of wind, waves and current shall be applied.

507 If site specific data is not available the following two combinations of wind, wave and current shall be applied:

Collinear environment:

— wind, waves and current acting in the same direction. The direction shall be 15° relative to the unit's bow.

Non-Collinear environment:

— wave towards the unit's bow (0°)
— wind 30° relative to the waves
— current 45° relative to the waves.

Wind and current shall approach the unit from the same side, see Fig.4.

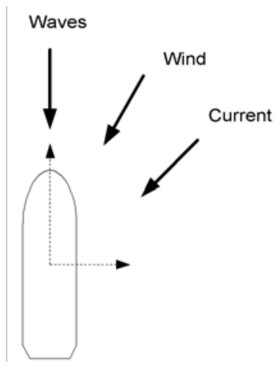

Figure 4
Non-collinear – Directions of wind, waves and current

508 The environmental directions in 507 are also applicable for freely weather vaneing units, which will rotate to an equilibrium position where the environmental directions have changed relative to the bow.

509 Directional distribution of wind wave and current may be applied if available.

510 The directionality shall be considered for units in regions where the directions of wind, waves and current are not correlated. Typical directionality for West Africa (offshore Nigeria) is shown in Fig.5.

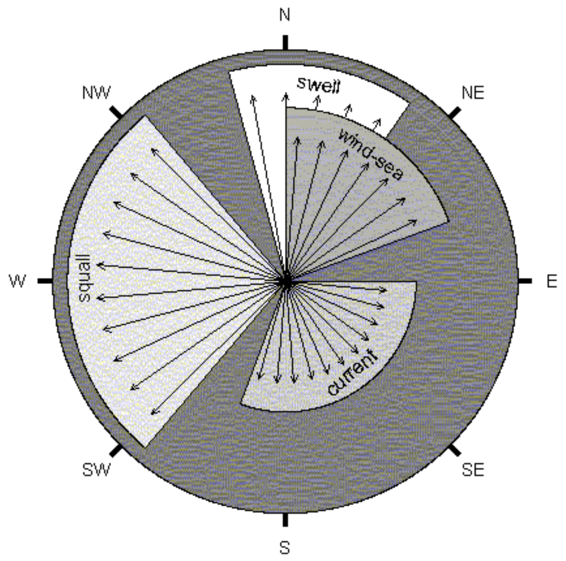

Figure 5
The directional sectors of swell, sea, current and squalls offshore Nigeria

B 600 Soil condition

601 For long term mooring, sea bed soil conditions shall be determined for the intended site to provide data for the anchor design. Soil data should be based on soil borings at location to a depth representative of anchor penetration.

B 700 Marine growth

701 Marine growth on the mooring lines shall be included in the analysis of long term mooring systems for production and storage vessels. The thickness of the marine growth shall be in accordance with the specification for the actual location. The marine growth is accounted for by increasing the weight of the line segments, and increasing the drag coefficients.

Guidance note:

Marine growth is dependent on the location. If no data is available the following data from NORSOK N-003 shall be used:

	56 -59 °N	*59 - 72 °N*
Water depth (m)	*Thickness (mm)*	*Thickness (mm)*
+2 to -40	100	60
below -40	50	30

The density of marine growth may be set to 1325 kg/m^3

Mass of marine growth:

$$M_{growth} = \frac{\pi}{4}\left[(D_{nom} + 2\Delta T_{growth})^2 - D_{nom}^2\right]\rho_{growth} \cdot \mu \quad (kg/m)$$

Submerged weight of marine growth:

$$W_{growth} = M_{growth}\left[1 - \frac{\rho_{seawater}}{\rho_{growth}}\right]\frac{9.81}{1000} \quad (kN/m)$$

ρ_{growth}	=	density of marine growth
$\rho_{seawater}$	=	density of sea water
D_{nom}	=	nominal chain or wire diameter
ΔT_{growth}	=	marine growth surface thickness
μ	=	2.0 for chain, 1.0 for wire rope.

Increasing the drag coefficient due to margine growth:

$$22C_{Dgrowth} = C_D\left[\frac{D_{nom} + 2 \cdot \Delta T_{growth}}{D_{nom}}\right]$$

C_D = stud chain: 2.6
studless chain: 2.4 with respect to chain diameter

C_D = six strand steel wire rope: 1.8
spiral stand without sheathing: 1.6
spiral strand with sheathing: 1.2.

Other methods for determing the increased drag coefficients due to marine growth may be accepted.

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C. Environmental Loads

C 100 Wind loads

101 The wind load may be determined by using wind tunnel tests, model basin tests or calculations according to recognised standards, such as:

- Classification Note 30.5 Section 5
- OCIMF Prediction of Wind and Current Loads on VLCCs, 2nd Edition 1994
- API RP 2SK.

102 Mean wind force may be calculated using a drag force formulation, with drag coefficients from model tests, or numerical flow analysis.

103 Mean wind forces described with a wind profile, and oscillatory wind forces due to wind gusts shall both be included. Wind profile according to Classification Note 30.5 Sec. 2 may be applied.

104 Model test data may be used to predict wind loads for mooring system analyses provided that a representative model of the unit is tested. The condition of the model in the tests, such as draught and deck arrangement should closely match the expected conditions that the unit will see in service. Care should also be taken to ensure that the character of the flow in the model tests is the same as the character of the flow for the full scale unit.

105 Documentation of the load analysis method shall be available. The accuracy of numerical models should be quantified by comparison with full scale or model tests. The accuracy of model test results applied in the design shall also be quantified.

C 200 Current loads

201 The current load may be determined from wind tunnel tests, model basin tests or calculations according to recognised theories, such as:

- Classification Note 30.5 Section 6
- OCIMF Prediction of Wind and Current Loads on VLCCs, 2nd Edition 1994.

202 Mean current force may be calculated using a drag force formulation, with drag coefficients from model tests, or numerical flow analysis.

203 If the water depth is less than three times the draught of a ship, the current drag coefficients will increase. Current coefficients for ships given in the OCIMF guideline referred above include shallow water effects.

204 Current profiles shall be used. The current profile described in Classification Note 30.5.

205 Site specific current profiles have to be developed for regions where loop or solition current is dominant.

206 The current loads on multiple riser systems have to be included. Current load is normally neglected for a riser system consisting of a single drilling riser.

207 Current loads on mooring lines are normally neglected. However, in regions where current is dominating (see A202 and B403) current loads on the anchor lines have to be included.

208 Model test data may be used to predict current loads for mooring system analyses provided that a representative model of the under water hull of the unit is tested. The draughts of the model in the tests have to match the expected conditions that the unit will see in service.

209 Documentation of the load analysis method shall be available. The accuracy of numerical models should be quantified by comparison with full scale or model tests. The accuracy of model test results applied in the design shall also be quantified.

C 300 Wave loads

301 Interaction between waves and a floating unit results in loads of three categories:

a) Steady component of the second order loads known as mean wave drift loads.
b) First order wave loads oscillate the wave frequencies inducing first order motions known as wave frequency motions.
c) Second order wave loads that act together with oscillatory wind loads to induce low frequency motions.

302 Documentation of the load analysis method shall be available. The accuracy of numerical models should be quantified by comparison with full scale or model tests. The accuracy of model test results applied in the design shall also be quantified.

C 400 Wave drift forces

401 The mean wave drift load is induced by the steady component of the second order wave loads. The determination of mean drift load requires motion analysis e.g. radiation or diffraction theory or model testing results.

402 The wave drift force coefficients calculated by potential theory do not include viscous forces. Effects from wave/current interaction have to be included together with viscous effects if relevant.

C 500 Wave frequency motions

501 Wave frequency motions shall be calculated according to recognised theory or based on model testing. The following calculation methods are recommended:

a) Wave frequency motions of large volume structures shall be calculated by diffraction theory. For slender structures, strip theory may be applied.
b) Wave diffraction solutions do not include viscous effects. When body members are relatively slender or have sharp edges, viscous effects may be important and viscous effects should be added to the diffraction forces. For slender bodies such as ships viscous damping in roll has to be included.
c) Wave frequency motions of column-stabilised units, which consist of large volume parts and slender members should be calculated by using a combination of wave diffraction theory and Morisons's equation.

502 The JONSWAP spectrum shall normally be used to describe wind induced extreme sea states. The formulation of the JONSWAP spectrum is given in Classification Note 30.5. If no particular peakedness parameter is given, the relation between the significant wave height, peak period and the peakedness parameter given in Sec.2 B204 should be applied.

503 Extreme wind generated waves may be considered to be long crested or the short crestedness may be described by cosine to the power of 4.

504 Consideration of swell should be included if relevant. Sea states comprising unidirectional wind generated waves and swell should be represented by a recognised doubled-peaked spectrum. The formulation of a doubled peak spectrum /3/ is given in Classification Note 30.5. Swell shall be considered long crested.

505 The most probable largest wave frequency motion amplitude may be calculated assuming that the maxima of the motion response fit a Rayleigh distribution according to Sec.2 B405.

506 When anchoring takes place in shallow water, the following shall be included in the calculation of wave frequency motion:

a) The effect on wave frequency motion caused by restoring forces due to the mooring system and risers shall be investigated when the water depth is below 70 m. The effect shall be taken into account if the wave frequency motions are significantly affected.

b) When the water depth is less than 100 m, the finite depth effect shall be included in the horizontal wave frequency motions. If calculations of wave frequency motions are not available for the actual water depth, the amplification factors given in Fig.6, Fig.7 and Fig.8 can be multiplied with the maximum wave frequency motion calculated for water depths larger than 100 m according to Sec.2 B405.

Guidance note:

For column-stabilised units the amplification factors for the wave frequency motion can be taken according to Fig.6

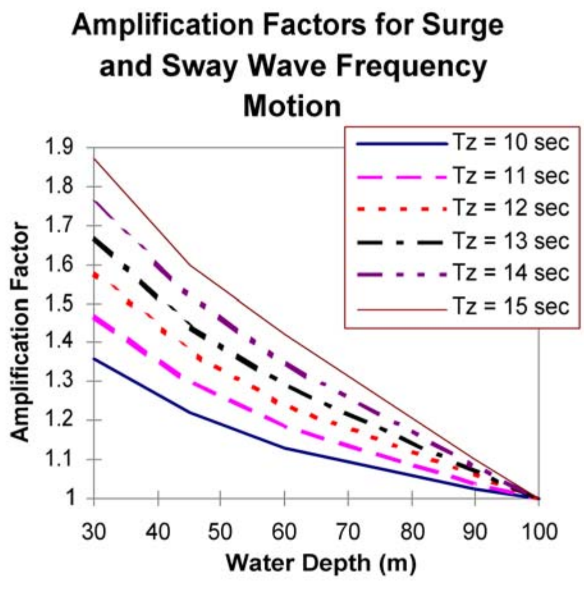

Figure 6
Amplification factors for surge and sway (column-stabilised units)

For ship-shaped units the amplification factors to be applied for wave frequency motion may be taken according to Fig.7 and Fig.8.

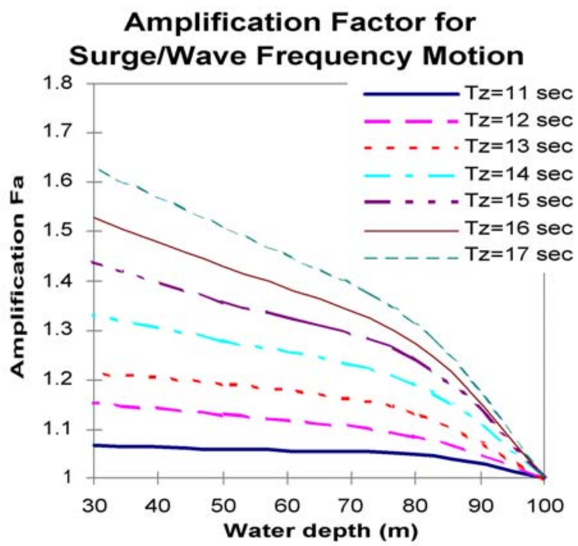

Figure 7
Amplification factors for surge (ships)

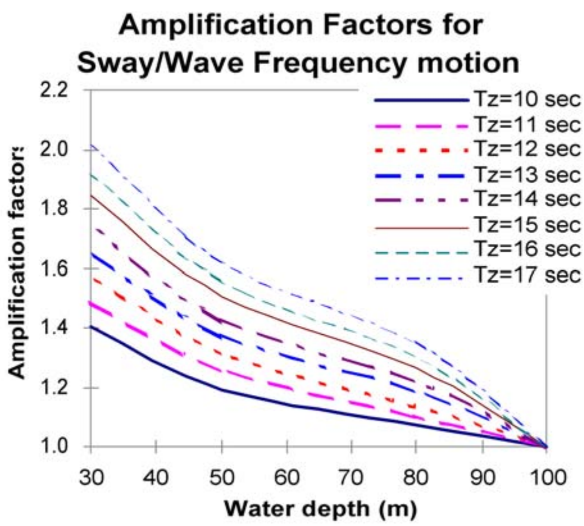

Figure 8
Amplification factors for sway (ships)

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507 For taut leg mooring systems the stiffness of the mooring system and risers shall be included in the calculation of wave frequency motions regardless of water depth if the wave frequency motions are significantly affected.

C 600 Low frequency motions

601 Environmental actions due to wind, waves and current shall be taken into account in the analysis of the mean and low frequency motion response of the vessel. Only horizontal modes of motion (surge, sway, yaw) are usually considered for ships and semisubmersibles, while vertical modes need to be included for deep draught floaters /4/.

602 Mean wind and current forces may be calculated using a drag force formulation, with drag coefficients from model tests, or numerical flow analysis. The drag coefficients are dependent on the angular orientation of the vessel relative to the incoming fluid flow direction.

603 Mean wave forces may contain components due to both potential and viscous effects. Potential effects may be based on the results of a prior first-order analysis, which provides mean drift force coefficients for each mode of motion, as a function of wave frequency, current speed, and angular orientation of the vessel. Linear superposition may be applied to obtain the mean forces in irregular, long-crested waves, by combination of the mean drift force coefficients with a wave spectrum. Viscous effects on the mean force due to waves are usually omitted in practice.

604 The mean position of the vessel in an environmental state is computed by finding the position where equilibrium is established between the mean environmental loads and the restoring forces from the positioning system. The nonlinear characteristic of a catenary mooring should be taken accurately into account in establishing the mean offset. If the vessel is free to rotate, then the effect of any rotation should be taken into account in computing the magnitude of the mean environmental forces. A stable equilibrium position should be sought.

605 Low-frequency wind forces may be based on a drag force formulation, with wind speed as the sum of the mean wind speed and an unsteady wind speed, from a wind spectrum. Expansion of the quadratic term in wind speed yields:

— the mean force, already considered above
— a force proportional to the unsteady wind spectrum, scaled by the mean speed
— a quadratic term in the unsteady speed, which is neglected.

606 The low-frequency wave forces may contain components due to both potential and viscous effects. In this case, it may be necessary to take the viscous effects into account for column-stabilised units, but they may be neglected for ships. Potential effects may still be based on first-order analysis, using the mean drift force coefficients, mentioned above. The spectral density of exciting forces in irregular waves may then be obtained as described in /5/.

607 It is more difficult to incorporate viscous contributions to the low-frequency excitation in a frequency domain analysis. Hence a time domain analysis may be needed for semisubmersibles.

608 Low-frequency motion response to the exciting forces may be calculated in the frequency domain or the time domain. Linearisation of the restoring forces from the mooring system is necessary in frequency domain analysis. The linearisation should be applied around the mean vessel offset for the environmental state being considered, using stochastic linearisation, or assuming a realistic response amplitude.

609 Low frequency wave induced motion may be based on model testing in stead of, or in addition to numerical calculations.

610 The test or simulation duration time shall be sufficient to provide adequate statistics, and shall not be taken less than three hours.

611 The most probable largest low frequency motion amplitude may be calculated assuming that the maxima of the motion response fit a Rayleigh distribution. See Sec.2 B405.

612 The effect of the current velocity on the low frequency damping shall be considered. Comparison with relevant model test data is recommended.

Guidance note:

Low frequency motion of a moored unit is dominated by the resonance at the natural frequency of the moored unit. The motion amplitude is highly dependent on the stiffness of the mooring system, and on the system damping. A good estimate of damping is critical in computing low frequency motions. There are four main sources of damping:

- viscous damping of the unit
- wave drift damping
- mooring and riser system damping
- thruster damping (only applicable for thruster assisted mooring)

The wave drift damping and the mooring or riser system damping are often the most important contributors to the total damping.

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D. Vortex Induced Motion (VIM)

D 100 General

101 Moored platforms constructed from large circular cylinders, such as Spars and some other deep draught floaters, may experience vortex-induced vibrations (VIM) when exposed to a steady current. VIM should be considered in the design of mooring systems for such floaters, because it may induce additional loads on the mooring system.

102 Vortex-induced vibrations occur transversely to the current direction, and in line with the current. These vibrations contribute to the offset away from the still water position. The occurrence of VIM also increases the mean drag force in the current direction, making a further contribution to offset. Increased offset implies increased mooring line tensions, to be checked against the line strength in the ULS and ALS. VIM also causes oscillations in the line tension, which may contribute to fatigue damage, to be checked in the FLS.

103 The present guidance is largely based on general principles, and will need to be refined when more full scale experience with VIM of moored platforms has been accumulated.

D 200 Conditions for VIM to occur

201 Significant VIM is only expected to occur if a natural frequency of the moored system lies in the vicinity of the vortex shedding frequency of a major cylindrical component of the platform. Natural frequencies for rigid body modes transverse to the current direction (e.g. sway and roll) should be considered. They may be compared to the vortex shedding frequency given by

$$f_S = S_t \frac{V}{D}$$

where V is the current speed, D is the cylinder diameter, and St is the Strouhal number. The Strouhal number is dependent on Reynolds number. The Reynolds number tends to be > 10^7 for the large cylinder diameters used in these platforms. Hence, it should be appropriate to consider a Strouhal number $S_t \approx 0.22$ in such cases.

Only the maximum current speed needs to be considered when checking for occurrence of VIM i.e. the current speed with 100-years return period. If the natural frequencies are appreciably greater than the vortex shedding frequency for this current speed, then VIM is not expected to occur. Otherwise, VIM may occur at this speed or at lower speeds.

202 It is most convenient if significant VIM can be ruled out. In some cases, it may be possible to increase the stiffness of the mooring system, such that the natural frequencies lie above the vortex shedding range. However, an increase in the stiffness of the mooring system usually implies higher mooring line tensions, increased wear in the lines and increased mooring loads on the platform. A highly nonlinear restoring force from the mooring system will also tend to suppress VIM.

D 300 VIM analysis

301 VIM should be analysed when it cannot be ruled out. This can require considerable effort, and is likely to depend on careful model testing. DNV Classification note no.30.5 provides further guidance and some data that can be used in a preliminary, rough assessment of VIM response. The objective of the VIM analysis is primarily to obtain:

a) the amplitude of the transverse VIM, under varying current speeds
b) the magnitude of the mean drag coefficient, dependent on the amplitude of VIM
c) the amplitude of the variation in the drag force, at twice the vortex shedding frequency.

302 It is usually convenient to present results in a non-dimensional form, giving the ratio of transverse VIM amplitude to cylinder diameter A/D as a function of the reduced velocity

$$V_r = \frac{V}{Df_n}$$

where f_n is the natural frequency of the transverse rigid body mode. Some random variation of the VIM amplitude will normally be found in test results for a given velocity. The mean amplitude is appropriate for use in the FLS, while the USL should take account of the random variation.

303 It should be acceptable to assume that the oscillation frequency is equal to the natural frequency of the transverse oscillation mode, for lightly damped systems, although there is some tendency for the oscillation frequency to increase with Ur. The drag coefficient is given as a function of the amplitude ratio A/D. The following functional form is sometimes used:

$$C_D = \kappa C_{D0}\left(1 + k_1 \frac{A}{D}\right)$$

where κ is a correction for 3-D effects, C_{D0} is the initial hull drag coefficient, including strakes, but without VIM, and k1 is an amplification factor for transverse VIM.

It should be noted that these results are dependent on:

— mass (or inertia) ratio of the cylinder to the displaced fluid
— any system damping in addition to direct fluid effects on the cylinder
— Reynold's number
— surface roughness of the cylinder
— turbulence or shear in the incoming velocity field
— any VIM suppression devices, such as strakes.

304 Hence, scale effects should be considered carefully when utilising model test results. When Froude scaling is applied and the viscosity is about the same at both scales, then the Reynolds number falls by the scale factor raised to the power 3/2 in the model tests. It is important to check the effect of this change on VIM. A roughened model can be useful to compensate for a low Reynolds number; i.e. to provide the correct flow regime in the model tests.

Additional considerations for model tests include:

— accurate representation of the actual underwater hull with cut-outs, terminations, etc.
— sufficient heading angles are tested to cover all aspects of asymmetry in the hull
— sufficient simulation/towing length in the basin such that vortex shedding can be fully developed
— an adequate range of reduced velocity is covered.

305 Platform VIM response may include both translational and rotational modes (e.g. sway and roll), especially when these two modes have fairly similar natural frequencies. However, it is more convenient to only consider a single translational mode of freedom in VIM model tests. Care should be exercised when applying such model test results to evaluate the actual platform response. The frequency extent of lock-in, and the magnitude of the forces are known to be dependent on the motion amplitude; i.e. they may vary over the length of a cylinder vibrating in a rotational mode. Hence, a strip method, that takes account of amplitude variation over the cylinder length, might possibly be useful in some cases.

306 VIM analysis concentrates on the effect of current. The frequencies of incoming waves are unlikely to cause vortex shedding loads in the vicinity of the low natural frequencies for sway and roll. If wind and waves are present at the same time as currents causing VIM, then they will certainly affect the system response. It seems plausible that the wave-induced fluid velocities will tend to disorganise the combined velocity field, as compared to a pure current field, and be more likely to reduce the mean amplitude of the lift force due to vortex shedding, than to increase it. Hence, it should be conservative to superimpose the forces calculated separately due to waves and vortex shedding. The nonlinearity of the mooring system stiffness normally needs to be taken into account in the response analysis; i.e. it is not generally acceptable to calculate separately the line tensions due to coincident wind, waves and current, and then superimpose these results. However, this may be acceptable for a nearly linear system stiffness, as might be the case with a taut mooring system.

D 400 ULS and ALS

401 Appropriate combinations of wind, wave, and current-induced load-effects need to be considered, such that these environmental combinations each have a joint annual probability of exceedence of 10^{-2}; i.e. a 100-year return period. Relevant directions of the separate environmental effects also have to be considered. The usual combination of 100-year return period for wind and waves with 10-year return period for current, from Ch.2 Sec.1 B, is not necessarily adequate in cases with significant VIM.

402 A time domain mooring system analysis is advisable to include the effects of VIM on mooring line tensions. The drag coefficient should be adjusted for the effect of VIM in this analysis. This may be achieved by initially assuming a VIM amplitude, and subsequently iterating on that amplitude. Mean environmental loads are then applied to determine the mean platform offset. The natural frequencies of sway and roll are determined for that mean position. The VIM amplitude is extracted from the VIM analysis, and a sinusoidal force (or force and moment) is found which will result in the same amplitude of transverse platform displacement relative to the mean position. This transverse sinusoidal force and an in-line drag force variation at twice the frequency are then imposed, together with the other wind, wave and current loads. The vortex shedding loads should be modelled as independent of the oscillatory wind and wave loads. The resulting time histories of mooring line tensions are analysed in the usual way to obtain the characteristic line tensions. The VIM effects contribute primarily to the mean and low-frequency components of line tension. Care should be taken to ensure that the length of the realisations is adequate to avoid significant statistical uncertainty.

403 A strip model for variation of vortex shedding loads along the cylinder length would introduce more complexity into this mooring system analysis, and possibly require additional model test results for vortex shedding forces on a cylinder undergoing forced vibrations.

404 The distribution of the maxima of the low-frequency tension component should be checked to ensure that it does not seriously deviate from the usual distribution type (between exponential and Rayleigh distributions), not in a conservative direction.

