GL Noble Denton

TECHNICAL POLICY BOARD

GUIDELINES FOR MOORINGS

0032/ND

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PREFACE

This document has been drawn with care to address what are likely to be the main concerns based on the experience of the GL Noble Denton organisation. This should not, however, be taken to mean that this document deals comprehensively with all of the concerns which will need to be addressed or even, where a particular matter is addressed, that this document sets out the definitive view of the organisation for all situations. In using this document, it should be treated as giving guidelines for sound and prudent practice on which our advice should be based, but guidelines should be reviewed in each particular case by the responsible person in each project to ensure that the particular circumstances of that project are addressed in a way which is adequate and appropriate to ensure that the overall advice given is sound and comprehensive.

Whilst great care and reasonable precaution has been taken in the preparation of this document to ensure that the content is correct and error free, no responsibility or liability can be accepted by GL Noble Denton for any damage or loss incurred resulting from the use of the information contained herein.

1 SUMMARY

1.1 SCOPE

1.1.1 This document describes the guidelines which will be used by GL Noble Denton for the approval of moorings, including:

a. Offshore catenary or taut leg moorings of mobile offshore units (MOU)
b. Offshore catenary or taut leg mooring of floating offshore installations (FOI)
c. Inshore mooring of MOUs and FOIs, e.g. for stacking
d. Temporary mooring of offshore installations in an afloat condition during construction, installation or decommissioning
e. Quayside mooring of MOUs and FOIs, e.g. during maintenance or conversion
f. Mooring of vessels during loadouts and installation operations.

1.2 CONTENTS

1.2.1 The following aspects of moorings are described:

a. The approval process
b. Codes and standards
c. Information required
d. Design environmental conditions
e. Environmental loads
f. Motion response
g. Mooring analysis
h. Design and strength
i. Clearances
j. Mooring equipment
k. Procedural considerations
l. Documentation
m. Special considerations for inshore and quayside moorings
n. Special considerations for permanent moorings.

2 INTRODUCTION

2.1 This document describes the guidelines which will be used by GL Noble Denton for the approval of moorings, including:

a. Offshore catenary or taut leg moorings of mobile offshore units (MOU)

b. Offshore catenary or taut leg mooring of floating offshore installations (FOI)

c. Inshore mooring of MOUs and FOIs, e.g. for stacking

d. Temporary mooring of offshore installations in an afloat condition during construction, installation or decommissioning

e. Quayside mooring of MOUs and FOIs, e.g. during maintenance or conversion

f. Mooring of vessels during loadouts and installation operations.

2.2 Where GL Noble Denton is acting as a consultant rather than a Warranty Surveyor, these Guidelines may also be applied as a guide to good practice.

2.3 This document is not intended to apply to “standard”, temporary moorings such as ships in port or anchored or moored by the bow where the vessels are fully manned, have a full marine watch, live engines and tugs available.

2.4 This document does not cover all types of mooring and every mooring application. Readers should therefore satisfy themselves that the Guidelines used are fit for purpose for the actual mooring under consideration.

2.5 This document refers to recognised standards and design codes and to other GL Noble Denton Guidelines as appropriate. All current GL Noble Denton Guideline documents can be downloaded from www.gl-nobledenton.com.

2.6 This document gives guidance on engineering analysis and practical marine considerations, both of which will form the basis for any approval.

2.7 These Guidelines are intended to lead to an approval by GL Noble Denton. Approval by GL Noble Denton does not necessarily imply that submitted proposals will comply with the requirements of any other party or organisation (e.g. as defined by codes, national legislation, guidelines, etc).

2.8 This document is submitted for general guidance and it should be noted that each mooring will differ in design due to the nature of the moored structure and the particulars of the location. This document therefore contains general guidance and detailed recommendations that will apply to individual cases.

2.9 These Guidelines are not intended to exclude alternative methods, new technology and new equipment, provided that an equivalent level of safety can be demonstrated.

3 DEFINITIONS

Referenced definitions are underlined.

Term or Acronym	Definition
Approval	The act, by the designated GL Noble Denton representative, of issuing a 'Certificate of Approval'.
ATA	Automatic Thruster Assist
Barge	A non-propelled vessel commonly used to carry cargo or equipment. (For the purposes of this document, the term Barge can be considered to include Vessel or Ship where appropriate).
Benign Area	An area that is free from tropical revolving storms and travelling depressions, (excluding the North Indian Ocean during the Southwest monsoon season and the South China Sea during the Northeast monsoon season). The specific extent and seasonal limitations of a benign area should be agreed with the GL Noble Denton office concerned.
Certificate of Approval	A formal document issued by GL Noble Denton stating that, in its judgement and opinion, all reasonable checks, preparations and precautions have been taken to keep risks within acceptable limits, and an operation may proceed.
Client	The company to which GL Noble Denton is contracted to perform marine warranty or consultancy activities.
Cold Stacking	Cold stacking is where the unit is expected to be moored up for a significant period of time and will have minimum or, in some cases, no services or personnel available.
DNV	Det Norske Veritas
DP	Dynamic Positioning
FLS	Fatigue Limit State
FOI	Floating Offshore Installation
FOS	Factor of Safety
GL Noble Denton	Any company within the GL Noble Denton Group including any associated company which carries out the scope of work and issues a Certificate of Approval, or provides advice, recommendations or designs as a consultancy service.
HAZID	Hazard Identification
Hot Stacking	Hot stacking may be defined as mooring the vessel in a manned functional condition, with the option to run machinery to provide sufficient power to operate all mooring winches, thrusters, etc as may be required.
IACS	International Association of Classification Societies.
Inshore Mooring	A mooring operation in relatively sheltered coastal waters, but not at a quayside.
Insurance Warranty	A clause in the insurance policy for a particular venture, requiring the approval of a marine operation by a specified independent survey house.
Loadout	The transfer of a major assembly or a module onto a barge, e.g. by horizontal movement or by lifting.

Term or Acronym	Definition
MBL	Certified Minimum Breaking Load (of a wire, chain or other mooring system component).
Mobile Mooring	Mooring system, generally retrievable, intended for deployment at a specific location for a short-term duration, such as those for mobile offshore units.
MODU	Mobile Offshore Drilling Unit
Mooring System	Consists of all the components in the mooring system including shackles windlasses and other jewellery and, in addition, rig/vessel and shore attachments such as bollards.
MOU	Mobile Offshore Unit
n/a	Not Applicable
NMD	Norwegian Maritime Directorate.
Operational Reference Period	The planned duration of the operation, including a contingency period.
OCIMF	Oil Companies International Marine Forum.
Permanent Mooring	Mooring system normally used to moor floating structures deployed for long-term operations, such as those for a floating production system.
PSA	Petroleum Safety Authority Norway
QTF / Quadratic Transfer Function	Refers to the matrix that defines second order mean wave loads on a vessel in bi-chromatic waves. When combined with a wave spectrum the mean wave drift loads and low frequency loads can be calculated.
Quayside Mooring	A mooring that locates a vessel alongside a quay (usually at a sheltered location).
RAO / Response Amplitude Operator	Defines the vessel's (first order) response in regular waves and allows calculation of vessel wave frequency (first order) motion in a given seastate using spectral analysis techniques.
Redundancy Check	Check of the failure loadcase associated with the applicable extreme (survival) environment, e.g. the one leg damaged case.
Semi-Submersible Unit	A floating structure normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns connected to submerged pontoons.
Self-Elevating Unit	More commonly know as a 'Jack-up'. It is a Marine Unit equipped with legs and jacking systems capable of lifting the hull clear of the water. A 'Jack-up' unit may be used as a production platform, drilling platform, construction support platform or accommodation platform.
SLS / Serviceability Limit State	A design condition defined as a normal Serviceability Limit State / normal operating case.
Survey	Attendance and inspection by a GL Noble Denton representative. Other surveys which may be required for a marine operation, including suitability, dimensional, structural, navigational, and Class surveys.
Surveyor	The GL Noble Denton representative carrying out a survey. An employee of a contractor or Classification Society performing, for instance, a suitability, dimensional, structural, navigational or Class survey.
TA	Thruster Assist
UKCS	United Kingdom Continental Shelf

Term or Acronym	Definition
ULS / **Ultimate Limit State**	The intact loadcase associated with the applicable extreme (survival) environment.
VLA	Vertical Load Anchors.
Vessel	Within the scope of this document refers to any structure which is being moored.

4 THE APPROVAL PROCESS

4.1 GENERAL

4.1.1 GL Noble Denton may act as a warranty surveyor, issuing an approval for a particular mooring or mooring operation, or as a consultant providing advice, recommendations, calculations and/or designs as part of the scope of work. These functions are not necessarily mutually exclusive.

4.1.2 Agreement is required on the start point (or point of no return) for the mooring or mooring operation and the end point (or termination) which may apply to each issued certificate of approval.

4.2 SCOPE OF WORK LEADING TO AN APPROVAL

4.2.1 Technical studies leading to the issue of a certificate of approval may consist of:

a. Reviews and audits of procedures, calculations and/or physical model tests submitted by the client or his contractors, or

b. Independent analyses carried out by GL Noble Denton to verify the feasibility of the proposals, or

c. A combination of third party reviews and independent analyses.

4.2.2 Surveys and attendances carried out as part of GL Noble Denton's scope of work typically include:

a. Site survey or examination of the mooring system, confirming that it complies with mooring design as submitted to GL Noble Denton

b. Review of the certification of all component parts of the system

c. Confirmation of the general condition of the vessel in terms of machinery and manning

d. Inspection and verification of procedures for maintenance and operation of mooring equipment and actions in an emergency including availability of tugs, etc.

e. Discussions with the local port authority or pilots as appropriate

f. Examination and/or function testing of any key items of equipment, vessels, etc. to be employed during the installation of the mooring system or in the as installed operational condition

g. Attendance at HAZIDs, risk assessment meetings as required

h. Attendance and witnessing mooring installation activities, including deployment, test tensioning, etc.