405 It is assumed that the safety factors already defined for the ULS and ALS may be applied in cases when VIM contributes significantly to the dynamic line tension. To ensure that this assumption is permissible, the following should be observed:

a) bias in the analysis of VIM effects should be avoided, and any unavoidable bias should be conservative with respect to line tension

b) VIM effects should imply a coefficient of variation less than 10% for the estimation of the standard deviation of low-frequency tension, under specified environmental conditions

c) model uncertainty in the estimation of VIM effects should imply a coefficient of variation less than 5% for the estimation of the mean tension, under specified environmental conditions.

Additional conservatism should be applied to compensate, if conditions (b) and (c) are not fulfilled.

D 500 FLS

501 VIM may contribute appreciably to the accumulation of fatigue damage if sufficiently severe VIM events are expected to occur, with an appreciable duration. If this appears to be the case, then detailed analysis of VIM is required for the FLS. The joint environment must be made discrete in enough detail to allow a reasonably accurate estimate of the total fatigue damage. This can require consideration of an extensive set of environmental states. If VIM events coincide with line tension due to wind and/or wave effects, then it is essential to consider the effects together, because of the nonlinear nature of the Miner-Palmgren hypothesis for fatigue damage accumulation.

502 The same analysis technique as described for the ULS and ALS may be applied to determine the tension time history in an environmental state. It seems likely that the VIM effects will contribute to the low-frequency tension, without significantly increasing the bandwidth of this tension component. Hence, combined spectrum or dual narrow-banded approaches described in Ch.2 Sec.2 G300 may be applicable to calculation of the fatigue damage. It may be advisable to check a few cases by rainflow counting. If VIV events occur in the absence of wind and waves, then the fatigue damage calculation may possibly be simplified, by assuming constant amplitude for the tension oscillations.

The accuracy and computational expense of time domain analysis may be somewhat excessive for the fatigue analysis. Somewhat more uncertainty is normally tolerable for an individual environmental state, since the total fatigue damage is the sum of damages from many states. Hence, it may well be possible to develop an acceptable frequency domain analysis for this purpose.

503 It is assumed that the safety factors already defined for the FLS be applied in cases when VIM contributes significantly to the fatigue damage, provided the bounds on the model uncertainty are observed.

E. References

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SECTION 2
MOORING SYSTEM ANALYSIS

A. General

A 100 Objective

101 This section provides a structural design procedure for the mooring lines of floating offshore units, in a partial safety factor format.

A 200 Application

201 The design criteria are formulated in terms of three limit states ULS, ALS and FLS. Definitions are given in B101.

202 The safety factors for the limit states have been calibrated against more detailed calculations using the methods of structural reliability analysis. Turret moored ships and semi-submersibles in water depths from 70 m to 2000 m, and environmental conditions for the Norwegian continental shelf and for the Gulf of Mexico were included in the calibration.

203 The safety factors are also applicable to deep draught platforms (such as SPAR), provided that additional attention is applied to current loads and current directions. Possible effects of low frequency excitation on vertical plane motions shall be considered.

204 The design procedure is intended to be applicable for floating units with position mooring systems consisting of chain links, steel wire ropes, synthetic fibre ropes and a combination of these mooring line components.

205 The design procedure should be applicable to other geographical locations where the environmental conditions are more or less severe than considered in the calibration.

206 The design procedure is intended to be equally applicable to mobile drilling units, floating production units, loading buoys and floating accommodation units. Distinction between the possible consequences of a mooring system failure for different types of units is included in the ULS and ALS.

B. Method

B 100 General

101 The mooring system shall be analysed according to design criteria formulated in terms of three limit state equations:

a) An ultimate limit state (ULS) to ensure that the individual mooring lines have adequate strength to withstand the load effects imposed by extreme environmental actions.

b) An accidental limit state (ALS) to ensure that the mooring system has adequate capacity to withstand the failure of one mooring line, failure of one thruster or one failure in the thruster system for unknown reasons.

c) A fatigue limit state (FLS) to ensure that the individual mooring lines have adequate capacity to withstand cyclic loading.

102 Each limit state is formulated as a design equation or inequality in the form:

Design capacity — Design load effect ≥ 0

Where typically:

$$\text{Design capacity} = \frac{\text{Characteristic capacity}}{\text{Partial safety factor on capacity}}$$

Design load-effect = Characteristic load-effect · Partial safety factor on load-effect.

The characteristic values are computed according to a recipe in the procedure. The anchor line design for long term mooring must satisfy all the limit states.

103 The environmental condition and loads shall be in accordance with Sec.1.

104 Unless otherwise documented a friction coefficient of 1.0 between the mooring line (chain) and the sea bottom can be applied. For steel wire rope a friction coefficients of 0.5 can be applied. Further guidance regarding friction coefficients for mooring lines resting on clay bottom are provided in DNV-RP-E301 and DNV-RP-E302.

105 The stiffness characteristics of the mooring system shall be determined from recognised theory taking account of both line elasticity and weight.

106 The effective elastic modulus shall be obtained from the manufacturer of the mooring line component.

Guidance note:

For preliminary design the effective elastic modulus applied in the mooring analysis may be taken as:

- Stud chain R3: $(12.028 - 0.053 \cdot d) \cdot 10^{10}$ N/m^2
- Stud chain R4: $(8.208 - 0.029 \cdot d) \cdot 10^{10}$ N/m^2
- Studless chain R3: $(8.37 - 0.0305 \cdot d) \cdot 10^{10}$ N/m^2
- Studless chain R4: $(7.776 - 0.01549 \cdot d) \cdot 10^{10}$ N/m^2

Where d is the chain diameter in mm. Vicinay has provided the elastic moduli for chain.

- Six strand wire rope:
  $7.0 \cdot 10^{10}$ N/m^2 corresponding to nominal diameter of the steel wire rope.
- Spiral strand wire rope:
  $1.13 \cdot 10^{11}$ N/m^2 corresponding to nominal diameter of the steel wire rope.

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107 Synthetic fibre ropes are made of visco elastic materials, so their stiffness characteristics are not constant and vary with the duration of load application, the load magnitude and number of cycles. In general, synthetic mooring lines become stiffer after a long service time. The following stiffness models can be applied in the analysis:

a) Define a non-linear force elongation relation model, which replaces the one stiffness (E-module) model.

   If a non-linear elongation relation is not available the following procedure should be applied to analyse the effects of anchor line stiffness under the following conditions:

b) To establish the unit's excursion and demonstrate that it does not exceed the excursion capability of risers or other offset constraints. This analysis is carried out using the post-installation stiffness in ULS and ALS.

c) To establish characteristic line tension in ULS and ALS the storm stiffness shall be applied. Alternatively, a model consisting of an intermediate (drift) stiffness for calculation of characteristic tension due to mean loads and low frequency motions, and a storm stiffness for the characteristic tension due to wave frequecy motions.

d) The fatigue (FLS) shall be performed using the storm stiffness.

Examples of non-linear force elongation cure together with stiffness are given in Sec.4 J700.

108 The stiffness of synthetic fibre ropes has to be verified by testing in connection with certification of the ropes.

109 The analysis of the mooring system behaviour may be based on quasi-static or dynamic approaches. For water depth exceeding 200 m a dynamic analysis according to 407 and 408 has to be carried out.

110 For floating production, storage units or CALM buoys analysis including effect from anchor line dynamics shall be carried out regardless of water depth where other significant dynamic effects are likely to occur.

111 The maximum allowable azimuth deviation between the design and "as laid" anchor pattern for long term pre laid mooring system is ±1.5° for each anchor line. The maximum allowable deviation is ±5° for mobile units, typically drilling units and accommodation units.

B 200 Floating platform response analysis

201 The response of the floating platform in a stationary, short-term, environmental state may conveniently be split into three components:

1) Mean displacement due to mean environmental loads.
2) Low frequency displacements, in the frequency range of the natural periods of the moored platform in surge, sway and yaw modes of motion, due to low-frequency wind loads and second-order wave loads. (Low frequency response for other modes such as pitch and roll can be important for some platform types, such as deep draught floating platforms).
3) Oscillations in the frequency range of the incoming waves, due to first-order wave loads.
4) Vortex induced vibration shall be considered for deep draught floating platforms.

202 The analysis must take due account of all these elements of excitation and response. Forces due to the mooring lines and risers must also be taken into account, but some simplification is usually appropriate with mooring lines in a catenary configuration:

1) The restoring forces due to the mooring lines must be taken into account in the mean displacement. The non-linear restoring force function due to the mooring system should be applied directly.
2) The restoring force and damping effect due to mooring lines must be taken into account in the low-frequency response. The effects may be linearised, but the linearisation should be centred on the mean position applicable in the environmental state.
3) The effects of mooring lines on the wave-frequency response can be neglected in most cases , see Sec.1 C506.
4) The effects of a single riser are usually negligible in comparison with the effects of the mooring lines, but the effects of multiple risers may need to be included. Risers may cause restoring forces, damping and excitation forces, which have to be taken into account.

203 The damping of the low-frequency motions is a critical parameter, which may be difficult to quantify. It is dependent on water depth, the number of mooring lines and risers in addition to the actual sea state and current profile. If model tests are available, then they can provide a basis to quantify the damping. The basis for the damping should always be clearly documented by relevant model tests for units designed for production and/or storage of hydrocarbons. If an adequate basis is lacking, then a conservative estimate should be made.

Guidance note:

Some examples of damping coefficients:

For a ship in 150 m water depth, with 12 mooring lines and no risers:

- the surge damping coefficient was 5 to 10 % of critical damping
- the sway damping coefficient was 15 to 20 % of critical damping.

For a twin-pontoon drilling semi-submersible in 450 m water depth, with 8 mooring lines and no risers:

- the surge damping was 10 % of critical damping
- the sway damping was 15 % of critical damping.

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204 Critical damping is given by

$$2\sqrt{k \cdot m}a$$

Where k is the restoring coefficient at the mean platform position and m is the platform mass including added mass.

205 Documentation of the unit's response analysis methods must be available. The accuracy of computer programs for response analysis must be quantified by comparison with relevant model test results. The accuracy of model test results applied in the design must be quantified.

B 300 Mooring line response analysis

301 Quasi-static analysis is usually appropriate to determine the mooring line response to mean and low-frequency platform displacements, while dynamic mooring line analysis is usually appropriate for mooring line response to wave-frequency displacements of the platform. The quasi-static mooring line response analysis must take account of:

— the displacement of the upper terminal point of the mooring line due to platform motions
— the weight and buoyancy of the mooring line components
— the elasticity of the mooring line components
— reaction and friction forces from the seabed.

302 In addition, dynamic mooring line response analysis must also take account of:

— inertia forces acting on the mooring line components, if the weight of the mooring system is large compared to the weight of the floating body
— hydrodynamic drag forces acting on the mooring line components.

303 The dynamic analysis may be linearised, but the linearisation point should take account of the line configuration at the instantaneous platform position in the environmental state, due to mean displacement and low-frequency motion.

304 The anchor position is assumed fixed in the mooring line analysis. Hydrodynamic excitation forces on mooring line components are normally negligible in comparison with the other forces, but may need consideration for buoyancy modules. The bending stiffness of the mooring line is normally negligible.

305 Documentation of the method applied in anchor line response analysis shall be available. The accuracy of computer programs for mooring line response must be checked by comparison with other methods, for instance model tests.

306 The relevant pretension shall be applied for the operating state that is considered. It is not allowed to take into account in the mooring analysis adjustment of pretension in the various lines by running the winches.

307 Adjustment of line tension caused by change of position or draught and shift of consequence class should be taken into account:

a) An accommodation unit with gangway connection to another installation, which is lifting the gangway and is running the winches to move to a standby position due to bad weather.

b) Units operating with continuously changing position e.g. pipe laying units.

c) A production unit, which is running the winches to increase the distance to a well head platform due to bad weather.

d) Shift from consequence class 2 to consequence class 1, prior to severe weather by e.g. changing to survival draught.

B 400 Characteristic line tension for the ULS

401 All mooring lines in the system are considered to be intact in the analysis of the ULS. Two components of characteristic line tension are considered:

a) T_{C-mean} the characteristic mean line tension, due to pretension and mean environmental loads in the environmental state.

b) T_{C-dyn} the characteristic dynamic line tension induced by low-frequency and wave-frequency environmental loads in the environmental state.

402 The following response statistics are determined in each environmental state considered:

— X_{mean} is the mean horizontal distance of the upper terminal point of the mooring line from the anchor
— σ_{X-LF} is the standard deviation of horizontal, low-frequency motion of the upper terminal point in the mean mooring line direction.

For dynamic analysis of wave-frequency tension:

— $\sigma_{T-WF}[X]$ is the standard deviation of the wave-frequency component of line tension, which is dependent on the mean excursion X applied in the analysis, computed for one location, with excursion $X = X_C - X_{WF-max}$, where X_C, X_{WF-max} are defined in 405 and 406.

For quasi-static analysis of wave frequency tension:

— σ_{X-WF} is the standard deviation of horizontal, wave-frequency motion of the upper terminal point in the mean mooring line direction.

403 If all lines are identical, then the statistics are only needed for the most heavily loaded line. If the lines are different, then the statistics are needed for each line. The line tension results are primarily needed at the most heavily loaded location along the line, usually close to the top, or to a buoyancy module. If different strengths of mooring line components are applied along the length of the line, then the line tension results can be applied for the most heavily loaded location of each component type.

404 Quasi-static mooring line response analysis provides the line tension T at a point in the line as a function of the horizontal distance between lower and upper terminal points of the line X, as can be represented by the function:

$$T_{QS}[X]$$

Thus, the characteristic mean tension is given by

$$T_{C-mean} = T_{QS}[X_{mean}]$$

Note that this mean tension includes the pretension of the line, which would occur at the mooring system equilibrium position, in the absence of environmental effects.

405 A Gaussian process model is applied in the development of the characteristic tension from the statistics listed in 402. This Gaussian model is adopted as a compromise between simplicity and accuracy in this design procedure. The inaccuracy of the Gaussian process model has been taken into account in the calibration of the design procedure. On this basis, significant and maximum low-frequency excursion are defined as

$$X_{LF-sig} = 2\sigma_{X-LF}$$

$$X_{LF-max} = \sigma_{X-LF} \cdot \sqrt{2\ln N_{LF}}$$

Where N_{LF} is the number of low-frequency platform oscillations during the duration of the environmental state, which is normally taken as 3 hours. Similarly, significant and maximum wave-frequency excursion are defined as

$$X_{WF-sig} = 2\sigma_{X-WF}$$

$$X_{WF-max} = \sigma_{X-WF}\sqrt{2\ln N_{WF}}$$

Where N_{WF} is the number of wave-frequency platform oscillations during the duration of the environmental state.

406 The characteristic offset X_C is taken as the larger of:

$$X_{C1} = X_{mean} + X_{LF-max} + X_{WF-sig}$$

$$X_{C2} = X_{mean} + X_{LF-sig} + X_{WF-max}$$

407 When dynamic mooring line analysis is applied, the maximum wave frequency tension is defined by:

$$T_{WF-max} = \sigma_{T-WF}[X_C - X_{WF-max}]\sqrt{2\ln N_{WF}}$$

where the notation is intended to provide a reminder that the standard deviation of wave frequency tension is a function of the excursion about which wave frequency motion takes place.

408 When dynamic mooring line analysis is applied, the characteristic dynamic tension T_{C-dyn} is defined by:

$$T_{C\text{-}dyn} = T_{QS}[X_C - X_{WF-max}] - T_{C-mean} + T_{WF-max}$$

409 When the quasi-static mooring line analysis is applied, then the characteristic dynamic tension T_{C-dyn} is defined by

$$T_{C-dyn} = T_{QS}[X_C] - T_{C-mean}$$

B 500 Characteristic line tension for the ALS

501 One mooring line is assumed to have failed, and is removed in the analysis of the ALS.

a) When all mooring lines are identical, several lines shall be removed one at a time in order to identify the line failure leading to the largest tension in an adjacent line.

b) If the mooring lines are not identical, then it may be necessary to consider a number of cases with different missing lines, to check the highest resulting tension in each type of mooring line.

502 The ALS addresses the situation where the initial line failure occurs in severe weather, and considers the stationary mooring system response to the same environmental conditions. Hence, no adjustment of line pretension after the initial line failure shall be considered in the analysis. For convenience, the same environmental conditions are applied as for the ULS, and the calibration of the safety factors has taken account of the low probability of occurrence of so severe weather together with a random initial failure.

503 The transient response immediately after the initial failure might be expected to lead to higher line tensions. This has been found to be very unlikely in the presence of severe environmental conditions, with considerable oscillatory excitation forces. If unusually high line tensions are required for some special operations in relatively calm weather, then it is advisable to also consider the transient case, but this is not covered here.

504 The platform response and mooring line response analysis is carried out exactly as for the ULS, but with one line missing. The characteristic tension components are computed as for the ULS.

B 600 Refined response analysis

601 The calibration of the present design procedure is based on linearised, frequency domain computations of both the floating platform response and the dynamic mooring line response, together with Gaussian process models. Many designers may wish to pursue more refined calculations of the system response, perhaps in the final verification of their designs. The present design procedure is not necessarily directly applicable to the results of different methods of analysis.

602 More refined analyses through refined numerical models, such as time domain simulation, or model tests should be encouraged in principle, since they can lead to better understanding of the mooring system design, and to better designs. Such refined analyses should be carried out for novel mooring systems.

603 The concept of a "method factor" is introduced to make some allowance for the use of more refined analysis results in conjunction with the present design procedure. The partial safety factor on the dynamic tension γ_{dyn} may be modified by a method factor f_m when the tension has been computed by more refined analysis. There is little reason to apply a method factor to the mean tension term, since this quantity is relatively well quantified by the present design procedure.

604 Method factors have been established for the case when the refined response analysis uses a more accurate distribution model for the low-frequency platform displacement (/1/,/2/). Detailed description is given in NORSOK N-003. Further a more accurate consideration of the effect of the quadratic drag force on the maximum of the wave-frequency tension (/3/). The method factor may be set to 0.95 for the ULS and 0.90 for the ALS in this case.

605 Response based analysis where the 100 year tensions are calculated using a long term environmental description involves more details of short-term tension distribution, which are not widely agreed. Reliability analyses have to be applied in order to focus on the details of short-term tension distribution and uncertainty modelling.

606 Method factors may be developed to allow for other analysis procedures, by extension of the calibration used here.

C. Characteristic Capacity

C 100 Characteristic capacity for the ULS and ALS

101 The mooring line components should be manufactured with a high standard of quality control, according to recognised standards, such as, Standard for Certification No. 2.5, Standard for Certification No. 2.6 or Standard for Certification No. 2.13.

102 Careful control of all aspects of handling, transport, storage, installation, and retrieval of the mooring lines is also imperative to ensure that the capacity of the mooring lines is not reduced. The characteristic capacity is defined on this basis.

C 200 Main body of mooring line

201 A mooring line is usually assembled from a large number of identical components of a few types, together with a few connecting links, line terminations, etc. A chain line obviously contains a large number of chain links. A long steel wire rope or a synthetic fibre rope may also be conceptually treated as a large number of wire rope segments. It is well known that the strength of a long line is expected to be less than the average strength of the components that make up the line. This effect is taken into account in the present definition of the characteristic capacity.

202 The following statistics are required for the strength of the components that make up the main body of the mooring line:

— μ_s the mean value of the breaking strength of the component
— δ_s the coefficient of variation of the breaking strength of the component.

Then the characteristic strength of the body of the mooring line constructed from this component is defined by:

$$S_c = \mu_s[1 - \delta_s(3 - 6\delta_s)], \quad \delta_s < 0.10$$

This formulation is applicable for components consisting of chain, steel wire ropes and synthetic fibre rope.

203 When statistics of the breaking strength of a component are not available, then the characteristic strength may be obtained from the minimum breaking strength S_{mbs} of new components, as

$$S_C = 0.95\, S_{mbs}$$

204 The statistical basis for the characteristic strength can also be applied to used components if breaking strength statistics are obtained for the used components by carrying out break load tests. However, the alternative basis using the minimum breaking strength should not be applied to used components without changing the reduction factor.

205 When the strength distribution is based on test statistics, the statistical uncertainty in the results depends on the number of tests performed. The uncertainty in the characteristic line strength has been simulated for different test sizes and for different coefficients of variation of the individual line component strength. Simplified reliability analyses, using a typical load distribution, have then been performed in order to quantify a reduction in the characteristic strength that is necessary in order to maintain the target reliability. A simple expression has been fitted to these results, and the reduced characteristic strength S^*_c can be expressed as:

$$S^*_C = S_c\left[1 - 2.0\left(\frac{\delta_s}{n}\right)\right]$$

— δ_s is the coefficient of variation of the breaking strength of the component
— n is the number of tests, not less than 5.

206 Creep properties for synthetic fibre ropes shall be evaluated by testing, see Sec.4 J1700 and Sec.5 F.

C 300 Connecting links and terminations

301 Other components in the mooring line such as connecting links and terminations should be designed to have strength exceeding the characteristic strength of the main body of the mooring line, with a very high level of confidence.

D. Partial Safety Factors and Premises

D 100 Consequence classes

101 Two consequence classes are introduced in the ULS and ALS, defined as:

Class 1, where mooring system failure is unlikely to lead to unacceptable consequences such as loss of life, collision with an adjacent platform, uncontrolled outflow of oil or gas, capsize or sinking.
Class 2, where mooring system failure may well lead to unacceptable consequences of these types.

102 The partial safety factors given in 200 and 300 are applicable to chain, steel wire ropes and synthetic fibre ropes.

D 200 Partial safety factors for the ULS

201 The design equation for the ULS is given by

$$S_C - T_{C-mean}\gamma_{mean} - T_{C-dyn}\gamma_{dyn} \geq 0$$

where the characteristic quantities are defined above, a partial safety factor of unity on the capacity is implicit, and the remaining partial safety factors are given in Table D1.

Table D1 Partial Safety Factors for ULS

Consequence Class	*Type of analysis of wave frequency tension*	*Partial Safety factor on mean tension* γ_{mean}	*Partial Safety factor on dynamic tension* γ_{dyn}
1	Dynamic	1.10	1.50
2	Dynamic	1.40	2.10
1	Quasi-static	1.70	
2	Quasi-static	2.50	

202 If the characteristic mean tension exceeds 2/3 of the characteristic dynamic tension, when applying a dynamic analysis in consequence class 1, then a common value of 1.3 shall be applied instead of the separate static and dynamic safety factors given in Table D1. This is intended to ensure adequate safety in cases dominated by the mean tension component.

D 300 Partial safety factors for the ALS

301 The design equation for the ALS is identical to the ULS, but the partial safety factors are given in Table D2.

Table D2 Partial Safety Factors for ALS

Consequence Class	*Type of analysis of wave frequency tension*	*Partial Safety factor on mean tension* γ_{mean}	*Partial Safety factor on dynamic tension* γ_{dyn}
1	Dynamic	1.00	1.10
2	Dynamic	1.00	1.25
1	Quasi-static	1.10	
2	Quasi-static	1.35	

302 The combination of an accidental line failure with characteristic loads based on a 100-year return period is, in itself, relatively conservative. Hence, the partial safety factors in table D2 are relatively small; i.e. close to unity. These factors should be adequate even when the loading is dominated by the mean tension, provided that 100-year environmental conditions give rise to a significant portion of the mean tension.

D 400 Typical operations covered by consequence class 1

401 Safety factors for consequence class 1 are applicable for the operations in 402 to 405:

402 Column-stabilised drilling units with the riser disconnected, when the unit is located at least a distance X_V (m) from other units or installations defined as follows:

$$X_v = 300\text{m} \qquad h \leq 300\text{m}$$
$$X_v = 1.5\,(h - 300) + 300 \quad (\text{m}) \qquad h > 300\text{m}$$

h = water depth in meter

For ship-shaped units the distance (X_V) shall be as follows:

$$X_v = 2L_{oa} \quad (\text{m}) \qquad h \leq 300\ \text{m}$$
$$X_v = 2.0(h - 300) + 2L_{oa} \quad (\text{m}) \qquad h > 300\ \text{m}$$

L_{oa}= overall length

See Fig.1.

403 Column stabilised accommodation units positioned 300 m away from another unit of fixed installation. However, column stabilised accommodation units in stand by position at least 150 m away from a fixed installation can be designed according to Consequence Class 1 provided it is documented that loss of all lines at one column will not cause collision with the fixed installation.

404 Units designed for production and or injection of oil, water or gas through a system of one flexible riser and an associated well control umbilical. The unit shall be located at least a distance X_V away from another structure and emergency disconnection of riser and associated umbilical must be available and it shall be documented that the riser and umbilical can withstand the offset caused by a single failure.

405 Offshore loading buoys with no tanker moored.

D 500 Typical operations covered by consequence class 2

501 Drilling units with the riser connected.

502 Drilling, support and accommodation units operating at a distance less than 50 m from other units or installations. See Fig.2.

503 Units designed for production and or injection of oil, water and or gas through a system of several flexible, steel catenary or rigid risers, and associated umbilicals shall be designed according to consequence class 2, when the unit is not designed for emergency disconnection..

504 When a column stabilised accommodation unit is positioned a distance between 50 m and X_V m from another unit or installation, the mooring lines pointing away from the installation have to be designed according to consequence class 2, while the mooring lines pointing towards the installation may be designed according to consequence class 1. See Fig.3.

505 Offshore loading buoys with a tanker moored. The buoy's distance from another installation shall be large enough to give sufficient space for manoeuvring of a tanker.

506 Production of hydrocarbons may take place after a line failure or a failure in thruster assisted systems provided the design equation for ULS and ALS given in 102 meets the requirements for consequence class 2 for all the remaining anchor lines.

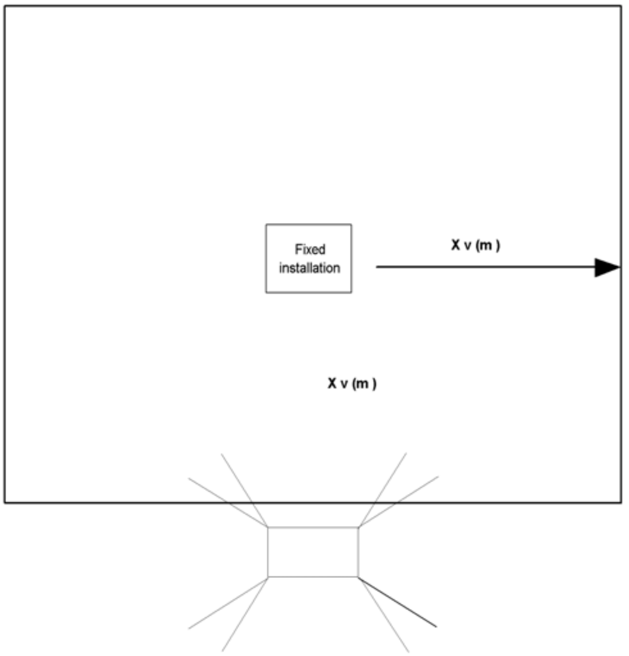

Figure 1
The position of a unit at least a distance X_v away from an installation

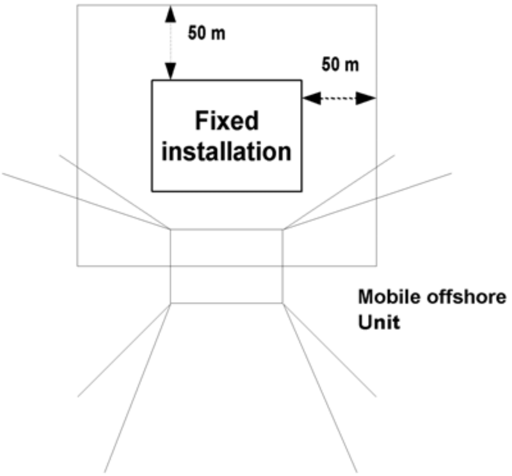

Figure 2
The position of a unit within 50 m of another installation

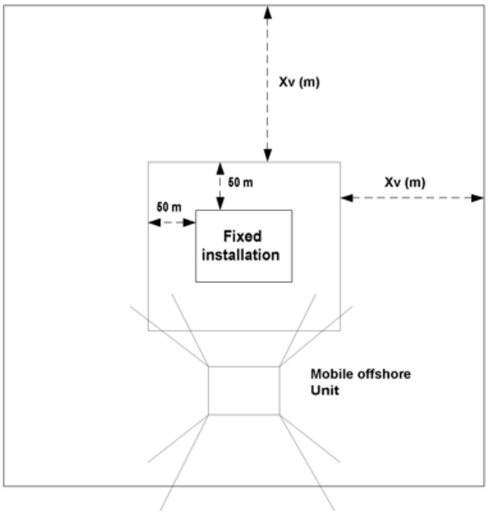

Figure 3
The position of a unit between 50 m and a distance X_v away from an installation

D 600 Permissible horizontal offset

601 The horizontal offset from a given reference point shall be within the operational service limitation, including offsets:

— for the intact mooring system
— after any single failure of a line or in the thruster system.

602 When the unit is connected to a rigid or vertical riser (e.g. drilling riser), the maximum horizontal offset is limited by the maximum allowable riser angle at the BOP flex joint. A safety margin of 2.5% of the water depth shall be included.

603 Maximum horizontal offset of flexible and steel catenary risers shall not exceed the manufacture specification.

604 Maximum environmental conditions for drilling operation are also to take the heave compensating capacity into consideration.

605 When the unit is connected by a gangway to another structure, the positioning system and the gangway structure shall meet the following criteria:

a) The distance between the unit and the installations shall notbe less than 10 m at any point.
b) During normal operation an excursion reserve of 1.5 m of the specified maximum excursion of the gangway shall be included.
c) The gangway shall be equipped with alarm in the control room, which shall be activated when the maximum excursion is exceeded.
d) The gangway shall be positioned so that it will not collide with any other structure after a single failure.

D 700 Permissible line length

701 For anchors not designed to take uplift forces, the following applies:

— the mooring lines shall have enough length to avoid uplift at anchors for all relevant design conditions in the ULS
— vertical forces on the anchors can be accepted in the ALS, if it is documented that these vertical forces will not significantly reduce the characteristic resistance of the anchors.

702 Anchors designed to withstand vertical forces will be accepted in both ULS and ALS conditions, see Sec.4.

703 Unrealistic line lengths to meet the requirements in 701 shall not be used in the mooring analyses.

Guidance note:

The maximum deployed line length allowed to be taken into account in the calculations is limited to the suspended length at a line tension equal to the breaking strength of the line plus 500 m.

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D 800 Anchor pattern

801 The anchor pattern shall not interfere with the safety of bottom pipelines, flowlines or other sub-sea petroleum systems. The minimum vertical clearance between mooring lines and all type of sub-sea equipment shall be at least 10 m in ULS condition. In ALS condition contact is not permitted i.e. the clearance should be larger than 0 m. Further information is given in DNV Rules for Planning and Execution of Marine Operations Pt.2 Ch.7 4.3.

802 Contact between a fibre rope mooring line and sub-sea equipment can be accept if contact will not cause damage to the fibre rope and the equipment.

803 Contact between risers and mooring lines is not permitted.

804 Crossing of anchor lines is normally not accepted. However, acceptance may be given if sufficient actions are taken to avoid contact, e.g. by use of buoyancy equipment on the upper anchor line. Further information is given in the Rules for Planning and Execution of Marine Operations Pt.2 Ch.7 4.3.

805 For operation in vicinity of a fixed installation, a positive clearance between the mooring lines and the installation has to be obtained in all limit state conditions.

E. Additional Requirements for Long Term Mooring

E 100 General

101 These requirements are applicable to all type of floating units equipped with a mooring system, which are positioned at the same location for 5 years or more.

102 Fatigue calculations shall be carried out for mooring lines and connection elements by using site specific environmental data.

103 It is recommended that fatigue calculations are carried out for units positioned at a location for less than 5 years, when the in service experience has shown anchor line fatigue damage.

104 Fatigue calculation of long term mooring (LTM) D-shackles dimension according to ISO 1704 may be omitted. These shackles are oversized compared to the common chain links, therefore the fatigue life of a LTM shackle is higher than the fatigue life of the chain.

E 200 Corrosion allowance

201 Corrosion allowance for chain, including wear and tear of chain and connection elements to be included in design. The minimum corrosion allowance given in Table E1 shall be used if corrosion allowance data is not available for the actual location.

Table E1 Corrosion allowance for chain

Part of mooring line	*Corrosion allowance referred to the chain diameter*		
	No inspection (mm/year)	*Regular inspection 1) (mm/year)*	*Requirements for the Norwegian continental shelf*
Splash zone 3)	0.4	0.2	0.8 2)
Catenary 4)	0.3	0.2	0.2
Bottom 5)	0.4	0.3	0.2 6)

1) Regular inspection e.g. in accordance with the Classification Societies or according to operators own inspection program approved by the National Authorities if necessary. The mooring lines have to be replaced when the diameter of the chain with the breaking strength used in design of the mooring system is reduced by 2%.

2) The increased corrosion allowance in the splash zone is required by NORSOK M-001 and is required for compliance with NPD , see DNV-OSS-201.

3) Splash Zone is defined as 5 m above the still water level and 4 m below the still water level.

4) Suspended length of the mooring line below the splash zone and always above the touch down point.

5) The corrosion allowance given in the table is given as guidance, lower values may be accepted provided it is documented.

6) Investigation of the soil condition shall be carried out in order to document that bacterial corrosion is not taking place.

202 The characteristic capacity of the anchor lines which forms the basis for the mooring calculations shall be adjusted for the reduction in capacity due to corrosion, wear and tear according to the corrosion allowance given in Table F1.

203 The lifetime of a steel wire rope is dependent on the construction and degree of protection. Guidance for choice of steel wire rope construction depending on the wanted design is given in Table F2.

Table E2 Choice of steel wire rope construction

Field design life (years)	*Possibilities for replacement of wire rope segments*	
	Yes	No
< 8	A/B/C	A/B/C
8 – 15	A/B/C	A/B
> 15	A/B	A

A) Half locked coil/full locked coil/spiral strand with plastic sheathing.

B) Half locked coil/full locked coil/spiral strand without plastic sheathing.

C) Six strand/multi strand.

204 Buoy pennant lines, clump weights and their fasteners attached to mooring lines shall be dimensioned with corrosion allowance according to Table F1 if no detailed data for the location is available.

F. Fatigue Limit State (FLS)

F 100 Accumulated fatigue damage

101 The characteristic fatigue damage, accumulated in a mooring line component as a result of cyclic loading, is summed up from the fatigue damage arising in a set of environmental states chosen to discretise the long term environment that the mooring system is subject to:

$$d_c = \sum_{i=1}^{i=n} d_i$$

where d_i is the fatigue damage to the component arising in state i and the discretisation into i=1,…,n states is sufficiently detailed to avoid any significant error in the total. Each environmental state is defined in terms of the heading angles, wind, wave and current parameters required to compute the stationary mooring system response in that state. The probability of occurrence P_i is required for each environmental state.

102 When the effects of mean tension can be neglected, the fatigue damage accumulated in an individual state may be computed as:

$$d_i = n_i \int_0^{\infty} \frac{f_{Si}(s)}{n_c(s)} ds$$

where n_i is the number of stress cycles encountered in state i during the design life of the mooring line component, $f_{Si}(s)$ is the probability density of nominal stress ranges (peak-to-trough) applied to the component in state i, and $n_c(s)$ is the number of stress ranges of magnitude s that would lead to failure of the component. The nominal stress ranges are computed by dividing the corresponding tension ranges by the nominal cross-sectional area of the component; i.e.

$\frac{2\pi d^2}{4}$ for chain, and $\frac{\pi d^2}{4}$ for steel wire rope, where d is the component diameter.

103 The number of stress cycles in each state can usually be determined as:

$$n_i = v_i \cdot P_i \cdot T_D$$

where ν_i is the mean-up-crossing rate (frequency in hertz) of the stress process (i.e. the mean up-crossing rate through the mean stress level) in state i, P_i indicates the probability of occurrence of state i, and T_D is the design lifetime of the mooring line component in seconds. In practice the integral in 102 is usually replaced by the cycle counting algorithm in 300.

F 200 Fatigue properties

201 The following equation can be used for the component capacity against tension fatigue:

$$n_c(s) = a_D s^{-m}$$

This equation can be linearised by taking logarithms to give:

$$\log(n_c(s)) = \log(a_D) - m \cdot \log(s)$$

$n_c(s)$	=	the number of stress ranges (number of cycles)
s	=	the stress range (double amplitude) in MPa
a_D	=	the intercept parameter of the S-N curve
m	=	the slope of the S-N curve

The parameters a_D and m are given in Table F1 and the S-N curves are shown in Fig.4.

Table F1 S-N Fatigue Curve Parameters

	a_D	m
Stud chain	$1.2 \cdot 10^{11}$	3.0
Studless chain (open link)	$6.0 \cdot 10^{10}$	3.0
Six strand wire rope	$3.4 \cdot 10^{14}$	4.0
Spiral strand wire rope	$1.7 \cdot 10^{17}$	4.8

202 The fatigue life of long term mooring (LTM) shackles can be calculated using the B1 curve parameter and appropriate stress concentration factors (SCF) obtained by a finite element method. S-N curves for kenter shackles are not included since these shackles shall not be used in long term mooring systems. Other type of connection elements such as pear links, C-links and D-shackles with locking pin through the shackle bow and pin shall not be used in long term mooring systems.

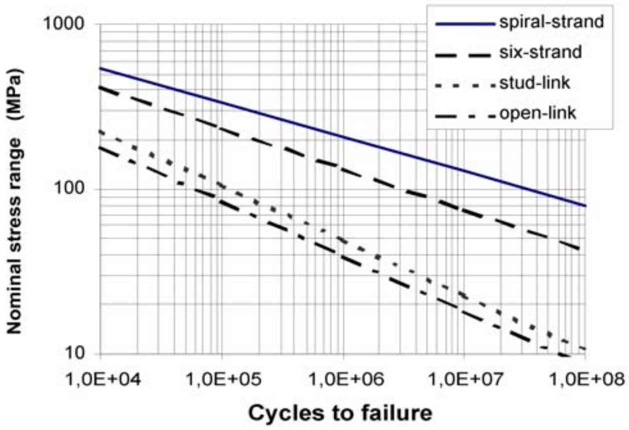

Figure 4
Design S-N curves

203 The S-N curves for chain given Table G1 and Fig.4 are intended to be applicable in sea water, while the S-N curves for steel wire ropes assume that the rope is protected from the corrosive effect of sea water.

204 It is permissible to use test data for a specific type of mooring line component in design. A linear regression analysis shall then be used to establish the S-N curve with the design curve located a little more than two standard deviations below the mean line, with the use of the procedure given in G 500. In the case of chain tests in air, the effect of sea water shall be accounted for by a reduction of the fatigue life by 2 for stud-link chain, and by a factor of 5 for studless chain.

205 It should be noted that the recommended reduction factor for stud chain is only applicable when the stud is perfectly fitted in the chain link. The fatigue life of a stud chain link is highly sensitive to variations depending on the tightening of the stud. When the stud gets loose, the scenario of stress distribution changes totally and this may lead to a significant reduction in fatigue life. These problems are avoided by using studless chain.

206 Note that only tension fatigue is considered. Additional consideration of bending effects may be needed for:

— chain links that are frequently located on a chain wheel (fairlead)
— wire rope that is passed over sheaths, pulleys or fairleads.

F 300 Fatigue analysis

301 The long term environment can be represented by a number of discrete conditions. Each condition consists of a reference direction and a reference sea state characterised by a significant wave height, peak period, current velocity and wind velocity. The probability of occurrence of these conditions must be specified. In general 8 to 12 reference directions provide a good representation of the directional distribution of a long-term environment. The required number of reference sea states can be in the range of 10 to 50. Fatigue damage prediction can be sensitive to the number of sea states, and sensitivity studies can be necessary.

302 In the fatigue analysis 50% of the chain's corrosion allowance can be taken into account.

303 Provided the equation given in 201 is applicable to the fatigue properties, the fatigue damage in environmental state i can be computed as:

Where $E[S_i^{\ m}]$ is the expected value of the nominal stress

$$d_i = \frac{n_i}{a_D} E[S_i^{\ m}]$$

ranges raised to the power m in state i. The nominal stress ranges should be computed taking into account the effects of pretension and the effects of the environmental loads due to wind, waves and current, as described for the ULS. Although the cumulative effect of the stress cycles is required in the FLS, rather than the extreme tension required in the ULS, it is still necessary to take care to compute the dynamic response of the mooring line to wave-frequency loads at a representative offset for each environmental state. The method given in the guidance note can be used.

Guidance note:

Determine all loads and motions (low and wave frequency) as described for ULS, see B400.

Compute mooring system responses under mean loading using quasi-static analysis. Then impose wave frequency motions and calculate the standard deviation of the wave frequency tension from dynamic analysis.

Add the standard deviation of the low frequency motion to the mean position and calculate the corresponding tension. The standard deviation of the low frequency tension is the calculated tension minus the tension in the mean position.

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304 The computed tension range divided by the nominal cross-sectional area of the chain link or the wire rope component gives the nominal stress range, The cross sectional areas are defined in 102.

305 If the low-frequency content of the stress process is negligible, then a narrow-banded assumption may be applied to give:

$$d_{NBi} = \frac{v_{0i} T_i}{a_D} (2\sqrt{2}\sigma_{Si})^m \Gamma\left(\frac{m}{2} + 1\right)$$

where σ_{Si} is the standard deviation of the stress process and Γ(.) is the gamma function. In this case, the number of tension cycles is computed from the mean-up-crossing rate in hertz of the tension process ν_{0i} and the duration of the environmental state $T_i = P_i \cdot T_D$.

306 If there are both significant wave-frequency and low-frequency components in the tension process, then the expression for a narrow-banded process is no longer appropriate. There is fairly general consensus that the rain-flow counting technique provides the most accurate estimate for the probability density of the tension ranges, but this requires relatively time-consuming analysis. Therefore the following alternatives are recommended:

— combined spectrum approach
— dual narrow-band approach.

307 The combined spectrum approach provides a simple, conservative approach, which may be used in computing the characteristic damage. The fatigue damage for one sea state is denoted by d_{CSi}:

$$d_{CSi} = \frac{v_{yi} T_i}{a_D} (2\sqrt{2}\sigma_{Yi})^m \Gamma\left(\frac{m}{2} + 1\right)$$

The standard deviation of the stress process is including both wave-frequency σ_{Wi} and low-frequency components σ_{Li}.

$$\sigma_{Yi} = \sqrt{\sigma_{Li}^{\ 2} + \sigma_{Wi}^{\ 2}}$$

The mean-up-crossing rate ν_{yi} in hertz for one sea state is computed from the moments of the combined spectrum:

$$\nu_{yi} = \sqrt{\lambda_{Li}\nu_{Li}^2 + \lambda_{Wi}\nu_{Wi}^2}$$

λ and λ_w are defined in 310.

308 The number cycles in the combined spectrum, per sea state in the lifetime is:

$$n_i = \nu_{yi} T_i = \nu_{yi} \cdot P_i \cdot T_D$$

309 The dual narrow-banded approach takes the result of the combined spectrum approach and multiplies it by a correction factor ρ, based on the two frequency bands that are present in the tension process.

$$d_{DNBi} = \rho_i \cdot d_{CSi}$$

The correction factor is given by

$$\rho = \frac{\nu_P}{\nu_Y}\left[(\lambda_L)^{\frac{m}{2}+2}\left(1 - \sqrt{\frac{\lambda_W}{\lambda_L}}\right) + \sqrt{\pi\lambda_L\lambda_W}\,\frac{m\Gamma\left(\frac{1+m}{2}\right)}{\Gamma\left(\frac{2+m}{2}\right)}\right]$$

$$+ \frac{\nu_w}{\nu_y} \cdot (\lambda_W)^{m/2}$$

Where subscript Y refers to the combined stress process, subscript P refers to the envelope of the combined stress process, subscript L refers to the low-frequency part of the stress process, and subscript W refers to the wave-frequency part of the stress process.

310 The symbol λ represents the normalised variance of the corresponding stress component

$$\lambda_L = \frac{\sigma_L^{\ 2}}{\sigma_L^{\ 2} + \sigma_W^{\ 2}}, \qquad \lambda_W = \frac{\sigma_W^{\ 2}}{\sigma_L^{\ 2} + \sigma_W^{\ 2}}$$

Where σ_L is the standard deviation of the low-frequency part of the stress process, and σ_W is the standard deviation of the wave-frequency part of the stress process. The symbol ν represents the up-crossing rate through the mean value, as computed from the second and zero order moments of the corresponding part of the stress spectrum, for subscripts Y, L, and W. For the envelope of the stress process, the mean-up-crossing rate is given by

$$\nu_P = \sqrt{\lambda_L^{\ 2}\nu_L^{\ 2} + \lambda_L\lambda_W\nu_W^{\ 2}\delta_W^{\ 2}}$$

Where δ_W is the bandwidth parameter for the wave-frequency part of the stress process, but is here set equal to 0.1.

311 A subscript i could have been attached to all the short-term statistics in equations in 310 to indicate dependency on the environmental state, but it has been omitted for clarity.

312 Values of the gamma function to be used in the equations given in 307 and 308 for different values of m are given in Table F2

Table F2 Gamma Functions

m	*3.0*	*4.0*	*4.8*
$\Gamma\left[\frac{m}{2}+1\right]$	1.3293	2.0000	2.9812
$\Gamma\left[\frac{1+m}{2}\right]$	1.0000	1.3293	1.8274

313 Results from other approaches may be accepted provided they are conservative in comparison to the dual narrow-banded approach, or to the rainflow counting approach, for the mooring system under consideration.

F 400 Design equation format

401 The fatigue limit state is intended to ensure that each type of component in an individual mooring line has a suitable resistance to fatigue failure. The design equation for FLS is:

$$1 - d_c \cdot \gamma_F \geq 0$$

d_c = the characteristic fatigue damage accumulated as a result of cyclic loading during the design life time. The combined spectrum approach or the dual narrow band shall be applied as the cycle counting algorithms. See 307 and 308.

γ_F = the single safety factor for the fatigue limit state.

402 The fatigue safety factor γ_F shall cover a range of uncertainties in the fatigue analysis. The following values shall be used for mooring lines which are not regularly inspected ashore:

$$\gamma_F = 5 \quad \text{when } d_F \leq 0.8$$

$$\gamma_F = 5 + 3\left(\frac{d_F - 0.8}{0.2}\right) \quad \text{when } d_F > 0.8$$

Where d_F is the adjacent fatigue damage ratio, which is the ratio between the characteristic fatigue damage d_c in two adjacent lines taken as the lesser damage divided by the greater damage. d_F cannot be larger than one.

403 A single line failure in fatigue is taken to be “without substantial consequences,” while near-simultaneous fatigue failure of two or more lines is taken to have “substantial consequences.” Analysis has shown that nominally identical mooring lines will have very nearly the same fatigue capacity, and that the recent practice of grouping mooring lines leads to very nearly the same loads in lines within a group. Hence, this practice may lead to an increase in the occurrence of multiple fatigue failures. The safety factors defined above are intended to allow the use of grouped lines while retaining a suitable level of safety.

404 If the mooring line is regularly inspected ashore, which is common for mobile offshore units such as drilling units, then a safety factor of 3 should be applicable.

405 For long term mooring systems stress concentration factors (SCF) due to bending of the chain links in the fairleads, bending shoes, guide tubes and chocks shall all be considered in the fatigue analysis.

F 500 Effect of number of fatigue tests on design curve

501 It is usual practice to offset the design value of the *a*-parameter of the S-N curve by two standard deviations relative to the mean value

$$\log(a_D) = \log(a) - 2\sigma$$

502 With a normal distribution assumption, this implies that the realised value of the *a*-parameter for a mooring line component is likely to exceed the design value with probability 0.9772:

$$P[A > a_D] = 0.9772$$

503 This holds true when the underlying distribution values of a, σ are applied, but not when estimates of these parameters are applied. It may be expected that this probability is very nearly achieved from estimates based on a large number of fatigue tests, and deviates more when the number of tests is small. The effect of the number of test data may be included by introducing a correction factor $k_p(l)$ into the expression for the design value of the *a*-parameter

$$\log(\hat{a}_D) = \log(\hat{a}) - (2 + k_p(l))\hat{\sigma}$$

The value of the correction factor $k_p(l)$ can be evaluated for any test set size l, by making a large number of simulations of A and a_D, and iterating the value of the correction factor until the relative frequency of 0.9772 is obtained for realisations of A exceeding realisations of $\hat{a}_D$. Naturally, the normal distribution assumption has to be retained to make these simulations feasible.