5 CODES AND STANDARDS

5.1 GENERAL

5.1.1 A number of recognised standards and design codes covering moorings are already in existence. It is not intended that this document should redefine recommendations in areas already well covered by established codes. The default standard for mooring system design and approval is ISO 19901-7.

5.1.2 Although many aspects of mooring design and practice are covered by existing codes, it is often necessary to draw upon more than one source. This document aims to collate relevant guidance from several sources where necessary. Care shall be taken to use coherent input data, analysis methods and safety factors; in general this means that these should be taken together from a single source. Combining the least conservative options from different sources is not acceptable.

5.1.3 References to guidance on best practice relating to specific issues are provided in this document wherever possible.

5.1.4 In some subject areas, particularly in relation to inshore or quayside moorings of offshore units, there is little relevant guidance available. It is intended that this document be a primary source of reference for these areas.

5.2 OFFSHORE MOORINGS

5.2.1 The International Standard ISO 19901-7, Ref. [2], represents the most modern and widely accepted set of criteria and guidelines for offshore moorings. GL Noble Denton considers ISO 19901-7 to be the preferred code for the design of all mooring systems.

5.2.2 API Recommended Practice 2SK (RP 2SK), Ref. [3] is to be incorporated within, and superseded by, ISO 19901-7 but at present it includes extensive guidance that is not included within the International Standard. This document makes reference to API RP 2SK guidance on some subjects not covered in detail by ISO 19901-7:2005.

5.2.3 DNV OS E301, Position Mooring (POSMOOR E301), Ref. [6], is considered by GL Noble Denton to be an acceptable alternative to ISO 19901-7 when used in conjunction with DNV RP C205.

5.2.4 DNV Rules for the Classification of Mobile Offshore Units, Part 6, Chapter 2: Position Mooring (POSMOOR '96), Ref. [6] has been superseded by DNV Offshore Standard E301. However POSMOOR '96 still remains the *de facto* standard code in some regions. GL Noble Denton will accept its use in some circumstances, such as if specifically requested by a field operator for MOUs with existing POSMOOR notation under the Rules for the Classification of Mobile Offshore Units Ref. [6].

5.3 INSHORE MOORINGS AND QUAYSIDE MOORINGS

5.3.1 Although the environmental loads experienced by a vessel moored in a sheltered inshore location or alongside a quayside are likely to be significantly lower than those it may experience offshore, the risk profile of these types of mooring is high due to a combination of the following factors:

a. Offshore mooring systems are generally designed for large deployed lengths of mooring wire or chain whereas inshore moorings will generally have short taut lines which can lead to very high tensions and can result in uplift on anchors

b. High consequence of failure given the proximity to shore, other assets and limited response time

c. Potential lack of suitable or degraded connection points on the vessel and onshore, e.g. quayside

d. Uncertainty in the calculation of environmental forces due to wind shear effects and shallow water blockage effects

e. Potential limitations on the ability to adjust moorings and balance the line tensions in adverse weather conditions

f. Potential difficulty in knowing the actual tensions in the lines, in other words a lack of instrumentation

g. Potential for failures due to chafe points and abrasion (especially for quayside moorings).

5.3.2 The basic approach to the review and approval of inshore and quayside moorings will be similar to that for offshore moorings, and the basic design philosophy should be the same although suitably modified to take account of the key features of these applications. Acceptance criteria (safety factors, etc.) should be based upon either the codes discussed in Section 5.2 (subject to the limitations stated therein) or those given in Sections 5.3.4 and 10 of this Guideline.

5.3.3 BS6349-6 "Design of Inshore Moorings and Floating Structures", Ref. [7], whilst somewhat outdated in a number of aspects (material selection and analytical techniques being two primary areas) provides suitable guidance for the assessment of pontoons, floating docks and Admiralty-type buoy moorings. If used, the general philosophy must be consistent with that laid out in this guideline.

5.3.4 OCIMF, Ref. [11], is considered appropriate for evaluating quayside mooring requirements of marine vessels such as tankers. It also provides good guidance on the use of quayside moorings and on design factors of safety for common vessel connections such as bitts, Smit brackets and Panama chocks.

6 INFORMATION REQUIRED

6.1 GENERAL

6.1.1 This section outlines the information required for the approval of a mooring or for carrying out mooring-related consultancy work.

6.1.2 Where relevant the approved operations manual should be submitted, for example, where it contains details of approved wind and current load coefficients, motions response amplitude operators, wave drift coefficients, etc. The manual is also likely to be relevant where it defines any limitations, guidelines or performance criteria relating to the active control of winches, windlasses and thrusters.

6.2 OPERATION

6.2.1 Details of the operation to be undertaken should be established, including:

a. Nature of operation
b. Timing, e.g. dates
c. Duration
d. Any operational mooring system performance criteria
e. Whether the mooring system will be active or passive; an active system allows line tension/length adjustment
f. Manned or unmanned and, if manned, whether on a 24 hour basis.

6.3 DESIGN CRITERIA

6.3.1 All relevant design criteria should be established, including the code or standard to which the design has been carried out.