504 Such simulations have been carried out for a range of values of test set size l. A million realisations were found sufficient to make the variability in the results for the correction factor negligible, and were applied in the simulations. A simple algebraic function has also been fitted to these results, and is given by

$$k_p(l) = \frac{3.3}{l} + \frac{11.2}{l^2}, \quad 6 < l < 200$$

It is suggested that this correction factor should be applied when establishing fatigue design curves for mooring line components from relatively small numbers of fatigue tests.

G. Fatigue Limit State (FLS) for Fibre Ropes

G 100 General

101 Tension – tension fatigue life of fibre ropes shall be calculated according to the procedure given in G. However, the fatigue capacity is related to the relative tension R rather than the stress. The fatigue has to be calculated using the R-N cure given in 201.

102 Tension – compression fatigue has to be documented by the manufacturer. Calculation is not required since R-N curves for different materials are not available. However, for long term mooring systems where compression will take place, the tension – compression fatigue life shall be documented by testing.

103 The manufacturer shall propose the procedure for tension – compression testing and the company responsible for the certification shall approve the procedure.

G 200 R-N curve for tension – tension fatigue

201 The fatigue curve shown in Fig.5 is developed for polyester ropes /7/, but may be used for other type of fibres due to lack of information.

202 The following equation described in F201 can be used for the component capacity against tension fatigue:

$$\log(n_c(R)) = \log(a_D) - m \cdot \log(R)$$

Where R is the ratio of tension range to characteristic strength defined in C202.

The parameters a_D and m are given in Table G1.

Table G1 T-N Fatigue Curve Parameters		
	a_D	*m*
Polyester rope	0.259	13.46

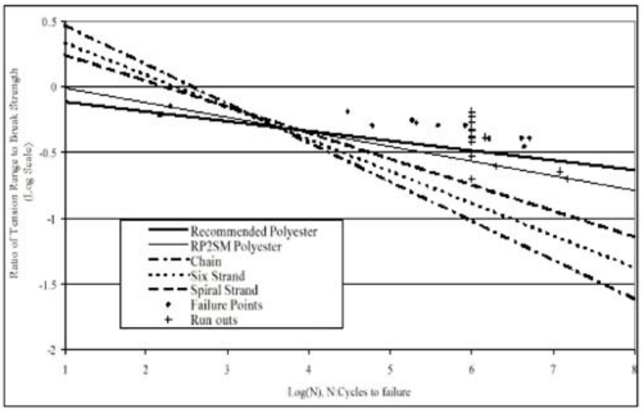

Figure 5
Polyester rope fatigue data and design curve

G 300 Design equation format

301 The fatigue limit state is intended to ensure that each type of component in an individual mooring line has a suitable resistance to fatigue failure. The design equation for FLS is:

$$1 - d_c \gamma_F \geq 0$$

d_c = is the characteristic fatigue damage accumulated as a result of cyclic loading during the design life time. The combined spectrum approach or the dual narrow band shall be applied as the cycle counting algorithms. See F307 and F309.

γ_F = is the single safety factor for the fatigue limit state.

302 The fatigue safety factor γ_F is 60 for polyester ropes and shall cover a range of uncertainties in the fatigue analysis.

Guidance note:

The fatigue safety factor specified for polyester rope is unusually large compared to values in the range from 1 to 10 typically applicable to steel components. This is partly due to the larger variability in the fatigue test result around the fitted R–N curve. Secondly, it is a consequence of the large exponent m = 13.46 of the polyester R-N curve, compared to m = 3 to 4 for typical steel components. The safety factor of 60 on the fatigue lifetime together with m =13.46 correspond to a safety factor of 1.36 on the line tension. The same safety factor on the line tension would also correspond to a safety factor of 2.5 on the design lifetime if the exponent were m = 3.

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H. Reliability Analysis

H 100 Target annual probabilities

101 A mooring system may be designed by direct application of structural reliability analysis, as an alternative to the simplified design calculation presented in B, C, D and G.

102 Such an analysis should be at least as refined as the reliability analysis used to calibrate the present design procedure /4/, /5/, /6/, and must be checked against the results of the calibration, for at least one relevant test case.

103 The probability levels given in Table H1 have been applied in the calibration, and should also be applicable in a comparable reliability analysis:

Table H1 Probability levels

Limit state	*Consequence class[1)]*	*Target annual probability of failure*
ULS	1	10^{-4}
	2	10^{-5}
ALS	1	10^{-4}
	2	10^{-5}
FLS	Single line	10^{-3}
	Multiple lines	10^{-5}

1) Consequence Classes are not considered for FLS

I. References

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SECTION 3
THRUSTER ASSISTED MOORING

A. General

A 100 Objective

101 This section provides recommendations and methods for the design of thruster assisted moorings.

A 200 Application

201 For units equipped with thrusters, a part of or full net thrust effect may be taken into account in all design conditions.

202 The effect of thruster assistance may be included in the computation of the characteristic tension for the ULS.

203 The ALS analysis shall be carried out for :

— loss of one mooring line
— loss of thruster assistance.

204 If the thruster system includes redundant power systems, the reliability and availability of the system shall be documented by a failure mode and effect analysis.

205 The effect of thruster assistance is depending on the layout of the thrust control system and the design conditions. The permissible use of thrusters and the effects are given in Table A1.

206 Thrusters may be used to assist the mooring system by reducing the mean environmental forces, heading control and damping of low frequency motions or a combination of these functions.

207 The net thrust referred to in Table A1 shall be based on the following conditions:

— fixed propellers can be considered only if thrust produced contributes to the force or moment balance
— azimuthing thrusters can be considered to provide thrust in all direction, unless specific restrictions are defined
— thruster induced moment shall be taken into account when thruster assistance is analysed.

208 When thrusters are used, failures leading to stop of thrusters shall be considered equivalent to line failure as defined in Sec.2 B101, and the corresponding safety factors will apply. See Sec.2 D.

Table A1 Permissible use of thrust effect in thruster assisted mooring systems

Consequence class	*Limit state*	*Manual remote control*	*Automatic remote control*
1	ULS	70% of net thrust effect from all thrusters	The net thrust effect from all thrusters
	ALS	70% of net thrust effect from all thrusters 1)	The net thrust effect from all thrusters 1)
2	ULS	70% of net thrust effect from all thrusters	The net thrust effect from all thrusters
	ALS	70% of net thrust effect from all thrusters 1)	The net thrust effect from all thrusters 1)

1) A failure leading to stop of thrusters shall be considered equivalent to a line failure. Redundancy in the thruster systems is not required if blackout is considered as a single failure, and the design equation given in Sec.2 D201 fulfilled.

209 The maximum effect of single failure shall not cause a design load effect higher than the characteristic capacity. See Sec.2 A202 and D202.

210 Blackout is one typical maximum effect of a single failure. If blackout leads to that sum of line tensions multiplied with the relevant safety factors is higher than the characteristic capacity than permitted in ALS (see Sec.2 D300), the power and control systems have to be arranged with redundancy.

211 Manual thruster control is intended only for limited time periods, and the arrangement assumes continuous attention of an operator.

212 Turret moored units, which are not naturally weather vaneing, and hence dependent on heading control shall be equipped with an automatic remote control system. Blackout has to be considered as an single failure if an emergency shut down is causing stop of all thrusters.

A 300 Definitions

301 The thruster assisted mooring system which is dependent on a manual remote thruster system, signifies a system comprising:

— thruster system
— power system
— control system
— reference system.

302 The remote thrust control system is a semi-automatic control system, which enables the operator to give a defined thrust (force and direction) and/or a turning moment to the unit.

303 The thruster assisted mooring system, which is dependent on an automatic remote thruster control system, signifies a system similar to a manual remote system with the addition of an automatic control mode.

304 The thruster system comprises the thruster units, included gear drives and control hardware for control of thruster speed/pitch and azimuth.

B. Available Thrust

B 100 Determination of available thrust capacity

101 The available thrust (net thrust) shall be documented by the manufacturer and verified by sea trials. In an early design stage the net thrust capacity may be estimated by calculation.

Guidance note:

To determine the available trust capacity the propeller thrust at bollard pull has to be calculated first by using the following conversion factor for nozzle propellers:

0.158 kN/kW.

For open propellers the following factor shall be used:

0.105 kN/kW.

This thrust has to be corrected by applying thrust reduction factors. These factors are depending on the following:

- propeller/thruster installation geometry and arrangement
- inflow velocity into the propeller
- propeller sense of rotation (ahead or reverse).

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102 Determination of reduction factors can be carried out according to ISO/TR 13637 or API RP 2SK. These standards contain guidelines which apply to the following:

— open and nozzled propellers installed in the stern of a ship-

shaped unit i.e. conventional main propulsion arrangement
— azimuthing or direction fixed nozzled thrusters installed under the bottom of a hull
— tunnel thrusters installed in a transverse tunnel in the hull.

C. Method

C 100 Mean load reduction

101 This is a simplified approach where the thrusters are assumed to counteract only the mean environmental actions in surge, sway and yaw direction. Available thrust from thrusters shall be evaluated according to Table A1. The mean load minus the thrust load together with the wave frequency and low frequency motions would be taken by the mooring system.

102 For spread mooring systems where the yaw moment has insignificant effect on the mooring (column-stabilised units), the force balance in the yaw direction can be neglected. In this case the surge and sway components of the allowable thrust can be subtracted from the mean surge and sway environmental loads.

103 For vessels equipped with a single point mooring system where the vessels heading is controlled by thrusters, the balance of yaw moment about the turret must be taken into consideration. A procedure to determine the mean load reduction is given in the guidance note below.

Guidance note:

1) Determine the mean environmental yaw moment as a function of the unit's heading, typically in the range of -90° to +90°, and locate the equilibrium heading at which the yaw moment is zero.

2) Determine a target heading, which is the desired heading to maintain based on operation requirements and the consideration of minimising the unit's loads and motions. For collinear environments, the target heading is normally 0° to the environment. For non-collinear environments the target heading could be the wave direction.

3) Search for the maximum yaw moment (M_E) between the target and the equilibrium heading.

4) Determine the maximum yaw moment that can be generated by the thrusters (M_T) under the damaged condition.

5) If M_T is less than M_E, thruster assist should be neglected, and the mooring system should be analysed without thruster assistance. If M_T is equal or greater than M_E go to step 6.

6) Determine the mean environmental loads in surge (F_X), sway (F_Y) and yaw (M_Z) at the target heading plus or minus an angle α, whichever is more critical where α = 10° for collinear environment and 15° for non-collinear environment.

7) Determine the surge (T_X) and sway (T_Y) thrust components from the thruster system that can be used to counteract the environmental load. T_X and T_Y can be determined as follows:

   - Thrust from the whole system is the vector sum of the thrust from each thruster.
   - Output from each thruster shall satisfy the available thrust according to the thruster control system.
   - The moment generated by T_X and T_Y shall balance M_Z.
   - The thrust generated by an individual thruster shall not exceed the allowable thrust.

8) Combine T_X and T_Y with F_X and F_Y to obtain reduced mean surge and sway loads.

9) Perform analysis to obtain mooring system response under reduced mean load.

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C 200 System dynamic analysis

201 A system dynamic analysis is normally performed using a three-axis (surge, sway and yaw) time domain simulator. This simulator generates the mean offset and low frequency vessel motions and thruster responses corresponding to specific environmental force during time records. In this analysis, constant wind, current, mean wave drift forces and low frequency wind and wave forces are included. Wave frequency forces, which are not countered by the thruster system, can be excluded in the simulation.

D. System Requirements

D 100 Thruster systems

101 The thruster configuration may consist of both fixed and rotating thrusters. Variable pitch and variable speed can e.g. control thrust output. The thruster configuration has to be evaluated on the basis of the mooring system.

D 200 Power system

201 An automatic power management system shall be provided which will ensure adequate running generator capacity relative to power demand, i.e. available power reserve.

202 The automatic power management system shall be able to execute immediate limitations in power consumption to prevent blackout due to overload caused by sudden shortage of available power.

203 The capacity of the power system shall be evaluated on the principle that a single failure in the power system shall be considered equivalent to an anchor line failure. The limiting requirements for tensions and motions for the type of operation shall be applied.

204 Detailed requirements to power systems are given in the Rules for Classification of Ships Pt.6 Ch.7 Sec.5.

205 If the design capacity is dependent on certain thrusters to remain intact after failure as in 203, the power system shall be designed with redundancy to ensure operation of these thrusters.

Guidance note:

The following can be used as guidance:

The Rules for Classification of Ships Pt.6 Ch.7 shall be used as reference.

NMD: Regulations of 4 September 1987 No. 857 concerning anchoring/positioning systems on mobile offshore units and Guideline No. 28 to the NMD regulations and Appendix B to Guideline No. 28.

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206 The definition of design capacity is given in Sec.2 B102.

D 300 Control systems

301 Manual remote thrust control system shall include:

— manual control of each thruster
— remote thrust control, joystick system.

302 Automatic remote thrust control system shall include:

— manual control of each thruster
— automatic control of all thrusters.

303 A mode selector shall be arranged in the thruster assistance control area to enable switching between remote thrust control, or automatic control and manual control.

304 Detailed requirements for control systems are given in the Rules for Classification of Ships Pt.6 Ch.7 Sec.3.

D 400 Manual thruster control

401 Manual operation of each thruster, start, stop, azimuth and pitch or speed controls shall be arranged. Displays shall be provided for all information necessary for safe and practical operation.

402 Individual stop (emergency stop) of each thruster shall be possible from thruster assistance control area.

403 The location of the thruster assistance control stand shall be chosen with consideration of the operation. Units operating at a safe distance from other stationary structures can have the control stand in a control room with no direct view of the unit's surroundings. Units operating in the vicinity of other structures, see Sec.2 D400 and D500 shall have a control stand from where there is a good view of the unit's surroundings.

404 The thruster assistance control stand shall be equipped with displays for line tensions and line length measurements.

D 500 Remote thrust control, joystick system

501 The remote thrust control system shall be located in the control area together with the manual thruster controls and with the same access to thruster and mooring displays.

502 The remote thrust control system shall be a joystick system with integrated control of all thrusters. Automatic heading control shall be included.

503 At least one gyrocompass shall be interfaced to the joystick system.

D 600 Automatic thruster control

601 The automatic control mode shall include the following main functions:

1) *Automatic control* for optimal use of available thrust in co-operation with the mooring system forces, and automatic compensation of the effects of anchor line failure, thruster failure and thruster power failure. Detailed requirements are given in 700.
2) *Monitoring* of position and mooring line tension and alarms for excursion limits. Detailed requirements are given in 800.
3) *Consequence analysis* consisting of prediction of line tensions and the unit's position in the event of a single anchor line failure or thruster failure under the prevailing environmental conditions. Detailed requirements are given in 900.
4) *Simulation* of motions and anchor line tensions during manoeuvres, changing of anchor patterns, effect of changing weather conditions, and failures in thrusters and anchor lines. Detailed requirements are given in 1000.
5) *Logging* of relevant parameters for display or hard copy on operator's request. Detailed requirements are given in 1100.
6) *Self-diagnostics* with alarms for faults within the automatic control system or in data received from interfaced equipment. Detailed requirements are given in 1200.
7) *System response to major failures*. Information is given in E.

602 The automatic control system shall be powered from a non-interruptible power source, UPS. The battery power reserve in the UPS shall be sufficient for 15 minutes operation.

603 Redundant automatic thruster control is required when the mooring analysis is based on thruster assistance to the required design capacity in ALS.

D 700 Automatic control

701 The thrusters automatic control system shall be designed to cover one or combination of the following functions:

— heading control
— counteracting the static environmental forces
— reducing the low frequency motions.

Turret moored units, which are not freely weather vaneing have to be designed with an automatic heading control system.

702 When the thruster shall be controlled to produce thrust to counteract the static environmental forces, the thrust shall be proportionate to the magnitude of anchor line tension and position offset. Thrusters can be deactivated when anchor line tension and position offset are within acceptable limits.

703 The thrusters shall be controlled to produce thrust to compensate for the effect of anchor line failure if necessary.

704 The thruster control system shall able to reallocate thrust when failure of a thruster is detected, or the operator deselects a thruster.

705 When the power demand for use of thrusters exceeds available power, the control system shall use the available power in an optimal manner and introduce thrust limitations to avoid overloads and blackout situations. The method of thrust limitation shall be quick enough to avoid blackout due to a sudden overload caused by stop of one or more generators.

D 800 Monitoring

801 Continuous monitoring shall be provided of all important parameters, which at least shall include:

— position
— heading
— anchor line tension, see Sec.4 P
— available electrical power.

802 Deviations from the specified position and heading shall be compared with at least two adjustable limits. An alarm shall be released when passing both limits. When passing the first limit, the alarm can be considered as a warning and shall be distinguishable from the other alarms realised at a more severe limit.

803 Anchor line tensions shall be monitored and compared to both high and low limits.

804 Low anchor line tension alarms can be interpreted as an anchor line failure if the anchor line tension measurement system has self check facilities, and these have not detected a measurement failure. Otherwise, the low tension alarm shall not be interpreted as anchor line failure and used for thruster control unless one more parameter e.g. position or heading indicates anchor line failure.

805 Monitoring of position shall be based on position measurements from at least one position reference system. If redundancy is required at least two position reference systems are required. Typical position reference systems are:

— hydro acoustic
— taut wire
— microwave (ARTEMIS. MINIRANGER)
— radio wave (SYLEDIS)
— riser angle sensors
— satellite (DGPS)
— gangway sensor.

806 The position being calculated from mooring system data can be used to check the direct position measurement, and can be used in the event of failure of the position reference systems.

807 The position measurements shall have an accuracy of 2% of the water depth, obtained either directly by one source of reference, or by pooling the results of several.

808 The position reference systems shall be installed in a location and in a way, which is most suitable for its type.

809 The position measurements shall be transformed to represent the position of any critical point on the unit as determined by its application.

810 The automatic remote thrust control panel shall be equipped with alarm display for thrusters, which can be relayed from the thruster alarm panel or general alarm system.

811 There shall be alarm displays for failure of external devices interfaced to the automatic remote thrust control system, e.g. gyrocompass, wind sensor and UPS.

812 All alarms shall be acknowledged by the operator at the automatic remote thrust control panel. For alarms relayed from general alarm systems or other common source, the acknowledgement shall have only local effect.

813 Further information is given in the Rules for Classification of Ships Pt.6 Ch.7 Sec.3.

D 900 Consequence analysis – Failure mode and effect analysis (FMEA)

901 Concurrent with control and monitoring, there shall be performed an analysis of the consequences of certain defined failures under prevailing operating conditions. The consequences are defined as anchor line tensions and position deviations in excess of accepted limits.

902 The failures to be considered shall include failure of any anchor line, failure of any single thruster, or stop of thrusters which will occur in the event of the most serious failure in the power system. If there is no redundancy in power supply or control systems, the most serious event is blackout.

903 The consequence analysis shall check the consequence criteria against all defined faults in sequence, and the repetition rate shall not be less than once per 5 minutes.

904 All computed consequences shall release an alarm or a warning. The consequence and reason shall be suitably identified. The warning or alarm shall be acknowledged.

905 The software or hardware used for preparing the consequence analysis is exempted from the redundancy requirements for automatic control system, see 603.

906 If the consequence analysis function is carried out by non-redundant equipment, failure of this shall cause alarm.

907 Further information is given in the Rules for Classification of Ships Pt.6 Ch.7 Sec.1.

D 1000 Simulation

1001 The simulation function can be executed in an off-line computer system with access to process data. If the control system is used for simulation, the priority shall be next to control, monitoring and consequence analysis.

1002 The simulation facility can use the display system of the control system, but shall not obstruct the presentation of alarms.

1003 The simulation facility should at least provide for:

— mooring conditions on input of proposed anchor pattern and anchor line tensions
— effects of changing weather conditions
— anchor line tensions, low frequency motions, wave frequency motions and final position caused by anchor line failure. The effects shall be displayed in true time scale
— relevant functions both with and without thruster assistance.

D 1100 Logging

1101 Automatic logging shall be carried out of important parameters. This will at least include all anchor lines' tensions, position and heading deviations, power consumption, thrust resultant in magnitude and direction, wind speed and direction.

1102 The frequency of data recording shall be high enough to give reasonable presentation of the unit's behaviour.

1103 The data shall be presented in graphical form covering at least one hour back in time.

D 1200 Self-monitoring

1201 There shall be automatic self-monitoring of automatic control system, which shall detect computer stop, software hang-ups, power failures, and false operation of interfaced equipment as far as this can be determined from the central system.

E. System Response to Major Failures

E 100 Line failure

101 For both manual and automatic thruster systems there shall be no need to consider the use of thrusters to compensate for line failure at the time of failure or immediately after. Any compensation should be the results of considering the new mooring pattern i.e. with one line missing, and making adjustments to the required heading and position as appropriate.

102 Line failure during offtake operations should be considered and the effect on the shuttle tanker shown to be without serious consequences.

E 200 Blackout prevention

201 In situations where thruster assist is not essential a blackout prevent system or a system whereby thrusters have power priority is also not essential provided it can be shown that the sudden loss of thrusters or control system cannot cause an unmanageable problem. This includes times when a shuttle tanker is engaged in loading.

202 Both systems to give thrusters priority for power and a blackout prevention system shall be installed on units where heading control is essential and where heading control and mooring load reduction by thrusters are required.

E 300 Thruster to full power

301 Thruster faults should not result in unwanted power being applied, or power applied in the wrong direction.

302 If this fault is possible then the duration of the unwanted thrust should be so short that it does not risk a heading excursion larger than 15° or a line tension to increase greater than accepted from the worst failure case. This means that these faults shall be detected and alarmed so that the thruster can be correctly stopped either by the operator or automatically.

E 400 Gyro compass drift

401 If the drift of one gyro compass can cause a change of heading there shall be a method of fault detection and alarm that enables the system and the operator to reject the gyro data and restore the correct heading before an excursion of 15° is reached. Alternatively there shall be adequate redundancy of position references.

E 500 Position reference fault

501 If the drift or jump of one position reference or two references of the same type can cause unnecessary thrust then the detection and rejection of false data shall be fast enough to prevent an increase in mooring line tensions greater than what will occur from a single line failure. Alternatively there must be adequate redundancy of position references.

E 600 Other major failures

601 The major faults described shall illustrate the principles involved and are not an exhaustive list of major failure modes that have to be considered by designers and operators.

F. Thrusters

F 100 General

101 Thrusters shall comply with DNV-OS-D101 Marine and Machinery System Equipment.

SECTION 4
MOORING EQUIPMENT

A. General

A 100 Objective

101 This section contains requirements regarding equipment and installation for temporary and emergency mooring, position mooring and towing.

A 200 Anchor types

201 The anchors are normally to be of fluke, plate, pile, suction or gravity type. Other anchor types can be accepted on a case to case basis.

202 For mobile offshore units (drilling, accommodation etc.) the anchors of embedment type shall be designed in such a way that additional anchors can be attached (piggyback).

B. Structural Design and Materials for Anchors

B 100 Structural strength

101 The structural strength of anchors for long term mooring is to be designed for a design load equal to the characteristic breaking strength of the anchor line. The nominal equivalent linearised primary membrane and bending stress σ_e shall not exceed 0,9 σ_f , e.g. local peak stresses may exceed yield ref. DNV-OS-C101 Sec.5 A400.

102 Alternatively the anchor may be design based on the characteristic loads calculated according to Sec.2 and principles given in DNV-OS-C101 with a material factor of 1.1.

103 Structural strength of fluke anchors for mobile mooring e.g. drilling and accommodation units may be designed according to Ch.3 Sec.2C.