6.4 LOCATION

6.4.1 All relevant details of the mooring location should be established including

a. Geographical location, e.g. grid coordinates and possible local currents e.g. river outflows
b. Water depth including bathymetry covering the full area of the mooring spread
c. Seabed conditions, e.g. soil type
d. Geotechnical information, e.g. soil properties derived from core samples, if required
e. Details of any existing installations or infrastructure on the surface and subsea, documented by reliable surveys
f. For inshore or quayside moorings some details of the local topography may be required to help determine the wind sheltering effects and the wind shear profiles that should be applied
g. Quay wall section drawings detailing water levels and elevation of fendering arrangements
h. Capacity of quayside bollards (see Section 15.5).

6.4.2 Further details of seabed and geotechnical data requirements are given in GL Noble Denton Guideline 0016/ND, Ref [9] “Seabed and Sub-seabed Data Required for Approvals of Mobile Offshore Units (MOU)”.

6.5 DESIGN ENVIRONMENTAL CONDITIONS

6.5.1 The environment considered in any analysis is dependent on the design criteria used but, in general, environmental information should include the following:

a. Design seastate is usually characterised by significant wave height and mean zero-crossing period, together with a parametric wave spectrum, e.g. JONSWAP spectrum
b. Design wind speed and, if applicable, gust spectrum
c. Design current and, if applicable, current profile
d. Long period swell and direction,

e. Minimum temperature if below 0°C.

6.6 VESSEL

6.6.1 The type and characteristics of the vessel to be moored should be established. The required information can be broadly categorised as shown below.

6.6.2 Vessel condition:

a. Intended draught(s)

b. Details of loading condition, if required.

6.6.3 Environmental loading and response characteristics (for all relevant draughts):

a. Response Amplitude Operators (RAOs)

b. Quadratic Transfer Functions (QTFs)

c. Wind load coefficients

d. Current load coefficients

e. Displacement and frequency dependent added mass and damping.

6.6.4 Vessel mooring points:

a. Fairleads - type, positions and documented structural capacity including supporting structure

b. Winches or windlasses - number, type, brake capacity, stopper capacity, stall capacity, pawl details, etc.

c. Position and capacity of onboard bollards, mooring bitts or Smit brackets

d. Dimensions, condition and load capacity of anchor racks (cow catchers).

6.6.5 Propulsion and dynamic positioning systems:

a. Thrusters - number, type, thrust and positions and operational; status

b. Control system - manual joystick or fully dynamically positioned (TA / ATA)

c. Critical failure modes - thrust available following a worst case single point failure.

6.7 MOORING SYSTEM

6.7.1 Details of mooring system components including:

a. Anchors - number, type and weight

b. Mooring line make-up, length, type and age of each component

c. Mooring line diameter, area, minimum breaking load, axial stiffness and weight per length

d. Latest mooring line inspection report

e. Details of any buoys or clump weights

f. Details of any connecting hardware

g. Condition and operational status of equipment.

6.7.2 If GL Noble Denton is undertaking a mooring analysis, details of any Operator or Drilling Contractor preferred or standard anchor patterns should be supplied.

7 DESIGN ENVIRONMENTAL CONDITIONS

7.1 GENERAL

7.1.1 Moorings shall be designed to withstand the loads caused by the most adverse environmental conditions expected for the location and duration of the mooring. Guidance and requirements relating to the design environment are included in most of the mooring codes, and these should be referred to in the first instance. This section contains general information and additional specific guidance covering situations outside the scope of existing codes.

7.2 UNRESTRICTED OPERATIONS

7.2.1 An unrestricted operation is one which is effectively free of any environmental limits. An unrestricted mooring is designed to be able to withstand a design environment with a large return period such that the probability of it being encountered is suitably small.

7.2.2 The following table identifies minimum return periods generally applicable to a variety of mooring types and durations.

Table 7-1 Environmental Return Periods

Mooring Type	Mooring Duration		
	< 6 months	6m ≤ t < 20 yr	≥ 20 years
Quayside / Inshore	10 year[1]	See Section 7.2.3	100 year
Offshore - Mobile near another asset	10 year		100 year
Offshore - Permanent	N/A		100 year
Offshore - Mobile in Open Location	5 year		N/A

[1] A longer return period will be required when the moored item is high-value, e.g. a concrete production platform under construction

7.2.3 For mooring durations greater than 6 months, 100 year return period can be used. Alternatively a project specific return period environmental return period may be determined to give risk levels equivalent to those of systems designed to 20 year exposure with 100 year return period.

7.2.4 Joint probability data should only be used when permitted by the referenced standard.

7.2.5 Mobile moorings should generally be designed with reference to a 10 year return period when in the vicinity of any other infrastructure. Where a mobile mooring is in an open location, with reduced consequence from mooring failure, a five year return period may be acceptable. Where applicable seasonal/monthly and/or directional metocean data as in Section 7.4 can be used with the specified return period.

7.2.6 When evaluating the consequence of failure, consideration should be given to whether risers will be connected, proximity to other installations and the type of operation being undertaken. For pipe laying operations, the expected duration of the operation, plus a suitable contingency value should be addressed.

7.3 WEATHER-RESTRICTED OPERATIONS

7.3.1 Where a weather restricted mooring is to be approved, procedures addressing all the issues identified in this section shall be provided for office review together with the mooring analysis.