B 200 Materials for fluke anchors

201 For fluke anchors and drag-in plate anchors the connection point to the anchor shackle is denoted the anchor head.

202 Anchor heads may be cast, forged or fabricated from plate materials. Shank or shackles may be cast or forged.

203 Cast or forged material for anchor heads, shank, flukes and shackles are to be manufactured and tested in accordance with relevant requirements of DNV-OS-B101 Ch.2 Sec.4 Steel Castings and Ch.2 Sec.3 Steel Forgings.

204 Plate material used for fabricated anchor heads and flukes is to comply with relevant requirements of DNV-OS-B101 Ch.2 Sec.1 Rolled Steel for Structural Applications.

The structural category shall be primary, see DNV-OS-C101 Sec.4 'Structural categorisation, material selection and inspection principles'.

205 Fabrication and inspection of anchor heads, shanks and flukes shall be in accordance with DNV-OS-C401.

B 300 Design of anchor pad eye

301 For other types of anchors than fluke anchors and plate anchors the connection point to the anchor shackle is denoted the anchor pad eye.

302 The mooring connection is to be designed for a design load equal the characteristic breaking strength of the anchor line. The nominal equivalent linearised primary membrane and bending stress σ_e in the pad eye and the supporting structure is not to exceed 0,9 σ_f , e.g. local stresses may exceed yield. Ref. DNV-OS-C101 Sec.5 A400.

303 Alternatively the pad eye and the supporting structure may be design based on the design loads calculated according to Sec.2 and principles given in DNV-OS-C101 with a material factor of 1.1.

304 Installation tolerances are to be accounted for.

B 400 Anchor shackle

401 The diameter of the shackle leg is normally not to be less than:

$$d_s \quad 1.4 \; D_{nom}$$

D_{nom} is the applied chain diameter with tensile strength equal to the shackle material. For long term mooring the material of the anchor shackle shall be according to the qualities given in Table B1. For mobile mooring systems the tensile strength for the shackle may differs from the chain material, and consequently D_{nom} has to be corrected correspondingly, see guidance note below.

Guidance note:

For shackle material with minimum tensile strength different from that of the steel grades R3, R3S and R4, linear interpolation between table values of D_{nom} will normally be accepted, see Table B1 and Table B2

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402 The diameter of the shackle pin is normally not to be less than the greater of:

$$d_p = 1.5 \cdot D_{nom}$$

$$d_p = 0.7 \cdot l_p$$

D_{nom} is given in Ch.3 Sec.2 A100 unless the design is documented otherwise.

l_p = free length of pin. It is assumed that materials of the same tensile strength are used in shackle body and pin. For different materials d_p. will be specially considered.

403 Anchor shackles to be applied in long term mooring system shall be tested according to Ch.2 Sec.5 A200

404 Anchor shackles to be applied in mobile mooring systems can be tested according to Ch.3 Sec.2 C303

Table B1 Mechanical properties of offshore mooring chain					
Grade	*Minimum yield strength (N/mm²)*	*Minimum tensile strength (N/mm²)*	*Minimum elongation (%)*		*Min. reduction of area (%)*
NV R3	410	690	17		50
NV R3S	490	770	15		50
NV R4	580	860	12		50
Grade	*Minimum Charpy V-notch energy (J)*				
	Temp.[1] *°C*	*Average*		*Single*	
		Base	*Weld*	*Base*	*Weld*
NV R3	0 -20	60 40	50 30	45 30	38 23
NV R3S	0 -20	65 45	53 33	49 34	40 25
NV R4	0 -20	70 50	56 36	53 38	42 27
1) At the option of the purchaser, and when chain segments are intended to permanently submerged, testing my be carried out at 0°C. Otherwise, testing to be carried out at -20°C					

Table B2 Formulas for proof and break test loads [1]	
Grade NV R3 (Chain links with studs)	
Proof test load (kN)	$0.0156 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0223 \cdot d^2(44-0.08 \cdot d)$
Grade NV R3S (Chain links with studs)	
Proof test load (kN)	$0.0180 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0249 \cdot d^2(44-0.08 \cdot d)$
Grade NV R4 (Chain links with studs)	
Proof test load (kN)	$0.0216 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0274 \cdot d^2(44-0.08 \cdot d)$
Grade NV R3 (Studless chain links)	
Proof test load (kN)	$0.0156 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0223 \cdot d^2(44-0.08 \cdot d)$
Grade NV R3S (Studless chain links)	
Proof test load (kN)	$0.0174 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0249 \cdot d^2(44-0.08 \cdot d)$
Grade NV R4 (Studless chain links)	
Proof test load (kN)	$0.0192 \cdot d^2(44-0.08 \cdot d)$
Break test load (kN)	$0.0274 \cdot d^2(44-0.08 \cdot d)$
1) $d = D_{nom}$ is the diameter in mm	

B 500 Pile, gravity and suction anchors

501 The load bearing part of the anchors shall be primary structural category, while the pad eye and the part of the structure distributing the load to the load bearing part shall be special structural category, see DNV-OS-C101 Sec.4.

502 The material shall be according to the requirements given in DNV-OS-B101, and fabrication and testing shall be in accordance with DNV-OS-C401.

C. Fluke Anchors

C 100 General

Conventional fluke anchors are also known as drag embedment anchors. A further development of this anchor type is the so-called drag-in plate anchor, which is installed as a fluke anchor, but functions as an embedded plate anchor in its operational mode. Plate anchors are treated in D.

Further information about design and installation of fluke anchors is found in DNV-RP-E301.

C 200 Fluke anchor components

201 The main components of a fluke anchor (see Fig.1) are:

— the shank
— the fluke
— the shackle
— the forerunner.

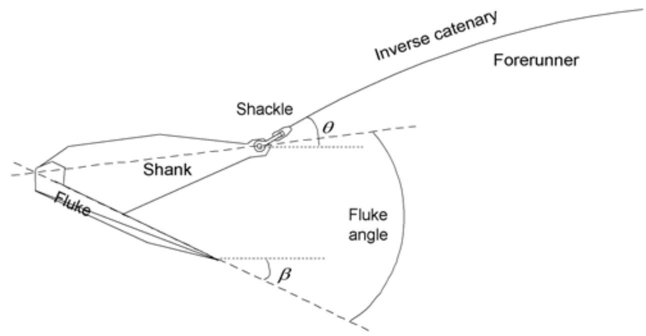

Figure 1
Fluke anchor

202 The fluke angle is the angle arbitrarily defined by the fluke plane and a line passing through the rear of the fluke and the anchor shackle. It is important to have a clear definition (although arbitrary) of how the fluke angle is being measured.

203 Normally the fluke angle is fixed within the range 30° to 50°, the lower angle used for sand and hard or stiff clay, the higher for soft normally consolidated clays. Intermediate angles may be more appropriate for certain soil conditions (layered soils, e.g. stiff clay above softer clay). The advantage of using the larger angle in soft normally consolidated clay is that the anchor penetrates deeper, where the soil strength and the normal component on the fluke is higher, giving an increased resistance.

204 The forerunner is the line segment attached to the anchor shackle, which will embed together with the anchor during installation. The anchor penetration path and the ultimate depth or resistance of the anchor are significantly affected by the type (wire or chain) and size of the forerunner, see Fig.1.

205 The inverse catenary of the anchor line is the curvature of the embedded part of the anchor line between the anchor padeye or shackle and the dip-down point at the seabed.

C 300 Definition of fluke anchor resistance

301 The characteristic resistance of a fluke anchor is the sum of the installation anchor resistance and the predicted post-installation effects of consolidation and cyclic loading. To this resistance in the dip-down point is added the possible seabed friction up to the line touch-down point.

302 The design anchor resistance at the line touchdown point, calculated according to the principles in DNV-RP-E301, shall be at least equal to the design line tension at the same point, calculated according to the principles laid down in this document.

303 The installation line tension applied shall account for any differences between the seabed line friction (length on the seabed) during installation and operation of the anchors. This tension shall be maintained during the specified holding time, normally 15 to 30 minutes.

C 400 Verification of fluke anchor resistance

401 The required resistance of fluke anchors to be applied in long term mooring, shall be assessed and verified by theoretical calculations as described in DNV-RP-E301, which also provides the basis for assessment of the target installation line tension for the anchors. For assessment of applicable consequence class reference is made to present document Sec.2 D400 and D500.

402 For mobile moorings such as drilling units with drilling riser disconnected and accommodation units in standby condition, when the consequence of anchor dragging during extreme environmental conditions is not critical, the anchor could be verified by applying an installation line tension equal to the maximum characteristic line tension, intact mooring. If the specified installation line tension cannot be obtained, the anchor should be verified by applying an installation line tension that previous experience with the same type of anchors at the same location has proved sufficient.

403 For mobile moorings where the consequence of anchor dragging during maximum characteristic environmental condition is critical to adjacent installations, human life or the environment, the anchor resistance shall be verified by applying a mooring test load of 1.25 times the maximum characteristic line tension, intact mooring system.

404 Acceptance of an uplift angle of the mooring line in the dip-down point can be given on a case to case basis, see DNV-RP-E301 for assessment of acceptable uplift angle.

405 The basis for assessment of the long-term anchor resistance and the requirement for installation line tension shall be documented.

406 Maximum installation line tensions:

a) *Chain:* proof loads, but maximum 80% of minimum breaking load.

b) *Steel wire rope:* maximum 50% of minimum breaking load.

c) *Synthetic fibre ropes:* maximum 50% of minimum breaking load.

407 In certain cases it may be required to pre-set the anchors to obtain the specified anchor resistance.

D. Plate Anchors

D 100 General

101 Plate anchors are anchors that are intended to resist the applied loads by orienting the plate approximately normal to the load after having been embedded. The embedment of the plate anchor may be by dragging (like a fluke anchor), by pushing, by driving or by use of suction.

102 For drag-in plate anchors a design and installation procedure has been developed, see DNV-RP-E302, which may be adopted as a tentative guidance for design also of other types of plate anchors. However, due consideration will have to be given to the differences in installation method and how this may affect the final pull-out resistance of the plate.

D 200 Drag-in plate anchors

201 Drag-in plate anchors are designed to take uplift or vertical loads in a taut mooring system. They are best described as a further development of the fluke anchor concept, with the added feature that the fluke (plate) after installation can be oriented normal to the applied load.

202 This triggering of the anchor leads to a significant (two-fold or more) increase of the anchor resistance expressed by the performance ratio, which gives the ratio between the pull-out resistance and the installation resistance.

203 This principle is utilised also in the development of other plate anchor concepts.

204 According to the design procedure recommended by DNV the anchor pullout resistance is split into a static component and a cyclic component.

205 The design anchor resistance, which is obtained by multiplying the characteristic value of the respective component by a material coefficient, shall be at least equal to the design line tension at the dip-down point (seabed), as explained in more detail in DNV-RP-E302.

D 300 Other types of plate anchors

301 Results from instrumented tests in clay with different push-in types of plate anchors indicate that the principles outlined in DNV RP-E302 for calculation of the pullout resistance of drag-in plate anchors can be adopted also for other types of plate anchors.

302 In the design of other types of plate anchors, like push-in plate anchors, drive-in plate anchors and suction embedment plate anchors, consideration shall be given to the special characteristics of the respective anchor type, particularly how the resistance of the plate in its operational mode is affected by the anchor installation.

303 In the assessment of the pullout resistance of plate anchors the extent and quality of the soil investigation shall be accounted for such that adequate conservatism is used in quantification of the governing design parameters.

E. Anchor Piles

E 100 General

101 Anchor piles shall account for pile bending stresses as well as ultimate lateral pile capacity. Pile embedment is also to be sufficient to develop the axial capacity to resist vertical loads with an appropriate factor of safety. The design shall be based on recognised codes and standards. Pile fatigue during installation shall be considered as relevant.

102 Design criteria for foundation of anchor piles may be taken according to DNV-OS-C101 Sec.11.

Guidance note:

An analysis method capable of accounting for both aspects of behaviour shall model the pile as a beam column on an inelastic foundation. The inelastic foundation can be modelled using a soil resistance-deflection (p-y) curve, which is described for various soils in API RP 2A.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

F. Suction Anchors

F 100 General

101 The foundation of suction anchors shall be designed according to relevant requirements given in DNV-OS-C101 Sec.11.

102 An important load case for suction anchors is buckling during installation due to the difference between outside and inside pressure. Design to be performed according to DNV-OS-C101.

G. Gravity Anchors

G 100 General

101 The foundation of gravity anchors shall be designed according to relevant requirements given in DNV-OS-C101 Sec.11.

102 The capacity against uplift shall not be taken higher than the submerged weight. However, for anchors supplied with skirts, the contribution from friction along the skirts may be included.

103 In certain cases gravity anchors with skirts may be able to resist cyclic uplift loads by the development of temporary suction within their skirt compartments.

H. Mooring Chain and Accessories

H 100 General

101 Chain cables for bow anchors on ships shall not be used by offshore units for position mooring.

102 Typical examples of stud chain links, studless chain links and accessories are shown in Fig.2 and Fig.3, respectively. Deviations in accordance with ISO 1704 will normally be accepted for position mooring of mobile offshore units, which are changing location frequently, and when the mooring lines are subject to regular onshore inspection.

103 Requirements concerning materials, manufacture, testing, dimensions and tolerances, and other relevant requirements for anchor chain cables and accessories can e.g. be found in Standard for Certification 2.6.

104 Typically connection elements such as kenter shackles, D-shackles, C-links and swivels are shown in Fig.2 and Fig.3. Kenter shackles ordinary D-shackles, C-links and pear links are not permitted in long term mooring systems due to their poor fatigue qualities. Fatigue life can not be calculated due to lack of fatigue data for these connection elements, with exception of Kenter shackles. API RP 2SK contains information sufficient for estimation of fatigue life for kenter shackles.

105 Long term mooring systems designed before 1996 may contain kenter shackles. These shackles shall be subject to regular inspection.

106 In mobile mooring systems, connection elements such as pear links and C-links should not be used. Kenter shackles are accepted.

107 Recommended connection elements in long term mooring systems are purpose made elements such as triplates, see Fig.4 and LTM D-shackles. New types of connection links may be accepted in long term mooring systems, provided their fatigue life is documented by testing and/or analysis..

108 Swivels are not permitted in long term mooring systems if they are not qualified with respect to functionality, structural strength and fatigue.

109 Twist of the chain links shall be avoided. Maximum allowable angle between each link is 5 degrees.

H 200 Identification

201 Every length of chain cable shall be marked at each end with a unique identifier traceable to appropriate certification. Every shackle or purpose made connection element shall be marked with a unique identifier traceable to appropriate certification.

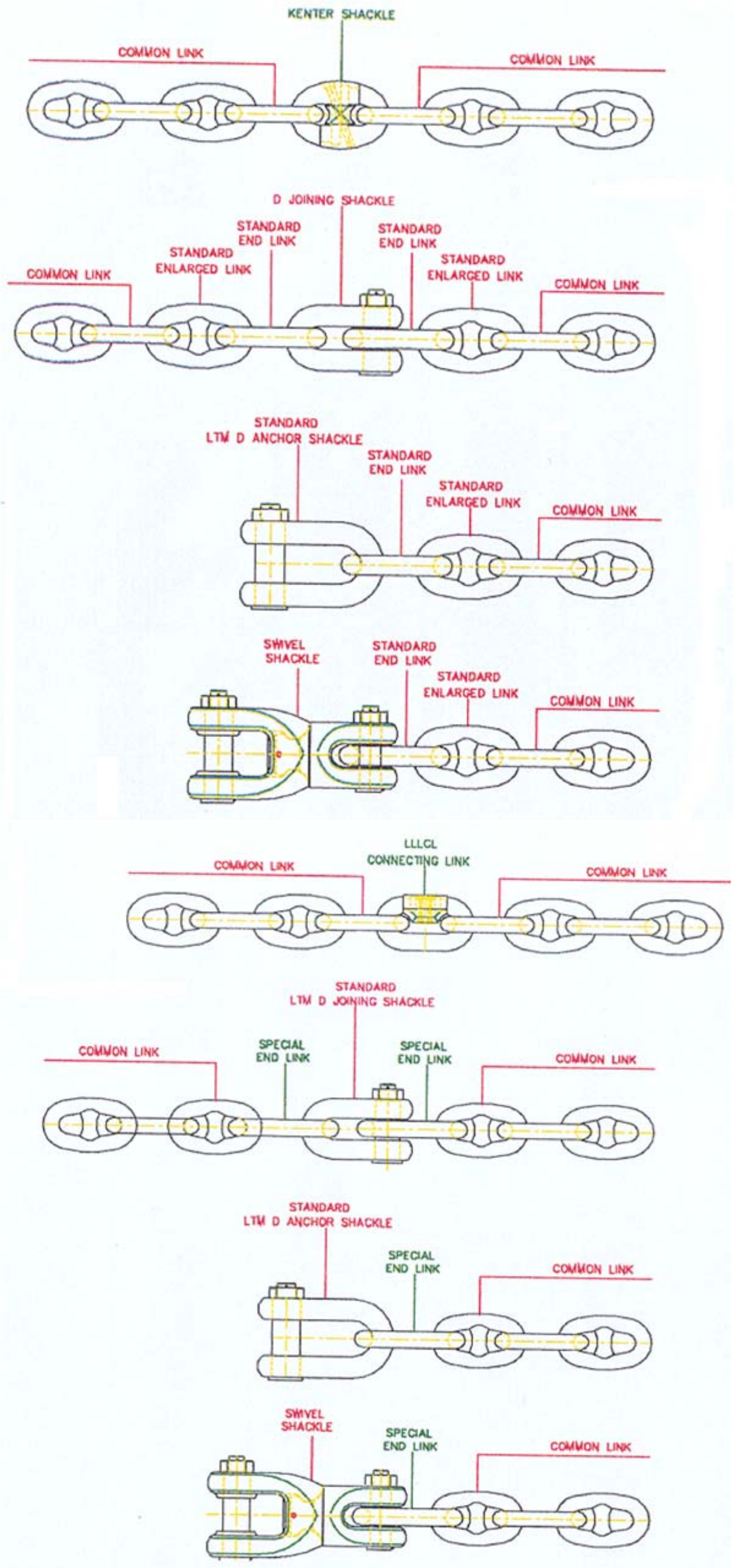

Figure 2
Standard stud link chain cable and accessories

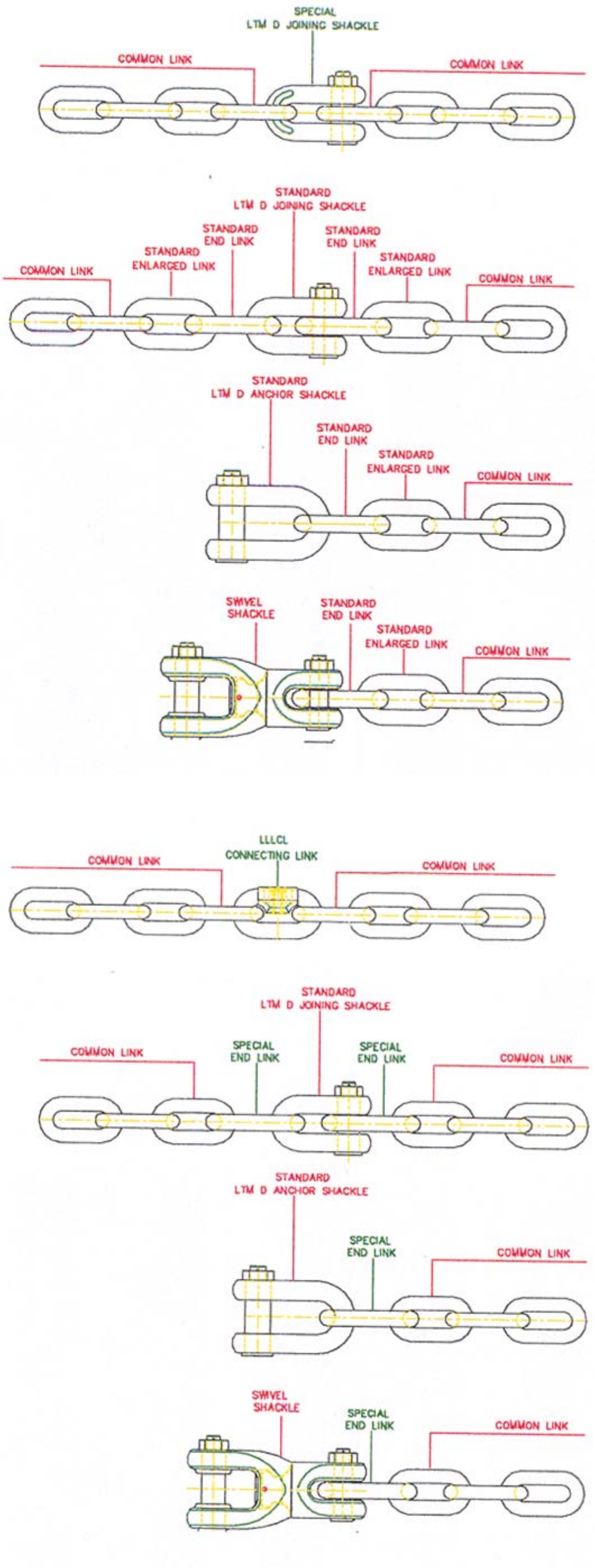

Figure 3
Standard studless link chain cable and accessories

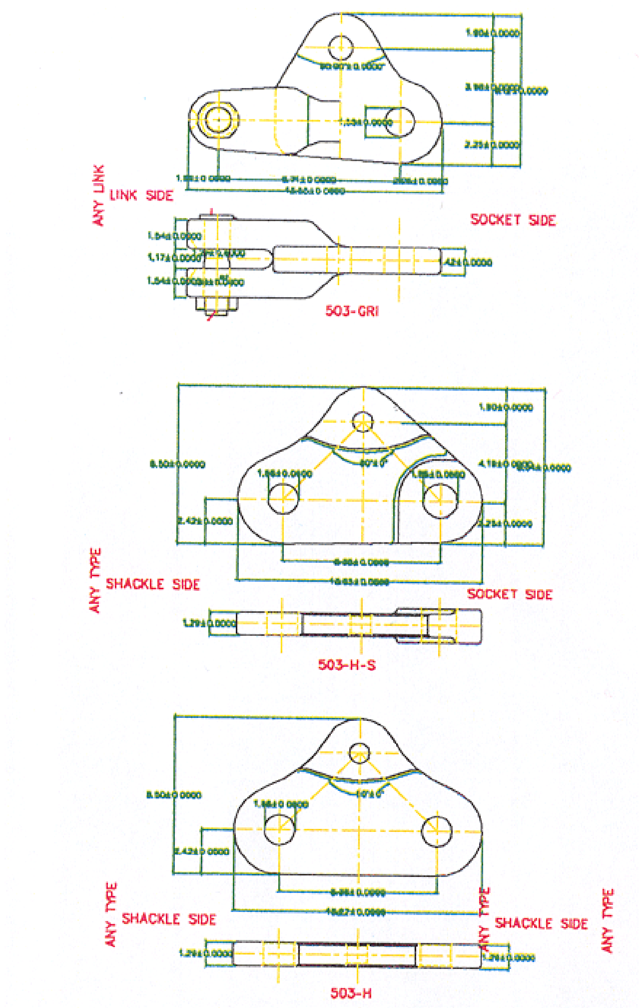

Figure 4
Triplates

I. Steel Wire Ropes

I 100 General

101 Steel wire rope sections can be of various constructions as shown in Fig.5.

102 Mobile offshore units normally use six strand wire ropes, either as anchor line segments instead of chain or as towing lines. Floating production units designed to stay at a location for more than 5 years normally use steel wire ropes of the spiral strand constructions due to better fatigue and corrosion performance, see Sec.2. Six strand wire rope can also be used for long term mooring, provided the replacement of the steel wire ropes are a part of the maintenance procedure.

I 200 Manufacture

201 The strands of 6 strand wire ropes are normally to be divided in groups as follows:

— 6 x 19 Group consists of 6 strands with minimum 16 and maximum 27 wires in each strand
— 6 x 36 Group consists of 6 strands with minimum 27 and maximum 49 wires in each strand.