7.3.2 A weather restricted operation is one in which a design environmental limit for an operation is identified, independent of extreme statistical data.

7.3.3 In general weather restricted operations will be operations with a total duration less than 72 hours.

7.3.4 To undertake any operation, the "operation criteria" shall be less than the "design criteria". The margin is a matter of judgement, dependent on factors specific to each case, but should be documented.

7.3.5 Unless agreed otherwise with GL Noble Denton, for marine operations with an operational duration of no more than 24 hours the maximum forecast seastate shall not exceed the design seastate multiplied by the applicable (sometimes called $alpha$, α) factor from Table 7-2 below. For operations with other durations alternative factors apply and should be agreed with GL Noble Denton. The forecast wind and current shall be similarly considered when their effects on the operation or structure are significant.

Table 7-2 Seastate Reduction Factors for 24 hour Operational Duration

Weather Forecast Provision	Reduction Factor
No project-specific forecast (in emergencies only)	0.50
One project-specific forecast source	0.65
One project-specific forecast source plus in-field wave monitoring (wave rider buoy)	0.70
One project-specific forecast source plus in-field wave monitoring and offshore meteorologist	0.75

7.3.6 In tropical and sub-tropical regions the short term extreme weather conditions are likely to be associated with the possibility of thunderstorm activity and the squalls associated with the passage of a storm front. Unless local weather radar is available together with an on site forecaster, it is difficult to predict the onset and severity of these squalls and even then there can be considerable uncertainty. Conduct of operations for design conditions below the 10 year seasonal squall may, therefore, be highly restricted during some seasons.

7.3.7 Planning and design of moorings shall be based on the length of time that the vessel is to be moored. Short term moorings of less than 72 hours (e.g. during a loadout) may be deemed weather-restricted operations provided that:

a. Metocean statistics indicate an adequate frequency and duration of the required weather windows
b. Regular, reliable weather forecasts for the specific location are readily available
c. The start of the operation is governed by an acceptable weather forecast covering the reference period
d. A documented risk assessment has been carried out and the results accepted by GL Noble Denton
e. Reference is made to an appropriate code
f. Detailed marine procedures are in place for the operation, including contingency plans in the event that the weather or the weather forecast deteriorates after the mooring has been established.

7.3.8 The length of time required to complete an operation is referred to as the reference period. When calculating the operational reference period, allowance should be made for:

a. The time anticipated, after the decision to commence the operation, for preparing to start or waiting for appropriate environmental conditions
b. The time anticipated for the operation itself
c. The time anticipated, upon completion, for awaiting correct tidal conditions for departure and for recovering the mooring spread
d. A contingency period allowing for over-run of the operation
e. The time required for intervention in the event of mooring component or equipment failure.

7.4 USE OF SEASONAL / DIRECTIONAL METOCEAN DATA

7.4.1 Metocean data specific to the month(s) or season(s) during which the mooring will be utilised may be used where appropriate.

7.4.2 Directional metocean data may also be used with suitable spreading functions to reflect directional divergence in the design environment.

7.5 WIND

7.5.1 Wind speeds should be referenced at 10m above the still water level.

7.5.2 For permanent moorings the more onerous of the following should be considered:

a. Steady one minute mean velocity; or

b. One hour mean plus a suitable gust spectrum.

7.5.3 Generally the ISO 19901 gust spectrum Ref. [2] would be applicable to 7.5.2b unless an alternative can be clearly justified.

7.5.4 For mobile moorings either a steady state wind speed or a suitable gust spectrum may be used depending upon the stiffness of the mooring system. The 10 minute averaged wind speed can be used to analyse catenary moorings if the effect of wind dynamics on the line tension is shown to be insignificant.

7.5.5 For inshore or quayside moorings care must be taken to ensure that all natural periods of response of the system have been considered. Some of the mooring system response periods may be shorter than one minute but on the other hand the use of shorter gust periods may not represent a sustained design wind that will act at the same time across the whole of the structure. The representative design wind sampling period, therefore, has to be carefully established on a case by case basis for inshore and quayside moorings.

7.6 CURRENT

7.6.1 The design current shall taking account of mean spring tide, the return period storm surge, fluvial (river) and wind-driven components.

7.7 WAVES

7.7.1 For mobile moorings it is generally acceptable to consider a single extreme significant wave height and associated zero crossing period corresponding to the relevant return period for a location.

7.7.2 For permanent moorings a number of Hs-Tz combinations along the 100 year return period contour line have to be considered for the analysis. If a contour plot is not available, a sensitivity study by varying peak period for the 100 year return period sea state is required. This is to ensure that extreme line tensions due to low frequency motion at lower periods are captured in the analysis, especially for ship shaped floaters.

7.8 TIDE

7.8.1 For moorings at locations where the tidal range is greater than 10% of the water depth, the highest and lowest still water levels at the location for the duration of the mooring should be established and considered in the analysis of the mooring.

7.8.2 For quayside moorings the effect of tide should always be considered including possible means to adjust line lengths for locations subject to substantial tidal variations and also to monitor line tensions with the possible provision of an alarm system (24 hour monitoring required) when tensions approach pre-specified levels.