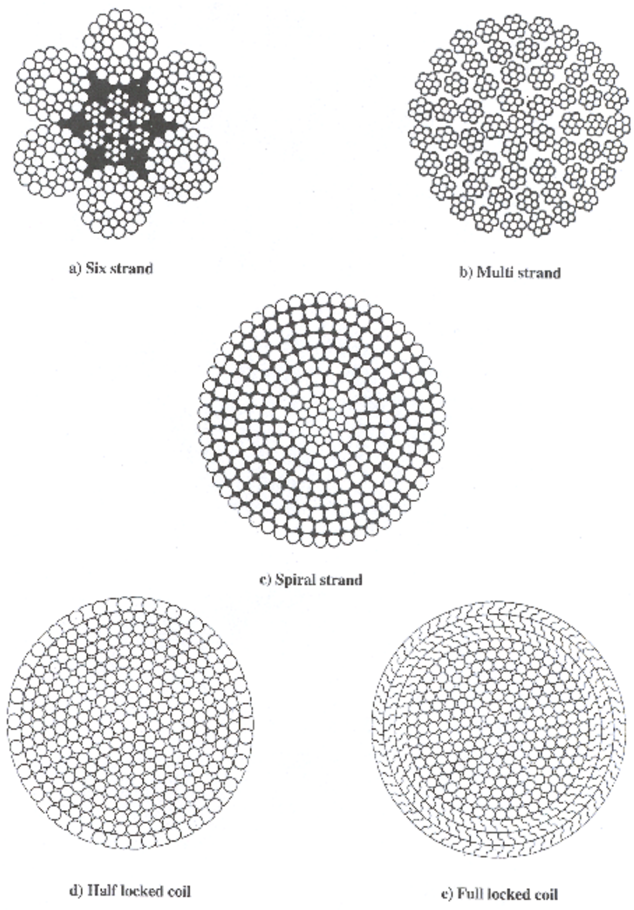

Figure 5
Constructions of steel wire ropes

202 Fig.6 gives examples of 6 strand wire rope constructions. Alternative types of wire ropes will be specially considered on the basis of an equivalent breaking load and the suitability of the construction for the purpose intended.

203 The steel core shall be an independent wire rope. The fibre core shall be manufactured from a synthetic fibre.

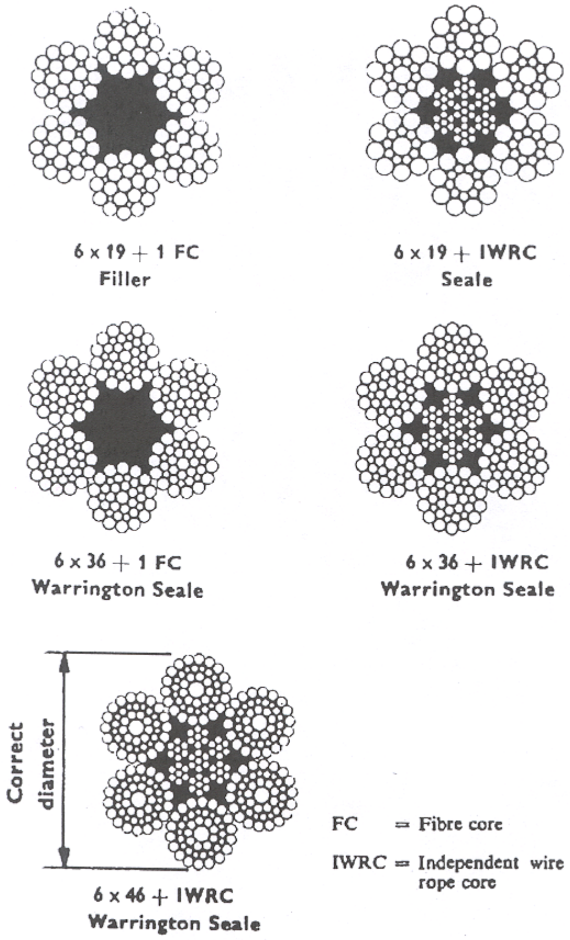

Figure 6
Constructions of six strands steel wire ropes

I 300 Steel wire for ropes

301 The wire used in the manufacture of the rope shall be drawn from rods rolled from steel made by an electric or one of the basic oxygen processes. Other processes may be used where demonstrated as appropriate. It shall be of homogeneous quality, consistent strength and free from visual defects likely to impair the performance of the rope.

302 The minimum tensile strength of the wire is defined as the tensile strength grade ordered. The tensile strength grade should be maximum 1960 N/mm^2. The upper tensile strength should not exceed the minimum tensile strength by more than 260 N/mm^2

303 The wire shall be sacrificially coated or bright (uncoated). In the case of galvanising, the wire shall comply with the requirements of ISO 2232 or equivalent. Use of Zn-Al alloys shall be evaluated in each case.

304 The following individual wire tests shall be performed as relevant:

— tensile test
— elongation test
— reverse bend test
— torsion test
— weight and adhesion of sacrificial coating.

305 For zinc coated round wires the tests shall be carried out and shall comply with the requirements of ISO 2232 or equivalent.

306 If the above tests are performed on wires taken from an already manufactured wire rope, the testing shall follow the requirements of ISO 3178 or equivalent.

307 For shaped wires and Zn-Al coated round wires arrangements for tests and acceptance criteria shall comply with the requirements of a recognised national or international standard.

308 Recognised standard is Standard for Certification 2.5.

309 The following material properties are to be specified for the sheathing:

— manufacturer and manufacturing plan
— designation
— sheathing weight/thickness
— permeability
— UV resistance
— hydrolysis resistance
— resistance to chemicals.

I 400 Identification

401 Every length of wire rope shall be marked at each end with a unique identifier traceable to appropriate certification.

J. Synthetic Fibre Ropes

J 100 General

101 Synthetic fibre ropes used in taut leg or as inserts in catenary mooring system shall be certified according to recognised standards, such as:

— Standard for Certification No. 2.13
— API RP 2SM.

J 200 Material

201 The materials used in fibre ropes are the yarns supplied form fibre makers. The rope core may also contain lubrication and fillers, and other materials. Outer protective jackets may be made from yarns or other materials such as plastic or rubber sheet.

202 Synthetic fibres currently being considered for use in mooring system are:

— Polyester (polyethylene terephthalate)
— Aramid (aromatic polyamide)
— HMPE (high modulus polyethylene)
— Nylon (polyamide).

Other types of synthetic fibres will also be accepted, provided the fibre properties are considered in the design and the fibre ropes quality is applicable for use in mooring systems.

J 300 Loadbearing yarn, material

301 The load bearing yarn properties that are important in order to determine the rope performance in mooring systems are listed below. Information on these properties shall be included in specification of the yarns to be used in the load bearing parts of the rope:

— manufacturer and manufacturing plant
— yarn designation
— yarn weight pr. unit length
— yarn breaking strength
— wet yarn-on-yarn abrasive resistance
— marine finish
— hydrolysis resistance
— safe long-term temperature
— resistance to chemicals
— creep rupture load (reduction in strength with time under load).

302 The yarn manufacturer, manufacturing plant, and yarn designation shall be identified. Yarn weight per unit length shall be stated in tex (g/km), while the breaking strength shall be stated in N.

303 The wet yarn-on-yarn abrasive resistance according to Cordage Institute draft standard CI 1505-98 shall be specified.

304 The type and amount of marine finish applied to the yarn, and its solubility in water after a time corresponding to the design life, shall be stated.

305 The effect of water at the pressure corresponding to maximum water depth, and a time corresponding to the design life, shall be documented.

306 The safe long-term temperature, i.e. the highest temperature at which the yarn with marine finish is not affected by temperature, shall be documented.

307 The effect of the chemicals listed as effluents from the installation shall be documented.

308 The creep rupture load of the load bearing yarn is defined as the load at which creep rupture occurs after a time equal to the design life of the mooring and shall be documented.

J 400 Sheathing material

401 The following material properties shall be specified for the sheathing:

— manufacturer and manufacturing plan
— designation
— sheathing weight or thickness
— permeability
— UV resistance
— hydrolysis resistance
— resistance to chemicals.

402 The manufacturer, manufacturing plant, and designation shall be identified. The sheathing weight or thickness shall be stated.

403 The permeability of the sheathing with respect to water and solids shall be stated.

404 The effect of UV light, of intensity corresponding to that experienced during operation, and after a time corresponding to the design life, shall be stated.

405 The effect of water at the pressure corresponding to maximum water depth, and a time corresponding to the design life, shall be stated.

406 The effect of the chemicals listed as effluents from the installation shall be stated.

J 500 Rope constructions

501 The fibre rope assembly is defined as the complete assembly including terminations and fibre rope.

502 There are several types of rope construction. Those under active consideration for deep water moorings according to /1/ are:

— “Wire rope constructions” (WCR)
— parallel strand
— parallel yarns.

503 Braided constructions have also been investigated, but are considered due to concern about their long-term fatigue performance.

J 600 Creep rupture

601 Polymer based fibre ropes are subject to creep, potentially leading to creep rupture. Polyester and aramid ropes are not subject to significant creep at loads normally experienced in mooring applications.

602 HMPE yarns creep substantially, although the rate of creep is very dependent on the particular HMPE yarn in question. When using HMPE ropes for deepwater mooring the risk of creep rupture should be evaluated in consultation with the yarn supplier and rope maker, taking into account the expected loading history, rope construction and other conditions.

J 700 Elongation and stiffness

701 Typical values of maximum (“Storm”), intermediate (“Drift”) and minimum (“Post-Installation”) stiffness data for deepwater fibre moorings, based on polyester, aramid and HMPE fibre ropes, are given in Table J1, which only gives typical values, actual values as determined by testing.

Table J1 Typical secant stiffness values in kN for parallel yarns, parallel strand and wire rope construction. (Based on a 10000 kN breaking strength rope)

Rope material	*Post*	*Drift*	*Storm*
Polyester	$1.00{\cdot}10^5$	$1.00{\cdot}10^5$ - $3.00{\cdot}10^5$	$3.00{\cdot}10^5$ – $4.500{\cdot}10^5$
Aramid	$3.30{\cdot}10^5$	$3.30{\cdot}10^5$ – $6.00{\cdot}10^5$	$6.00{\cdot}10^5$
HMPE	$3.50{\cdot}10^5$	$3.50{\cdot}10^5$ - $7.00{\cdot}10^5$	$7.00{\cdot}10^5$

A stress-strain cuve for a polyester rope with a breaking load of 13047 kN is given in Fig.7.

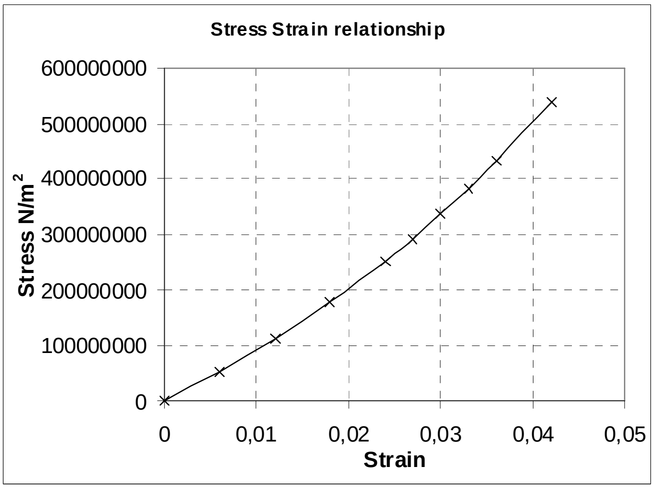

Figure 7
Stress - strain curve

J 800 Hysteresis heating

801 High internal temperatures can develop in tension-tension fatigue cycling of ropes at high strain amplitudes. The maximum temperature rise depends on diameter, internal pressure, constructional type, sheath type and thickness, lubricant, presence of water or fillers and many other factors. Studies indicate that heating effects will be small in large polyester ropes for strain amplitudes less than 0.25%.

802 Temperature limits for polyester, HMPE, nylon and aramid fibres can be determined from the fibre producer or rope manufacturer. The designer should consider alternate constructions and materials if prototype tests indicate that equilibrium temperatures exceed the recommended values.

803 Additional lubricants and fillers may also be used to provide heat transfer and reduce the formation of hotspots within the rope provided they are compatible with the yarn finishes.

J 900 Tension – tension fatigue

901 Fatigue test data for fibre ropes are quite limited, and most of the available fatigue test data are for polyester ropes. The fatigue curve shown in Sec.2 H200 is applicable for polyester ropes.

902 For other fibre ropes, such as aramid, HMPE, and nylon ropes, fatigue test data are insufficient for developing fatigue design curves. There are indications, however, that they also have better fatigue resistance than steel wire ropes. In the absence of better information, the fatigue cure for spiral strand wire ropes may be applied. However, at least one fatigue qualification test shall be carried out to demonstrate that the rope has at least equivalent fatigue resistance represented by the selected design curve.

J 1000 Axial compression fatigue

1001 Axial compression fatigue may occur when a rope experiences an excessive number of cycles at low tension and cause failures. But with proper precautions both in design and use of the rope, this axial compression problem is avoidable.

1002 In taut moorings, the rope tension may fall to low values or even go slack at times, especially on leeward lines during storms. Under these conditions, axial compression fatigue may be a problem for some fibre ropes. Although axial compression fatigue can also occur in steel, it is not generally a concern in catenary moorings because the weight of the steel components ensures that substantial tension is maintained at all times.

1003 In order to prevent rope components from going into axial compression, it is necessary to maintain a minimum tension on the rope. In the absence of test data, the guideline for minimum tension while in service is provisionally set at 5% for polyester ropes and 10% of minimum breaking strength for higher modulus ropes (such as HMPEs and aramids) provided that the ropes are not subject to significant twisting.

J 1100 Ingress of particles

1101 Strength loss in fibre ropes can be attributed to internal abrasion due to water-borne particles such as sand. The fibre rope assembly should not be used in areas of high content of particles in the water unless protected by suitable jackets which exclude particle penetration while allowing water ingress.

1102 During deployment, fibre rope contact with the seabed is undesirable. Where fibre ropes have been accidentally dropped to the seabed, the ingress of foreign particles such as sand will affect the rope’s yarn-on-yarn abrasion resistance and hence will adversely affect the rope’s fatigue life.

1103 A rope, which is dropped to the seabed, should not be used unless it has been demonstrated through testing that the rope jacket is impermeable to damaging ingress of the silt and other particles present on and near the seabed.

J 1200 Termination

1201 Three main types of end termination may be considered for fibre rope assemblies for mooring systems. These are the socket and cone (“barrel and spike”), the conventional socket (resin potted socket) and the spliced eye.

1202 Currently only the spliced eye has been qualified for strength and resistance to hysteresis heating at sizes of fibre ropes appropriate for deep water mooring system. However, developing work regarding resin socket terminations for fibre ropes is taking place and such a solution can be feasible in the near future.

J 1300 Materials for spliced eye termination

1301 For spliced eye terminations, protective cloth will normally be required between the eye and the bush that fits through the eye. Such cloth should provide low friction and high wear resistance between the fibre rope and the bush.

1302 If a thin cover of elastomeric material is used to protect against chafing, then it shall be elastic such that the rope is not constrained from stretching or bending. If a thick cover of elastomeric material is used to encapsulate the eye, it shall be applied over a tape or cloth which covers the eye and prevents direct adherence to and penetration into the rope.

1303 Other methods for protecting the fibre rope terminations from wear may be acceptable where considered on a case by case basis.

1304 Spliced eye hardware. Spools and pins are required to fit in the eye and should be made of steel. Spools and pins shall be cast or forged, ref. M201.

1305 Other materials, such as polymers and fibre-reinforced composites may be used if they have been proven satisfactory.

J 1400 Design verification of splice

1401 The rope manufacturer shall completely document all splicing procedures in the Manufacturing Specification for the splice. Measures taken to prevent slipping of the splice at minimum load shall be documented.

1402 The rope manufacturer or other parties carrying out the splices of the fibre rope shall follow the same splicing procedures when splicing the fibre ropes for rope assemblies to be tested and for rope assemblies for delivery. The following standards may be used as guidance:

— OCIMF Guidelines for the Purchasing and Testing of SPM Hawsers, First Edition – 2000.
— BS 3226.

1403 The purchaser may specify the type and dimensions of hardware and quality and strength of the materials used. If not, the manufacturer shall propose the type and quality of hardware, suitable for the intended service.

J 1500 Design verification of sockets

1501 If sockets or similar terminations are applied, free bending at the outlet may reduce the fibre rope fatigue life. To avoid premature fatigue failure, a bend-limiting device is often incorporated at these locations. Such a device is designed to smoothly transfer the loads from the socket to the rope. To prevent water ingress in the socket a sealing system may be incorporated in the device.

1502 Design and manufacturing of sockets shall be according to M201.

1503 The strength of the socket and pin material shall exceed the strength of the fibre rope assembly. The fatigue strength shall be evaluated against the design life of the mooring system. If a termination is chosen, which is not able to meet these requirements, the reduced strength and fatigue life shall be considered in the mooring system design. Requirements regarding procedure and prototype testing are given in:

— DNV Standard for Certification 2.5

J 1600 Manufacturing of fibre rope assembly

1601 Prior to manufacturing a quality plan shall be established by the manufacturer. The quality plan shall describe activities to be performed, frequency and type of inspection or tests, criteria to be met as well as give reference to applicable controlling documents.

1602 The manufacturer shall establish a Manufacturing Specification, describing how the rope is manufactured. The specification shall give complete manufacturing instructions for each step in the production process, including strand replacement criteria.

1603 The rope manufacturer shall document the following parameters for each lot of load bearing yarn used:

— manufacturer and manufacturing plant
— yarn designation
— yarn weight per unit length
— breaking strength

— marine finish.

J 1700 Testing

1701 Number of test specimens and type of tests have to be according to recognised standards such as:

— Standard for Certification 2.13
— API RP 2SM.

1702 Synthetic fibre ropes are subject to creep, potentially leading to creep rupture. Polyester and Aramid fibre ropes are not subject to significant creep at loads normally experienced in mooring applications. Only if ropes were seriously weakened by fatigue would creep rupture become significant as the final mode of failure.

1703 HMPE yarns creep substantially although the amount of creep is very dependent on the particular HMPE yarn in question. When using HMPE ropes for deep water mooring the risk of creep rupture should be evaluated in connection with certification together with yarn supplier and rope maker, taking into account the expected loading history and rope construction.

1704 Testing requirements are given in Sec.5.

K. Windlasses, Winches and Chain Stoppers

K 100 General

101 The windlass or winch shall normally have:

— one cable lifter or drum for each anchor
— coupling for release of each cable lifter or drum from the driving shaft
— static brakes for each cable lifter or drum
— dynamic braking device
— quick release system
— gear
— hydraulic or electrical motors.

K 200 Windlasses

201 The anchors are normally to be operated by a specially designed windlass.

202 The windlass shall have one cable lifter for each stowed anchor. The cable lifter is normally to be connected to the driving shaft by release coupling and provided with brake. The number of pockets in the cable lifter shall not be less than 5. The pockets, including the groove width etc., shall be designed for the joining shackles with due attention to dimensional tolerances.

203 For each chain cable there is normally to be a chain stopper device, see 214.

204 Electrically driven windlasses shall have a torque-limiting device. Electric motors shall comply with the requirements of DNV-OS-D201.

205 The windlass with prime mover shall be able to exert the pull specified by Table K1 directly on the cable lifter. For double windlasses the requirements apply to one side at a time.

Table K1 Lifting power

Lifting force and speed	*Grade of chain*		
	R3	*R3S*	*R4*
Normal lifting force for 30 minutes in N	46.6 $D_{nom}{}^2$	52.8 $D_{nom}{}^2$	49.5 $D_{nom}{}^2$
Mean hoisting speed for windlass dedicated to emergency mooring	> 9 m/minute		
Maximum lift force for 2 minutes (no speed requirement)	1.5 x normal lifting force		
D_{nom} = the diameter of chain (mm).			

206 The hoisting speed for windlasses applied for position mooring to be decided based on the operational aspects.

207 Attention shall be paid to stress concentrations in keyways and other stress raisers and also to dynamic effects due to sudden starting or stopping of the prime mover or anchor chain.

208 The capacity of the windlass brake shall be sufficient for safe stopping of anchor and chain cable when paying out.

209 The windlass with brakes engaged and release coupling disengaged shall be able to withstand a static pull of 65% of the chain cable minimum breaking strength, without any permanent deformation of the stressed parts and without brake slip.

210 If a chain stopper is not fitted, the windlass shall be able to withstand a static pull equal to the minimum breaking strength of the chain cable, without any permanent deformation of the stressed parts and without brake slip.

211 Calculations indicating compliance with the lifting power requirements in 205 and requirements for windlass brake capacity may be dispensed with when complete shop test verification is carried out.

212 The chain stoppers and their attachments shall be able to withstand the minimum breaking strength of the chain cable, without any permanent deformation of the stressed parts. The chain stoppers shall be so designed that additional bending of the individual link does not occur and the links are evenly supported.

K 300 Winches

301 When steel wire ropes are used as mooring lines winches are to be installed.

302 As far as practicable and suitable for the arrangement, drums are to be designed with a length sufficient to reel up the rope in not more than 7 layers. If the number of layers exceeds 7, special considerations and approval is required.

The ratio between winch drum diameter and wire diameter is normally to be in accordance with the recommendations of the wire manufacturer. However, the ratio should as a minimum satisfy the following requirement:

$$\frac{d_d}{d_w} \geq 16$$

d_d = winch drum diameter
d_w = nominal wire diameter

303 When all rope is reeled on the drum, the distance between top layer of the wire rope and the outer edge of the drum flange is to be at least 1.5 times the diameter of the wire rope. Except in the cases where wire rope guards are fitted to prevent overspilling of the wire.

Guidance note:

It is advised that the drums have grooves to accept the rope. Where a grooved rope drum is used the drum diameter is to be measured to the bottom of the rope groove. To avoid climbing of the rope on the grooves the fleet angle is not to exceed 4°.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

304 The strength of the drums is to be calculated, with the maximum rope tension acting in the most unfavourable position. The effects of support forces, overall bending, shear, torsion as well as hoop stresses in the barrel are to be considered.

305 The drum barrel is to be designed to withstand the surface pressure acting on it due to maximum number of windings, the rope is assumed to be spooled under maximum uniform rope tension.

K 400 Materials

401 Windlass and winch components shall be made from materials as stated in Table K2.

Table K2 Material requirements for windlasses and winches

Item	*Material requirements*
Cable lifter and pawl wheel	Cast steel Nodular cast iron 1)
Cable lifter shaft	Forged or rolled steel
Driving shaft	Forged or rolled steel
Gear wheels	Forged or rolled steel Cast steel Nodular cast iron 1)
Couplings	Forged steel Cast steel Nodular cast iron 1)
Wire drum, drum flanges	Cast steel Rolled steel Nodular cast iron 1)
Drum shaft	Forged or rolled steel
Stopper, pawl stopper with shafts	Forged or rolled steel Cast steel
Brake components	Forged or rolled steel Cast steel

1) To be considered in each case.

402 Windlasses, winches and chain stoppers may be cast components or fabricated from plate materials. The material in the cast components shall be cast steel or nodular cast iron with elongation not less than 14%, and otherwise with material properties according to DNV-OS-B101 Ch.2 Sec.4. Plate material in welded parts shall be of the grade as given in Table K3. The hardness of the material in the pockets of the cable lifter shall be less than the hardness of the chain.

Table K3 Plate material grades 1)

Thickness (mm)	*Normal strength structural steel (NS)*	*High strength structural steel (HS)*
$t \leq 20$	A	AH
$20 < t \leq 25$	B	AH
$25 < t \leq 40$	D	DH
$40 < t \leq 50$ 2)	E	EH

1) Steel of improved weldability, see DNV-OS-B101, may also be used

2) Larger thickness than 50 mm may be accepted upon special consideration

403 Drums are either to be fabricated from steel plates or to be cast. Ferritic nodular cast iron with minimum elongation (A5) 14% may be accepted. By special consideration a lower elongation may be acceptable. Impact testing of ferritic nodular cast iron will be waived for this application.