8 ENVIRONMENTAL LOADS AND MOTIONS

8.1 GENERAL

8.1.1 This section addresses the calculation of forces imposed by the environment upon a moored vessel, its mooring spread and appendages, such as risers and umbilicals.

8.1.2 Unless it is clearly demonstrated that any of the following forces or motions are insignificant, they should always be considered in any mooring analysis.

8.1.3 Drag coefficients or model tests should be representative of the vessel at the draught(s) under consideration. Line tensions should be evaluated for all possible vessel draughts.

8.2 WIND LOADS

8.2.1 Wind loads should be considered to have a variable component modelled by an appropriate gust spectrum.

8.2.2 Wind loads may be determined through model tests, by numerical modelling (computational fluid dynamics analysis), or by calculation using accepted drag coefficients.

8.2.3 Offshore wind shear profiles may also not be appropriate for inshore or quayside moorings. The use of an offshore design wind with an offshore shear profile will always be conservative for an inshore location unless it is exposed to funnelling or squalling effects. Conversely the use of an inshore sheltered wind extreme with an offshore wind shear profile may be non-conservative because of substantially different wind shear profiles that are typical of inshore locations.

8.2.4 Wind loads are likely to be the dominant source of loading for inshore and quayside moorings. Therefore the design wind conditions need to be very carefully established.

8.3 CURRENT LOADS

8.3.1 Current loads may be determined through model tests, by numerical modelling or by calculation using accepted drag coefficients.

8.3.2 If current profile information is available it should be utilised when calculating current loads and/or damping associated with mooring lines. Only the surface current speed need be considered when calculating current loads on conventional draught vessels (ship-shaped, barges, semi-submersibles).

8.3.3 Current loads upon mooring lines, risers, umbilicals and power cables shall be assessed and their effects must be taken into account in a mooring analysis unless they have been shown to have negligible effect.

8.3.4 Any increase in the effective drag diameter of mooring line and risers due to marine growth shall be taken into account when analysing a permanent mooring. Guidance on estimating the effect of marine growth can be found in Section 6.7.4 of DNV RP C205.

8.3.5 When mooring takes place in shallow water depths (<75m) account should be taken of increase in current loads due to current blockage effects. Note that additional blockage effects will also arise when mooring alongside a quay.

8.4 WAVE LOADS

8.4.1 In addition to causing motions (see Section 8.5) waves also impose mean and slowly varying loads upon a vessel. The mean wave drift force contributes to the mean environmental load. The slowly varying loads contribute to low frequency motions of a moored vessel at its natural periods, sometimes called slow drift behaviour.

8.4.2 Wave drift forces are generally calculated from the wave spectrum and QTFs.

8.4.3 The direct effect of waves upon mooring lines can generally be neglected.

8.4.4 Shallow water corrections will be required for vessels in water depths less than 100m.

8.4.5 The possible impact of long period swell should be checked.

8.5 WAVE FREQUENCY MOTIONS

8.5.1 Forces imposed by waves upon a vessel lead to a wave frequency motion response of the vessel. The magnitude and phase of this response is generally calculated from the wave spectrum and the vessel's RAOs. RAOs may be derived from the results of model tests, or by numerical analysis (e.g. diffraction analysis taking a suitable level of damping into account). The RAOs should be determined at the relevant vessel draughts.

8.5.2 Where moorings take place in areas where the seas can be considered short crested, a reduction in the first order motion may be justifiable, e.g. in line with Section A.8.7 of ISO 19901-1, Ref. [1]. In cases where short-crestedness increases the responses this should be taken into account.

8.5.3 When mooring takes place in shallow water depths (<100m), account should be taken of increase in wave frequency motions due to elliptical particle orbits and attenuation of motions due to reduced wave energy for standard wave height.

8.5.4 For quayside moorings in relatively exposed locations the impact of long period swell should be taken into account, preferably by a time domain analysis (see Section 15.4.1).

8.6 LOW FREQUENCY MOTIONS

8.6.1 Catenary moored vessels (i.e. not moored against a fixed structure) are often subject to low frequency surge, sway, and yaw motions. These are due to the excitation of the combined vessel / mooring system, at periods close the natural frequency of the overall system, by low frequency variable loads including

a. Varying wind load (due to gust spectrum);

b. Frequency difference components of the wave drift force.

8.6.2 Low frequency motions often have a marked influence on mooring line tensions, particularly in deeper water. Unless it is clearly demonstrated that second order motions are not significant they should always be considered in any mooring analysis.

9 MOORING ANALYSIS

9.1 GENERAL

9.1.1 This section addresses the calculation of mooring line tensions based on environmental loads evaluated using the methods described in the preceding section.

9.2 ANALYSIS CASES

9.2.1 To ensure that redundancy requirements discussed in Section 10.2 are met, mooring analyses should include, as a minimum, an examination of the following cases for each environment direction (at least every 45 degrees, and including the directions of environmental maxima):

a. The mooring system as designed (intact case)

b. For each line, as the environment is applied round the clock, but with one of the loaded lines removed from the analysis (single line failure case / redundancy check)

c. If thruster assistance is being considered, the system as designed, with available thrust reduced to that available following the worst case single point failure in the propulsion or DP system.

9.2.2 In cases where the moored vessel is in close proximity to a structure (other than a quayside) or specific operational constraints upon the vessel offset exist (e.g. a connected drilling riser), the vessel's trajectory immediately following each single point failure should be calculated (transient analysis). Relevant closest points of approach and maximum offsets of points of interest should be extracted from the output of the transient analysis.

9.2.3 Full guidance on expected analysis cases is given in Section 6.2 of ISO 19901-7, Ref. [2] and Table 1 therefrom is reproduced below:

Table 9-1 Recommended Analysis Methods and Conditions

Type of Mooring	Limit State	Conditions to be Analysed	Analysis Method
Permanent Mooring	ULS	Intact / Redundancy Check	Dynamic
		Transient[1]	Quasi-Static or Dynamic
	FLS	Intact	Dynamic
	SLS	No guidance given	No guidance given
Mobile Mooring	ULS	Intact / Redundancy Check	Quasi-static or Dynamic
		Transient[1],[2]	Quasi-static or Dynamic
	FLS	Not required	Not applicable
	SLS	No guidance given	No guidance given

NOTES

[1] Applicable only if another installation is in proximity to the mooring.

[2] Applicable for MODUs drilling in deepwater where excessive transient motions can cause stroke-out of the riser slip joint.

9.3 MOORING LINE LENGTH/TENSION ADJUSTMENT

9.3.1 ISO 19901-7, Ref [2] permits only the consideration of adjustments “for operational reasons and/or in advance of foreseeable environmental events” not “the modelling of active adjustments of line tension during the analysis of design situations”. This is interpreted as follows:

a. Line manipulations to maintain vessel position, etc, in operating (SLS) cases ARE permitted provided that tension levels remain below winch stall capacities

b. A reduction in line pretensions in advance of worsening weather or on moving to survival draft IS permitted provided a single adjusted spread is used for all environmental loadcases

c. Line adjustments following line failure ARE NOT permitted

d. Line adjustments to optimise tensions in particular loadcases, e.g. windward / leeward line manipulations ARE NOT permitted.

9.3.2 Where it is permissible under the selected code and is permitted by the vessel mooring equipment classification and where a policy of leeward line slackening has been demonstrated to be actively employed on a vessel, it is considered acceptable to take account of this in a survival analysis, provided:

a. Line manipulations are only performed in the intact case

b. Due consideration is made regarding to winch/windlass stall limits

c. The adjustments performed are intuitive and with regard to the intact mooring system only (i.e. not with regard to optimising tension distributions after line failure)

d. The operations are carried out in advance of any worsening weather conditions that have been forecast. Note location specific forecasts are required.

e. Adequate trained and experienced personnel are available on board (24 hour call off basis) to carry out mooring line adjustment operations.

9.4 ANALYSIS TECHNIQUES

9.4.1 Two principal classes of analytical technique for the calculation of mooring line tensions are in common use. The advantages, limitations and validity of each technique are briefly described below. Further guidance on analytical methods is available in Section 5 of API RP 2SK 3rd Edition (2005), Ref. [3].

9.4.2 In quasi-static analysis, the mean environmental force is applied and the mean vessel offset calculated. The low frequency and wave frequency responses in the horizontal plane are combined to find the maximum instantaneous offset. The wave frequency response shall be determined taking the effects of the mooring system into account when these are significant. Mooring line tensions are then calculated statically for this maximum offset position. Quasi-static analysis is known to increasingly underestimate line tensions as water depth increases. Design codes generally allow for this by requiring higher safety factors to be applied to the results of quasi-static analyses. However, in deeper water this is no longer a conservative approach.

9.4.3 In contrast, dynamic analysis takes account of both moored vessel responses and line dynamics resulting from the fairlead motions and the hydrodynamic forces on the mooring lines. It is generally more accurate than quasi-static analysis, particularly so in deep water.

9.4.4 Frequency domain analysis is significantly faster with respect to computation time than time domain analyses, but generally cannot handle nonlinear systems as accurately.

9.4.5 For most moorings a frequency domain analysis is adequate - for long term or non standard moorings the adequacy of results should be confirmed with a check of key cases by a time domain simulation.

9.4.6 Not withstanding any specific code requirements, the types of analysis shown in Table 9-2 are generally considered suitable:

Table 9-2 Types of Analyses

Type of Analysis	Quasi-Static	Dynamic	
		Frequency	Time
Quayside / Inshore	✓✓	×	✓
Short Term Offshore Open Location	✓	✓✓	✓
Short Term Offshore alongside a Fixed Installation	✓	✓✓	✓✓
Short Term Offshore Vessel alongside a Floating Offshore Installation	×	✓	✓✓
Long Term Offshore	×	✓✓	✓✓

Key: ✓✓ = Normally Preferred ✓ = Normally acceptable × = Not suitable

9.4.7 A recognised dynamic analysis method should be used, unless:

- it can be demonstrated that quasi-static analysis yields line tension capacity utilisations that are not significantly less than those produced by dynamic analysis, or
- code requirements dictate otherwise.