404 Components fabricated from plate material shall be manufactured in accordance with DNV-OS-C401. The components are categorised as primary structures according to DNV-OS-C101 Sec.4, while supporting structure is special structural category.

K 500 Capacity and system requirements applicable for windlasses and winches used in position mooring

501 The lifting force of the windlass or winch in stalling shall not be less than 40% of the minimum breaking strength of the relevant anchor line. The windlass or winch shall be able to maintain the stalling condition until the brakes are activated.

502 For windlasses or winches not fitted with stoppers, the braking system shall be separated into two independent systems, each able to hold a minimum static load corresponding to 50% of the minimum breaking strength of the anchor line. The brakes shall work directly on the wildcat or drum or wildcat or drum shaft.

503 For windlasses or winches not fitted with stoppers the brakes when engaged, shall not be affected by failure in the normal power supply. In event of failure in the power supply, a remainder braking force of minimum 50% of the windlass's or winch's braking force shall be instantly and automatically engaged. Means are also to be provided for regaining maximum braking capacity in event of power failure.

504 Windlasses or winches fitted with a stopper device, the capacity of the stopper device shall not be less than the minimum breaking strength of the anchor line. The windlasses or winches are also to be fitted with an independent brake, with static braking capacity of minimum 50% of the breaking strength of the anchor line. For winches the middle layer shall be used as reference.

505 The windlasses or winches are in addition to the static brakes also to be fitted with a dynamic brake. The characteristics of speed or load to which the dynamic brake system can be exposed during setting of the anchor without damaging overheating occurring, shall be documented and included in the operation manual. These characteristics are also to be reported to the relevant verifying authority and shall be clearly documented, e.g. in the Appendix to the classification certificate.

506 For preinstalled passive mooring system applicable for long term mooring, stalling capacity less than 40% of mooring line minimum breaking strength shall be considered on a case to case basis. Deviation with respect to the braking capacity and hoisting speed are acceptable, provided acceptance from the national authorities in question.

507 It shall be possible to carry out a controlled lowering of the anchor lines in case of an emergency. Individually or in convenient groups it shall be possible to release the brakes or stoppers from a well-protected area by the winch itself, and from a manned control room or bridge. During the emergency release it shall be possible to apply the brakes once in order to halt the lowering and thereafter releasing them again. No single error, including operator's error, shall lead to release of more than one anchor line.

508 A manually operated back-up system for emergency lowering of the anchor line shall be provided in the vicinity of the winch or stopper.

509 If a riser disconnect system is fitted then it is not possible to release the anchor lines while risers are connected to the unit. A special safety system preventing this shall be provided. Emergency release is nevertheless to be possible with risers connected after a manual cancellation of the above system.

510 It shall be possible to carry out a controlled lowering of the anchor lines in case of an emergency. The lowering shall be carried out individually or in convenient groups.

511 It shall be possible to release the brakes or stoppers from a protected area close to the winch itself, and from a manned control room or bridge. During the emergency release it shall be possible to apply the brakes once in order to halt the lowering and thereafter releasing them again.

512 No single error, including operator's error, shall lead to release of more than one anchor line.

513 An audible alarm system shall be fitted by each windlass or winch in order to warn that remote operation of the windlasses or winches shall take place.

514 At locations where remote operation of the windlasses or winches can be carried out, signboard shall state that the alarm system shall be engaged prior to remote operation of the windlasses or winches.

515 For long term mooring with preinstalled passive mooring systems, deviations from the standard can be acceptable, provided acceptance from the national authorities in question.

K 600 Stoppers

601 The chain stoppers may be of two different types:

a) A stopper device fitted on the cable lifter or drum shaft preventing the cable lifter or drum to rotate (pawl stopper).

b) A stopper preventing the anchor line to run out by direct contact between the stopper and the anchor line.

The latter type shall be of such design that the anchor line is not damaged at a load equivalent to the minimum breaking strength of the anchor line.

602 The material requirements are given in 400.

K 700 Strength and design load

701 For the structural part of windlass or winch and stopper, the strength requirements are given in Table K4.

Table K4 Design load and strength requirements for winches or windlasses

Case	*Load in anchor line*	*Maximum equivalent stress, σ_e to be the smaller of the following values*
Stopper engaged	S_{mbs}	0.73 σ_b or 0.9 σ_f in the stopper
Brakes engaged	0.5 S_{mbs} for each brake	0.73 σ_b or 0.9 σ_f
Pulling	0.4 S_{mbs}	0.5 σ_b or 0.6 σ_f

$$\sigma_e = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2 + 3\tau^2}$$

Where σ_1 and σ_2 are normal stresses perpendicular to each other, and τ is the shear stress in the plane of σ_1 and σ_2.

σ_f is the specified minimum upper yield stress of the material.

σ_b is the specified minimum tensile strength of the material.

S_{mbs} is the minimum breaking strength of the anchor line.

702 Chain stoppers and their supporting on offshore loading buoys (CALM) may be designed according to K701 and DNV-RP-C103 Ch.2, or DNV-OS-C101 using the LRFD method.

K 800 Other type of winches

801 There are other types of winches available such as:

— chain jack
— linear winch
— traction winch.

802 These winches shall be designed according to requirements for windlasses and winches as far as applicable. Other design codes can be accepted.

L. Fairleads

L 100 General design

101 Fairleads are normally of roller type.

102 Normally the chain cable shall be directly conveyed from the lower fairlead to the cable lifter, without interruption of an upper fairlead. An upper fairlead may be accepted only upon special consideration, taking into account the fairlead diameter, number of fairlead pockets and the distance between fairlead and cable lifter.

103 The lower fairlead is normally to be provided with a swivel arrangement. For a chain cable fairlead on mobile offshore units the number of pockets is normally not to be less than 5. The pockets shall be designed for the joining shackles with due attention to dimensional tolerances.

104 Sharp edges at interface structures with anchor chain or steel wire rope to be avoided.

105 Increasing number of pockets in fairleads above 5 will lead to lower stress and reduced wear. For units designed to stay at the same location for more than 5 years, it is recommended to have 9 pockets in the lower fairlead at least not less than 7 pockets. Other constructions provided with similar or better supporting for chain cable may be accepted.

106 For a steel cable fairlead the ratio between pitch diameter of fairlead wheel and nominal wire rope diameter shall not be less than 16. This applies to all sheaves including combined wire rope or chain arrangement of a mooring system. The groove in fairlead wheel is normally to satisfy the relations as indicated in Fig.8.

107 Fairleads for combined chain or wire anchor line will be considered in each case.

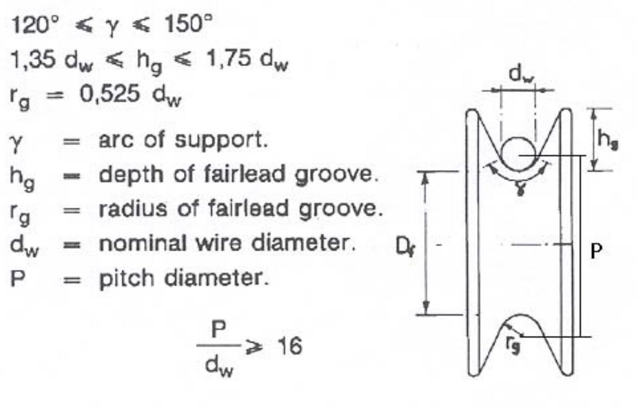

Figure 8
Fairlead for steel wire rope, diameter or groove

L 200 Materials

201 Generally the material in the fairlead wheel shall be of cast steel according to DNV-OS-B101 Ch.2 Sec.4. The hardness of the material is normally to be compatible but not exceeding that of the chain or wire rope.

202 The selection of material grades for plates in the fairlead housing shall be based on the plate thickness and the design temperature according to DNV-OS-C101 Sec.4. The parts, which shall be welded to the column structure, shall be considered as special structure. Manufacturing shall be in accordance with DNV-OS-C401.

203 If the fairleads are not exposed to air in operation and survival conditions, a design temperature of 0° may be accepted on a case by case basis.

204 The material in the fairlead shafts is normally to be of forged or rolled steel, see DNV-OS-B101 Ch.2 Sec.3 or Sec.1.

Highly stressed elements of the fairleads and their supporting structure are special structural category, see DNV-OS-C101 Sec.4. The other parts of the fairleads and supporting structures are categorised as primary.

L 300 Strength and design load

301 In the structural part of the fairlead the nominal equivalent stress σ_e is normally not to exceed 0.9 σ_f when subjected to a load equal to the breaking strength of the anchor line. The strength analysis shall be made for the most unfavourable direction of the anchor line. The horizontal design working range (DWR) and the vertical design inlet angle (DIA) normally to be considered in the strength analysis are shown in Fig.9.

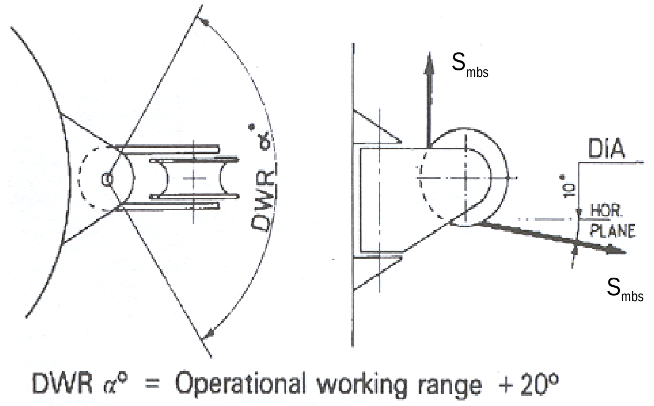

Figure 9
Horizontal DWR and vertical DIA

302 The skew load caused by bearing friction shall be included in the structural strength assessment.

303 The characteristic fatigue damage in fairlead and fairlead attachment shall be carried out if the unit is designed to stay at a location for 5 years or more. Load spectrum developed in accordance with Sec.2 F300 shall be applied. Stress concentration factors and S-N curves can be found in DNV-RP-C203.

304 Fairlead support shall be calculated according to DNV-OS-C103.

M. Steel Wire Rope End Attachment

M 100 Structural strength

101 The strength of end connections and connecting links for combined chain or wire rope systems shall be at least that of the strength of the anchor line.

102 Wire rope end attachments of the open or closed socket type are normally to be used, see Fig.10 and Fig.11. Other end attachment types will be considered in each separate case.

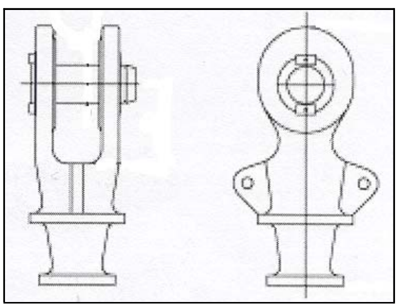

Figure 10
Open socket

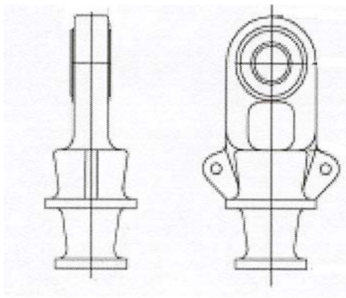

Figure 11
Closed socket

103 Fastening of the end attachments on the wire rope shall be carried out in accordance with the requirements of a recognised national or international standard and by personnel qualified by the manufacturer.

104 Design verification of sockets shall be in accordance with recognised standards:

— DNV Standard for Certification 2.5

105 The yield strength of the socket and pin material shall exceed the strength of the fibre rope assembly. The fatigue strength shall be evaluated against the design life of the mooring system. If a termination is chosen, which is not able to meet these requirements, the reduced strength and fatigue life shall be considered in the mooring system design. Requirements regarding procedure and prototype testing are given in:

— DNV Standard for Certification 2.5

M 200 Material and manufacture

201 The sockets shall be made from cast steel, forged steel and steel plates. The sockets shall be designed and manufactured according to Standard for Certification 2.5 with the following material requirements:

— Minimum 40 J Charpy V notch energy at -20°C
— Minimum 12% elongation

M 300 Fatigue

301 The fatigue life of sockets manufactured for use in long term mooring system shall be documented according to DNV-RP-C203.

N. Structural Arrangement for Mooring Equipment

N 100 General

101 The anchors shall be effectively stowed and secured in transit to prevent movement of anchor and chain due to wave action. The arrangements shall provide an easy lead of the chain cable or wire rope from the windlass or winch to the anchors. Upon release of the brake, the anchor is immediately to start falling by its own weight.

102 If anchors are supported directly by the shell, the shell plating in way of the anchor stowage shall be increased in thickness and the framing reinforced as necessary to ensure an effective supporting of the anchor.

103 Anchors bolsters shall be efficiently supported to the main structure. However, if the anchor bolsters are damaged or torn off, the main structure shall not be significantly damaged.

104 The chain locker shall have adequate capacity and a suitable form to provide a proper stowage of the chain cable, and an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. The chain locker boundaries and access openings shall be watertight. Provisions shall be made to minimise the probability of chain locker being flooded in bad weather. Drainage facilities of the chain locker shall be adopted.

105 Under normal operation of the mooring line provisions shall be made for securing the inboard end. The arrangement shall be such that the mooring line can be easily disconnected in case of emergency. A weak link can be arranged at the inboard end to secure disconnection in case of emergency.

106 Mooring systems with all-wire rope or chain or wire rope anchor lines shall have provisions for securing the inboard ends of the wire rope to the storage drum. This attachment shall be designed in such a way that when including the frictional force being applied through the turns of rope always to remain on the drum it is able to withstand a force of not less than the minimum wire rope breaking strength.

107 The fastening of the wire rope to the storage drum shall be made in such a way that in case of emergency when the anchor and chain or wire rope have to be sacrificed, the wire rope can be readily made to slip from an accessible position. The storage drum shall have adequate capacity to provide a proper stowage of the wire rope.

108 Fairleads fitted between windlass or winch and anchor shall be of the roller type.

109 The windlass or winch, chain stopper and fairlead shall be efficiently supported to the main structure. The nominal equivalent stress, σ_e in the supporting structures is normally not to exceed $0.8\ \sigma_f$ when subjected to a load equal to the breaking strength of the unit's anchor line. The strength analysis shall be made for the most unfavourable direction of the anchor line, i.e. angle of attack to structure. Detailed information regarding design of supporting structure is given in DNV-RP-C103.

O. Arrangement and Devices for Towing

O 100 General

101 The unit shall have a permanent arrangement for towing. Bridle(s) and/or pennant(s) for towing shall have clear way from the fastening devices to the fairlead. For column-stabilised units a bridle shall normally be used.

102 Normally the towing arrangement shall be designed for use of a single tug of sufficient capacity. If the size of the unit necessitates the use of two or more tugs pulling in the same direction, this can be allowed for in the design as specified in 303.

103 There shall be arrangements for hang-off and retrieval of the unit's towing bridle(s) and towing pennant(s).

104 In addition to the permanent towing arrangement, there shall be a possibility of using an emergency arrangement of equivalent strength. Application of the unit's mooring arrangement may be considered for this purpose.

105 The design load for the towing arrangement shall be clearly stated, e.g. for classed units, in the Appendix to the classification certificate.

O 200 Material

201 Plate materials in towline fastening devices and their supporting structures shall be as given in Table K3.

202 The termination of towing bridle(s) and/or pennant(s) where connected to the unit should be chain cable of sufficient length to ensure that steel wire rope segments of the towing arrangement will not be subject to chafing against the unit for towline pull sector between 90° port and 90°starboard. Alternatively the full length of bridle(s) and pennant(s) can be chain cable.

203 Chain cables and shackles to be used in the towing arrangement shall be in accordance with the requirements given in H.

204 Towing bridles and pennants of steel wire rope shall be in accordance with the requirements given in H and I.

205 All eyes in towing arrangement connections shall be fitted with hard thimbles or spelter sockets in accordance with M.

O 300 Strength analysis

301 The design load for the towing arrangement shall be based on the force, F_T, required for towing the unit when floating in its normal transit condition. For the purpose of determining the required towing force, thrust provided by the unit's own propulsion machinery should normally not be taken into account. The unit under tow shall be able to maintain position against a specified sea state, wind and current velocity acting simultaneously, without the static force in the towing arrangement exceeding its towing design load.

302 As a minimum the following weather conditions shall be used for calculation of environmental drift forces, F_T, for world-wide towing:

— sustained wind velocity: $U_{1\ min,\ 10}$ = 20 m/s (10 m above sea level)
— current velocity: V_C = 1 m/s
— significant wave height: H_S = 5 m
— zero up-crossing wave period in second: $6 \le T_z \le 9$.

Guidance note:

Environmental forces may be calculated according to Classification Note 30.5.

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303 The towing design load, F_D, to be used in the strength analysis for each towing bridle or pennant is a function of the required towing force and the number of tugs comprised in the design and given by:

$$F_D = f_{tow} F_T \quad (kN)$$

f_{tow} = Design load factor
= 1.0, if N_{TUG} = 1
= $1.5/N_{TUG}$, if N_{TUG} > 1
N_{TUG} = number of tugs comprised in the design of the towing arrangement.

Guidance note:

It is advised that the towing design load for each towing bridle or pennant not to be taken less than 1000 kN and that the towing arrangement is designed for use of a single tug.

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304 The minimum breaking strength, S_{mbs} of the unit's towing bridle(s) and/or towing pennant(s), shall not be less than 3 times the towing design load, F_D.

305 The nominal equivalent stress, σ_e in the flounder plate is normally not to exceed σ_f when subjected to a load equal to the breaking strength of the unit's towline, S_{mbs}. The strength analysis shall be made for the most unfavourable direction of the towline.

306 Towing fastening devices, including fairleads, and their supporting structures shall be designed for a load equal to the minimum breaking strength of the unit's towing bridle and/or towing pennants, S_{mbs}. Strength analyses shall be made for the most unfavourable direction of the towline pull, i.e. angle of attack to device or structure. The nominal equivalent stress, σ_e, in the towing devices and their supporting structures shall not exceed 0.9 σ_f and 0.8 σ_f, respectively.

P. Tension Measuring Equipment

P 100 General

101 Normally tensioning measuring equipment shall be installed.

Guidance note:

For special applications e.g. loading buoys this can be replaced by angle measurements during installation to verify the pretension, when continuous monitoring of anchor line tensions is not required.

Other mooring system such as submerged turret systems (buoys docked in a cone in a ship's hull) tension measuring can be carried out by calculations. This requires that the position of the anchors and anchor line lengths are known within acceptable tolerances, and the unit's position is known and continuously monitored.

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102 For tension measurement equipment the instrumentation shall comply with relevant standards such as DNV-OS-D202 in addition to requirements in Sec.3 D800.

SECTION 5
TESTS

A. Testing of Mooring Chain and Accessories

A 100 General

101 All chain shall be certified according to a recognised standard. Further, all chain shall be subject to proof load tests, break load test and mechanical tests.

102 The tests specified below shall be carried out, but deviation from the requirements given below can be accepted if the deviations are according to the standard used for certification.

A 200 Proof and break load tests

201 The entire length of the chain shall withstand the proof load without fracture and shall not crack in the flash weld. Proof loads to be used for stud and studless chain are given in Sec.4 Table B2.

These loads are valid for chain produced according to Standard for Certification 2.6

202 During the manufacturing process sufficient links shall be produced to provide the required test samples and mechanical test samples. These test links shall be suitably identified and attached evenly at both ends of the production chain to be heat-treated. A break test sample consists normally of three links.

A 300 Dimensions and dimension tolerance

301 The shape and proportion of links and accessories shall confirm to ISO 1704 or the design specially approved. The tolerances shall be according to requirements given in Standard for Certification 2.6.

A 400 Mechanical tests

401 Mechanical test shall be carried out according to requirements in Standard for Certification 2.6.

402 Mechanical properties shall be in accordance with the Standard for Certification 2.6.

B. Test of Steel Wire Ropes

B 100 Tests of finished wire ropes

101 Every length of wire rope shall be subjected to a breaking load test.

102 The breaking load shall be determined by testing to destruction a sample cut from the finished wire rope. The test length shall be taken as at least 30 times the rope diameter between the grips. The actual breaking load shall not be less than given in Table B2 for the rope constructions shown in Sec.4 Fig.6 and for the dimension concerned. For other wire rope constructions and/or diameters the breaking load shall be in accordance with the requirements of a recognised national or international standard such as Standard for Certification 2.5.

103 If facilities are not available for pulling the complete section of six strands ropes to destruction, the breaking load may be determined by testing separately 10% of all wires from each strand. The breaking load of the rope is then considered to be:

$$S_{mbs} = f\ t\ k_1 \quad (kN)$$

f = average breaking load of one wire (kN)
t = total number of wires
k_1 = lay factor as given in Table B1.

Table B1 Lay factor k_l

Rope construction group	*Rope with FC*	*Rope with IWRC*
6 x19	0.86	0.80
6 x36	0.84	0.78

Table B2 Test loads and masses for six strand steel wire ropes

Construction groups	Nominal diameter (mm)	Minimum required breaking strength in kN		Approximate mass (kg/100 m)
Rope with fibre core (FC)				
		1570 N/mm2	*1770 N/mm2*	
6 x 19 group	24 26 28 30	299 351 407 468	337 396 459 527	214 251 291 334
6 x 19 group and 6 x 36 group	32 36 40 44 48 52 56 60	530 671 829 1 000 1 190 1 400 1 620 1 860	598 757 934 1 130 1 350 1 580 1 830 2 100	380 480 593 718 854 1 000 1 160 1 330
Rope with independent wire-rope core (IWRC)				
Construction groups	*Nominal diameter (mm)*	*Minimum required breaking strength (kN)*		*Approximate mass (kg/100 m)*
		1570 N/mm2	*1770 N/mm2*	
6 x 19 group	24 26 28 30	323 379 440 505	364 428 496 569	241 283 328 376
6 x 19 group and 6 x 36 group	32 36 40 44 48 52 56 60 64 68	573 725 895 1 080 1 290 1 510 1 750 2 010 2 290 2 590	646 817 1 010 1 220 1 450 1 710 1 980 2 270 2 580 2 920	428 542 669 810 964 1 130 1 310 1 510 1 710 1 930
6 x 36 group	72 76 80 84 88 92 96 100 104 108 112 116 120 124 128	2 900 3 230 3 580 3 950 4 330 4 730 5 160 5 590 6 050 6 520 7 020 7 530 8 060 8 600 9 170	3 270 3 640 4 040 4 450 4 880 5 340 5 810 6 310 6 820 7 360 7 910 8 490 9 080 9 700 10 330	2 170 2 420 2 680 2 950 3 240 3 540 3 850 4 180 4 520 4 880 5 250 5 630 6 020 6 430 6 850

C. Test of Windlass and Winch and Chain Stoppers

C 100 Tests of windlass and winch

101 Before assembly the following parts shall be pressure tested:

- housings with covers for hydraulic motors and pumps
- hydraulic pipes
- valves and fittings
- pressure vessels.

The tests shall be carried out in accordance with relevant parts of DNV-OS-D101.

102 After completion, at least one windlass or winch of a delivery to one unit shall be shop tested with respect to required lifting capacity and static or dynamic braking capacity.

103 After installation onboard, functional tests of the windlasses/winches are to carried out. The tests are to demonstrate that the windlass with brakes etc. functions satisfactorily. For windlasses dedicated for emergency mooring the mean speed on the chain cable when hoisting the anchor and cable is not to be less than 9 m/minute and is to be measured over two shots (55 m) of chain cable during the trial. The trial should be commenced with 3 shots (82.5 m) of chain cable fully submerged. Where the depth of water in trial areas is inadequate, consideration will be given to acceptance of equivalent simulated conditions. The hoisting speed for windlasses intended for position mooring shall be according to design.

104 For windlasses or winches designed for long term mooring systems where deviations from requirements in Sec.4 K500. are accepted, deviations in the test requirements given in 103 can be accepted.

C 200 Test of chain stopper

After completion at the chain stoppers shall be function tested.

D. Test of Manual and Automatic Remote Thruster Systems

D 100 General

101 Tests of thrusters assisted mooring shall be carried out in a realistic mooring situation.

102 All control, monitoring, alarm and simulation functions of thruster control system shall be tested.

103 In addition to 102, tests of simulated failures shall be carried out to verify redundant system (if required) in thruster and power installations. Alternative means of demonstrating these functions can be accepted.

E. Testing of Synthetic Fibre Ropes

E 100 General

101 It is the rope manufacturer's responsibility to take sufficient number of samples of the completed fibre rope in order to complete the necessary test to document the fibre rope properties.

E 200 Specification of testing

201 The following properties shall be determined by testing:

— weight per unit length
— breaking load and post installation stiffness
— initial drift and storm stiffness
— residual strength – fatigue
— creep properties.

202 The fibre ropes samples shall be preconditioned in seawater at a temperature between 5º and 15º for 24 hours before testing.

203 Number of test samples shall be according to the standard used for certification.

204 The testing of a fibre rope assembly is only valid for the specified assembly. In cases of new deliveries with similar materials, constructions etc., the requirements for documentation and testing will be considered in each case.

E 300 Creep properties

301 The fibre rope's creep properties shall be documented. A test method is given in the guidance note.

Guidance note:

Two rope samples shall be tested. One test sample from the start of the production of the first rope segment and the other from the end of the last rope segment. The test samples shall be preconditioned in seawater according to 202.

The gage length over which elongation is measured shall be sufficiently long to achieve ±10% accuracy for expected extension. The gage mark shall not be closer than 0.5 m from the tail of each termination.

The entire rope section including termination shall be immersed in seawater, or at least the sample has to be kept wet by spraying during the test.

A test load equal to 30% of the rope's wet characteristic strength is applied to one rope sample. A higher tension load equal to 65% of the rope's wet characteristic strength is applied to the other rope sample.

Elongation of each test rope sample is measured at 30 s, 10 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, 12 hours, and every 24 hours from the start of the creep test for a period of 7 days or till creep rupture develops, whichever occurs first.

From a semi-log of the creep strain versus time in seconds, determine the creep rate of the rope samples using regression analysis.

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OFFSHORE STANDARD
DNV-OS-E301

POSITION MOORING

CHAPTER 3

CERTIFICATION AND CLASSIFICATION

CONTENTS PAGE

DET NORSKE VERITAS

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SECTION 1
CERTIFICATION AND CLASSIFICATION

A. General

A 100 Introduction

101 As well as representing DNV's recommendations of safe engineering practice for general use by the offshore industry, the offshore standards also provide the technical basis for DNV classification, certification and verification services.

102 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification is given by the DNV offshore service specifications documents for classification, see Table A1.

Table A1 DNV offshore service specifications	
No.	*Title*
DNV-OSS-101	Rules for Classification of Offshore Drilling and Support Units
DNV-OSS-102	Rules for Classification of Floating Production, Storage and Loading Units

103 Mooring aspects subject to classification covered by this standard include:

— temporary mooring
— emergency mooring
— towing arrangements
— mobile mooring
— long term mooring.

104 For the purpose of temporary and emergency mooring the unit shall be equipped with at least two of each of the following items:

— anchors
— chain cables
— windlass (one winch may contain two cable lifters)
— chain stoppers
— separate spaces in the chain lockers.

Details regarding structural arrangements are given in Ch.2 Sec.4 N. Specification of equipment is given in Sec.2

B. Main Class for Offshore Units (1A1)

B 100 General

101 Depending on type of unit, the main class (**1A1**) for offshore units covers requirements for:

— temporary mooring
— emergency mooring
— towing.

102 For units with the additional class notation **POSMOOR**, the requirements for emergency and temporary mooring are normally covered.

103 For units with the additional class notations **AUTS**, **AUT**, **AUTR**, **AUTRO**, the requirements for emergency and temporary mooring shall be complied with.

104 If required by flag administrations, DNV can perform certification of the complete mooring equipment according to the **POSMOOR** notation or the relevant national regulations.

105 Ship-shaped units shall have an arrangement for temporary mooring complying with the Rules for Classification of Ships Pt.3 Ch.3 Sec.3.

106 Equipment for drilling barges will be considered in each case.

107 Column-stabilised units shall have an arrangement for temporary and emergency mooring complying with Sec.2 A.

108 Self-elevating, tension-leg and deep-draught units are not required to have temporary or emergency mooring.

109 All type of units shall have arrangement and devices for towing complying with Sec.2 I.

110 When a unit is equipped with thruster assistance, the thrusters and thruster systems shall comply with Ch.2 Sec.3.

B 200 Documentation requirements

201 Documentation requirements shall be in accordance with the NPS DocReq (DNV Nauticus Production System for documentation requirements) and Guideline No.17.

C. Main Class for Offshore Installations (OI)

C 100 General

101 Main class **OI** does not have requirements for temporary and emergency mooring.

102 For installations with main class **OI**, the additional class notation **POSMOOR** is mandatory.

D. Class Notation POSMOOR

D 100 General

101 Units with mooring system and equipment complying with this standard may be assigned the class notation **POSMOOR** or **POSMOOR V**.

102 The additional letter **V** refers to a mooring system, which is designed for positioning of a unit in vicinity of other structures.

Guidance note:

For column-stabilised units with conventional mooring systems, the class notation **POSMOOR V** applies when the distance between the unit and other structures is less than 300 m. The safety factors of the anchor lines are dependant of the collision hazard and consequences of failure, see Ch.2 Sec 2 D.

For units with an unconventional anchoring system and for all types of moored ship-shape units, the limiting distance between the unit and other structures to avoid collision hazard is given in Ch.2 Sec.2 D400.

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103 If the unit's mooring system is designed for thruster assistance, the system notation letters **TA** or **ATA** can be added to the **POSMOOR** notation.

TA The unit is provided with thruster assisted mooring system which is dependent on a manual remote thrust control system

ATA The unit is provided with thruster assisted mooring system which is dependent on an automatic remote thrust control system.

Guidance note:

Classification according to **TA** and **ATA** does not imply specific requirements regarding number of thrusters or capacity of these.

The effect of thrusters will be determined and incorporated in the mooring analysis.

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D 200 Scope and application

201 Deviations from the requirements of this standard are only acceptable upon agreement with DNV.

D 300 Use of alternative recognised standards

301 For mobile offshore units like for instance drilling and accommodation units, **POSMOOR** notations shall only be granted if the mooring system is designed and components certified according to this standard.

302 For floating production and/or storage units and installations, **POSMOOR** notations may be based on alternative standards as for instance API RP2SK subject to agreement between DNV and client.

303 A note will be included in the Appendix to the class certificate for floating production units or installations with **POSMOOR** class notations, where the mooring system is designed according to another recognised standard.

D 400 Basic assumptions

401 It is the intention of this standard that by specifying environmental condition according to Ch.2 Sec.1 for upper and lower water depths, all intermediate water depths are covered.

402 For long term moored units, site specific environmental data shall be applied.

403 The classification is based on the condition that an up to date anchor line record is kept available for presentation to DNV's surveyor upon request.

D 500 Documentation requirements

501 Documentation requirements shall be in accordance with the NPS DocReq (DNV Nauticus Production System for documentation requirements) and Guideline No.17.

SECTION 2
EQUIPMENT SELECTION AND CERTIFICATION

A. Specification of Equipment

A 100 General

101 Equipment for temporary and emergency mooring shall in general be selected in accordance with the requirements given in Table A1.

102 For self-elevating units the requirements may alternatively be based on specified design conditions or design strength of mooring lines, which shall be included in the Appendix to the classification certificate.

A 200 Equipment number

201 The equipment number is given by the formula:

$$EN = \Delta^{2/3} + A$$

Δ = Moulded displacement (t) in salt waters (density 1.025 t/m^3) on maximum transit draught

A = projected area in m^2 of all the wind exposed surfaces above the unit's light transit draught, in an upright condition, taken as the projection of the unit in a plane normal to the wind direction. The most unfavourable orientation relative to the wind shall be used taking into account the arrangement of the mooring system.

202 The shielding effect of members located behind each other shall normally not be taken into account. However, upon special consideration a reduced exposed area of the leeward members may be accepted. The shape of the wind-exposed members shall normally not be taken into account.

203 The solidification effect shall normally not be taken into account.

204 To each group of equipment numbers, as they appear in Table A1, there is associated an equipment letter which will be entered in the Appendix to the classification certificate. If the unit is equipped with heavier equipment than required by classification, the letter, which corresponds to the lowermost satisfied group of equipment numbers, will replace the class requirement letter.

Table A1 Equipment table

Equipment number Exceeding – not exceeding	*Equipment letter*	*Stockless anchors*		*Chain cables*			
		Number	*Mass per anchor (kg)*	*Total length (m)*	*Diameter and grade*		
					NV R3 or K3 [1)]	*NV R3S*	*NV R4*
720 – 780	S	2	2 280	467.5	36		
780 – 840	T	2	2 460	467.5	38		
840 – 910	U	2	2 640	467.5	40		
910 – 980	V	2	2 850	495	42		
980 -1 060	W	2	3 060	495	44		
1 060 -1 140	X	2	3 300	495	46		
1 140 -1 220	Y	2	3 540	522.5	46		
1 220 -1 300	Z	2	3 780	522.5	48		
1 300 -1 390	A	2	4 050	522.5	50		
1 390 -1 480	B	2	4 320	550	50		
1 480 -1 570	C	2	4 590	550	52		
1 570 -1 670	D	2	4 890	550	54		
1 670 -1 790	E	2	5 250	577.5	56	54	50
1 790 -1 930	F	2	5 610	577.5	58	54	52
1 930 -2 080	G	2	6 000	577.5	60	56	54
2 080 -2 230	H	2	6 450	605	62	58	54
2 230 -2 380	I	2	6 900	605	64	60	56
2 380 -2 530	J	2	7 350	605	66	62	58
2 530 -2 700	K	2	7 800	632.5	68	64	60
2 700 -2 870	L	2	8 300	632.5	70	66	62
2 870 -3 040	M	2	8 700	632.5	73	68	64
3 040 -3 210	N	2	9 300	660	76	70	66
3 210 -3 400	O	2	9 900	660	78	73	68
3 400 -3 600	P	2	10 500	660	78	73	68
3 600 -3 800	Q	2	11 100	687.5	81	76	70
3 800 -4 000	R	2	11 700	687.5	84	78	73
4 000 -4 200	S	2	12 300	687.5	87	81	76
4 200 -4 400	T	2	12 900	715	87	81	76
4 400 -4 600	U	2	13 500	715	90	84	78
4 600 -4 800	V	2	14 100	715	92	87	81
4 800 -5 000	W	2	14 700	742.5	95	90	84
5 000 -5 200	X	2	15 400	742.5	97	90	84
5 200 -5 500	Y	2	16 100	742.5	97	90	84
5 500 -5 800	Z	2	16 900	742.5	100	92	87
5 800 -6 100	A*	2	17 800	742.5	102	95	90
6 100 -6 500	B*	2	18 800	742.5	107	100	95
6 500 -6 900	C*	2	20 000	770	111	105	97
6 900 -7 400	D*	2	21 500	770	114	107	100
7 400 -7 900	E*	2	23 000	770	117	111	102
7 900 -8 400	F*	2	24 500	770	122	114	105
8 400 -8 900	G*	2	26 000	770	127	120	111
8 900 -9 400	H*	2	27 500	770	132	124	114
9 400 -10 000	I*	2	29 000	770	132	124	114
10 000 -10 700	J*	2	31 000	770	137	130	120
10 700 -11 500	K*	2	33 000	770	142	132	124
11 500 -12 400	L*	2	35 500	770	147	137	127
12 400 -13 400	M*	2	38 500	770	152	142	130
13 400 -14 600	N*	2	42 000	770	157	147	137
14 600 -16 000	O*	2	46 000	770	162	152	142

1) K3 can by applied for units where the temporary and emergency mooring is not a part of the position mooring system such as DP units

B. Certification of Equipment

B 100 General

101 Equipment shall be certified consistent with its functions and importance for safety. The principles of categorisation of equipment subject to certification are given in the respective offshore service specifications, see Table B1.

B 200 Categorisation of equipment

201 Categorisation of equipment that is normally installed as part of the areas covered by this offshore standard is given in Table B1.

Table B1 Certification of equipment

Component	*Certificate*
Anchor	NV
Windlass or winch	NV
Fairlead	NV
Anchor chain cable and accessories	NV
Steel wire rope [1)]	W
Fibre rope incl. termination	NV
Chain stopper	NV

1) For units with class notation **POSMOOR**, NV certificate is required.

B 300 Certification of material

301 For the items given in Table B2 the following material certificates are required:

Table B2 Certificates for materials

Materials for:	
Anchor	NV
Mooring chain and accessories	NV
Steel wire Ropes	NV 1)
Steel wire rope end attachment	NV 1)
Fibre ropes	NV
Fibre Ropes termination	NV
Windlass cable lifter	NV
Winch drum and drum flanges	NV
Windlass/winch framework	NV
Shafts for cable lifter and/or drum	NV
Couplings	NV
Gear shafts and gear wheels	NV
Brake components (pawl wheel/stopper)	NV
Chain stopper	NV
Fairlead (cable lifter/sheaves, shafts, housing and support)	NV
Towing equipment (Shackles, flounder plate and chain)	NV

1) For six strand steel wire rope not applied in long term mooringsystem a work certificate will be accepted provided the steel wire rope is produced by an approved manufacturer.

C. Classification Requirements for Anchors

C 100 General

101 Anchor types relevant for classification are:

— ordinary stockless anchor
— ordinary stocked anchor
— HHP (High Holding Power) anchor.

102 The mass of ordinary stockless anchors shall not be less than given in A. The mass of individual anchors may vary by ±7% of the table value, provided that the total mass of anchors is not less than would have been required for anchors of equal mass.

103 The mass of the head shall not to be less than 60% of the table value.

104 For anchors approved as HHP anchors, the mass shall not be less than 75% of the requirements given in A. In such cases the letter *r* will be added to the equipment letter.

105 The total mass of the anchors corresponding to a certain equipment number may be divided between 3 or 4 instead of 2 anchors. The mass of one anchor will then be 1/3 or 1/4 respectively of the total mass required.

106 If steel wire rope is accepted instead of stud link chain cable, the mass of the anchors shall be at least 25% in excess of the requirement given in Table A1, see D203.

C 200 Additional requirements for HHP (High Holding Power) anchors

201 Anchors shall be designed for effective hold of the seabed irrespective of the angle or position at which they first settle on the sea bed after dropping from the anchor's stowage. In case of doubt a demonstration of these abilities may be required.

202 The design approval of HHP anchors is normally given as a type approval, and the anchors are listed in the Register of Approved Manufacturers or Register of Type Approved Products.

203 HHP anchors for which approval is sought shall be tested on sea bed to show that they have a holding power per unit of mass at least twice that of an ordinary stockless anchor.

204 If approval is sought for a range of anchor sizes, at least two sizes shall be tested. The mass of the larger anchor to be tested shall not be less than 1/10 of that of the largest anchor for which approval is sought. The smaller of the two anchors to be tested shall have a mass not less than 1/10 of that of the larger.

205 Each test shall comprise a comparison between at least two anchors, one ordinary stockless anchor and one HHP anchor. The mass of the anchors shall be as equal as possible.

206 The tests shall be conducted on at least 3 different types of bottom, which normally shall be: soft mud or silt, sand or gravel, and hard clay or similar compacted material.

207 The tests shall normally be carried out by means of a tug. The pull shall be measured by dynamometer or determined from recently verified curves of the tug's bollard pull as function of propeller r.p.m. Provided the pull is measured by verified curves of the tug's bollard pull the minimum water depth for the tests shall be 20 m.

208 The diameter of the chain cables connected to the anchors shall be as required for the equipment letter in question. During the test the length of the chain cable on each anchor shall be sufficient to obtain an approximately horizontal pull on the anchor. Normally, a horizontal distance between anchor and tug equal to 10 times the water depth will be sufficient.

C 300 Requirements for anchors used in mobile mooring

301 Proof testing of anchor strength is only applicable for ordinary fluke anchors such as :

— stockless anchor
— stocked anchor
— High Holding Power anchor (H.H.P)

302 These anchors are to be subjected to proof testing in a machine specially designed for this purpose or the structural strength of the anchor has to be documented by calculations, see 305.

303 The proof load of anchors to be used for mobile mooring is not to be less than 33% of the minimum breaking strength of the anchor line.

304 The anchors are to withstand the specified proof load without showing signs of defects.

305 Proof load testing of anchors can be omitted if calculations show that the safety factor required for documentation of the ability of the anchor to withstand the required proof load by calculation methods instead of testing to be equivalent to 0.9 of the material yield stress in each case. The corresponding anchor shackles for long term mooring systems and mobile mooring systems shall be tested according Ch.2 Sec.5 A200 and Ch.3 Sec.2 C303 respectively.

C 400 Fluke anchors for temporary moorings

401 Ordinary anchors and H.H.P. anchors are to be subjected to proof testing in a machine specially approved for this purpose.

402 The proof test are to be as given in Table C1. dependent on the mass of equivalent anchor, defined as follows:

— total mass of ordinary stockless anchors
— mass of ordinary stocked anchors excluding the stock

— 4/3 of the total mass of H.H.P. anchors.

For intermediate values of mass the test load is to be determined by linear interpolation.

Table C1 Proof test load for anchors

Mass of anchor (kg)	*Proof test load (kN)*	*Mass of anchor (kg)*	*Proof test load (kN)*	*Mass of anchor (kg)*	*Proof test load (kN)*
2 200	376	5 700	713	13 500	1 180
2 300	388	5 800	721	14 000	1 210
2 400	401	5 900	728	14 500	1 230
2 500	414	6 000	735	15 000	1 260
2 600	427	6 100	740	15 500	1 270
2 700	438	6 200	747	16 000	1 300
2 800	450	6 300	754	16 500	1 330
2 900	462	6 400	760	17 000	1 360
3 000	474	6 500	767	17 500	1 390
3 100	484	6 600	773	18 000	1 410
3 200	495	6 700	779	18 500	1 440
3 300	506	6 800	786	19 000	1 470
3 400	517	6 900	795	19 500	1 490
3 500	528	7 000	804	20 000	1 520
3 600	537	7 200	818	21 000	1 570
3 700	547	7 400	832	22 000	1 620
3 800	557	7 600	845	23 000	1 670
3 900	567	7 800	861	24 000	1 720
4 000	577	8 000	877	25 000	1 770
4 100	586	8 200	892	26 000	1 800
4 200	595	8 400	908	27 000	1 850
4 300	604	8 600	922	28 000	1 900
4 400	613	8 800	936	29 000	1 940
4 500	622	9 000	949	30 000	1 990
4 600	631	9 200	961	31 000	2 030
4 700	638	9 400	975	32 000	2 070
4 800	645	9 600	987	34 000	2 160
4 900	653	9 800	999	36 000	2 250
5 000	661	10 000	1 010	38 000	2 330
5 100	669	10 500	1 040	40 000	2 410
5 200	677	11 000	1 070	42 000	2 490
5 300	685	11 500	1 090	44 000	2 570
5 400	691	12 000	1 110	46 000	2 650
5 500	699	12 500	1 130	48 000	2 730
5 600	706	13 000	1 160		

C 500 Identification

501 The following marks shall be stamped on one side of the anchor:

— mass of anchor (excluding possible stock)
— HHP, when approved as high holding power anchor
— certificate no.
— date of test
— DNV's stamp.

D. Classification Requirements for Mooring Chain

D 100 General

101 Mooring chain and accessories shall be made by manufacturers approved by DNV for the pertinent type of anchor chain, size and method of manufacture.

102 The design of chain links and accessories are subject to approval and shall be in accordance with Ch.2 Sec.4 H. Deviations in accordance with ISO 1704 will generally be accepted. Detailed drawings shall be submitted for approval. Studless chain can also be accepted.

D 200 Temporary mooring

201 The diameter and total length of stud link chain shall not be less than given in Table A1.

202 Upon special consideration by DNV a steel wire rope and an increased mass of anchor may substitute the chain link, provided suitable winches having positive control of the steel wire rope at all times are installed. The length and strength of the steel wire rope and the mass of anchors shall be as given in E201 and C106.

203 If the total mass of anchors is divided between 3 or 4 instead of 2 anchors, the diameter of the anchor chain shall be based on a mass corresponding to 1/3 and 1/4 respectively of the total mass of the anchors required according to the equipment number of the unit.

204 The total length of the anchor chain shall be at least 50% respectively 100% in excess of the requirement given in Table A1 for the reduced diameter of the chain.

D 300 Position mooring

301 The chain cable anchor lines used in the position mooring system can be of stud or studless type. Chain grades shall be NV R3, NV R3S and NV R4. The chain cable can be substituted partly or completely by steel wire rope or by synthetic fibre rope.

Guidance note:
Upon special consideration other chain grades of offshore quality can be accepted.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

D 400 Testing of chain and accessories

401 All chain and accessories shall meet the requirements for materials, design, manufacture and testing in Standard for Certification 2.6.

402 The materials for mooring chain of grades NV R3, NV R3S and NV R4 shall be delivered with DNV material certificates.

E. Classification Requirements for Steel Wire Ropes

E 100 General

101 Steel wire ropes shall be manufactured by works approved by DNV.

E 200 Temporary mooring

201 If steel wire rope is accepted instead of stud link chain cable, the length of the wire rope shall be at least 50% in excess of the requirements given in Table A1 for the chain cables. The strength of the wire rope shall not be less than 75% of the minimum breaking strength required for the substituted chain cable.

202 Technical requirements for steel wire ropes are given in Ch.2 Sec.4 J.

E 300 Position mooring

301 Requirements concerning materials, manufacture and testing of steel wire ropes are given in Ch.2 Sec.4 J, Ch.2 Sec.5 B and Standard for Certification 2.5. Steel wire ropes shall be certified by DNV according to Standard for Certification 2.5.

F. Classification Requirements for Synthetic Fibre Ropes

F 100 General

101 Fibre ropes used in positioning systems shall be certified by DNV according to Standard for Certification No. 2.13.

102 Detail requirements are given in Ch.2 Sec.4 K and Ch.2 Sec.5 E.

G. Classification Requirements for Windlass, Winches and Chain Stoppers

G 100 General

101 Windlasses, winches and chain stoppers shall be certified by DNV.

102 Detailed requirements regarding design, material and testing are given in Ch.2 Sec.4 K and Ch.2 Sec.5 C.

103 Requirements for structural strength of supporting structure is given in Ch.2 Sec.4 N109.

H. Classification Requirements for Fairleads

H 100 General

101 Fairleads shall be certified by DNV.

102 Requirements regarding design and material are given in Ch.2 Sec.4 L.

103 Requirements for structural strength of supporting structure is given in Ch.2 Sec.4 N109.

I. Classification Requirements for Arrangement and Devices for Towing

I 100 General

101 Bridle(s) or pennants for towing shall have clear way from the fastening devices to the fairlead.

102 There shall be an arrangement for retrieval of the unit's towline in case the connection to the towing vessel should break.

103 In addition to the permanent towing arrangement, there shall be the possibility of using an emergency arrangement of equivalent strength. Application of the unit's mooring arrangement may be considered for this purpose.

104 The design load for the towing arrangement will be stated in the unit's Appendix to the classification certificate.

105 Requirements regarding material and structural strength are given in Ch.2 Sec.4 O.

J. Classification Requirements for Tension Measuring Equipment

J 100 General

101 Tension measuring equipment shall normally be installed on classed units.

102 Requirements regarding tension-measuring equipment are given in Ch.2 Sec.4 P.

K. Classification Requirements for Thrusters and Thruster Systems

K 100 General

101 Manual and automatic installed thrusters and thruster systems shall comply with requirements in Ch.2 Sec.3 and the Rules for Classification of Ships Pt.6 Ch.7.

L. Classification Requirements for anchors used in Long Term Mooring

L 100 General

101 Detailed requirements are given in
Ch.2 Sec.4 B, C, D E and F.

M. Survey during Installation

M 100 General

101 For floating production and/or storage units and CALM buoys a surveyor shall be present during installation of anchors and during hook-up and pre-tensioning of the mooring lines.