9.4.8 If dynamic analysis of line tensions is carried out, any increase in the effective drag diameter of mooring lines, risers, umbilicals and power cables due to marine growth shall be taken into account. Guidance on estimating the effect of marine growth can be found in Section 6.7.4 of DNV RP C205, Ref. [4]

9.4.9 Care should be taken when undertaking mooring analyses of systems with fibre ropes due to their nonlinear stiffness characteristics. Fibre rope conditioning and fibre rope storm stiffness should be addressed in the analyses.

9.4.10 Guidance on calculating the design maximum combined low frequency and wave frequency motion of a moored vessel is given in Section 8.10.2 of ISO 19901-7:2005, Ref. [2].

10 DESIGN AND STRENGTH

10.1 GENERAL

10.1.1 This section discusses how the design forces on mooring components may be calculated. It provides guidance on determining the acceptability of these calculated forces, together with guidance on general design considerations.

10.2 REDUNDANCY

10.2.1 The mooring system must have sufficient built in redundancy, such that the failure of any single component will not result in a loss of ability to maintain station or an infringement of safe clearances from other structures.

10.2.2 Failure cases should consider the worst potential failure case which may include shore or vessel connection points.

10.2.3 Mooring systems without single point failure capacity may be found acceptable and approved, provided that both the following are submitted:

a. Emergency response procedures showing that suitable arrangements are in place, e.g. 24-hour manning / monitoring, vessel assistance on standby and other practical arrangements to ensure that any loss of position can be identified and controlled;

b. A risk assessment that has been or can be accepted by GL Noble Denton; this shall include the effect of losing buoys if these are used.

Note: The approach of simply doubling the safety factor requirements to compensate for lack of redundancy is not acceptable for systems, including chain and associated connectors, because mooring failures are not always directly related to a design overload. A case by case review taking into account the age and condition of all the mooring line components should be carried out.

10.3 MOORING PATTERN

10.3.1 The mooring pattern chosen should be balanced, with line pretensions as evenly distributed as is practicable. Patterns should be as close to symmetrical as practicable taking into account the actual surveyed sea-bed infrastructure.

10.3.2 The methods for achieving design pretensions and sensitivity to variations therein will be of particular importance in quayside moorings where the typically short line lengths and highly asymmetric mooring arrangements can lead to very uneven load sharing between the lines.

10.3.3 Mooring line bearing angles should be selected to avoid placing out-of-plane loads on all components including padeyes and pivoting fairleads, which have limited rotation angles.

10.3.4 In deeper water analytical checks must be carried out to confirm that mooring lines do not make contact with the vessel itself or with the anchor racks/bolsters, as the resulting abrasive wear can damage both the mooring line(s) and the vessel.

10.4 MOORING LINE AND CONNECTION STRENGTH

10.4.1 For quayside moorings the implications of tidal variation and how this could potentially result in chafing and abrasion of moorings should be taken into account with respect to line protection and the arrangements for mooring line adjustment, monitoring and maintenance.

10.4.2 The maximum analysed line tensions, when multiplied by a recognised appropriate safety factor shall not exceed the MBLs of the mooring lines and the ultimate strength of the connections and attachments, taking their present condition into account.

10.4.3 Mooring line tension safety factors for various analysis methods and cases are given in Section 10.2 of ISO 19901-7:2005, Ref. [2].

Table 10-1 Line Tension Limits and Design Safety Factors

Analysis Condition	Analysis Method	Line Tension Limit (percent of MBL)	Design Safety Factor
Intact	Quasi-Static	50%	2.00
Intact	Dynamic	60%	1.67
Redundancy Check	Quasi-Static	70%	1.43
Redundancy Check	Dynamic	80%	1.25
Transient	Quasi-Static	95%	1.05

10.4.4 The above safety factors are applicable to wire, chain and fibre rope mooring lines.

10.4.5 Certification of minimum breaking strength of fibre ropes shall be according to Section 12.6.3. Where the minimum breaking strength of fibre ropes does not conform to this certification criteria or where equivalent reliability cannot be established (either on breaking strength or stiffness), the design safety factors in Table 10-1 shall be doubled.

10.4.6 The safety factors specified in design codes are intended for mooring hardware that is regularly inspected and maintained. The breaking loads used with these factors should account for any reduction in the diameter of the mooring lines due to mechanisms including wear and corrosion.

10.4.7 If inspection or maintenance is not proposed an additional agreed allowance shall be made for wear and corrosion. This also applies to quayside moorings if replacement lines are not readily available in case of chafing or abrasion damage.

10.5 ANCHOR CAPACITY

10.5.1 It shall be demonstrated that the design environment does not lead to anchor forces in excess of the holding capacity of the anchors, including a recognised safety factor.

10.5.2 The following safety factors, consistent with ISO 19901-7, Ref. [2], should be considered applicable in the absence of other code specific requirements:

Table 10-2 Drag Anchor Holding Capacity Design Safety Factors

Condition	Quasi-Static	Dynamic Analysis
Permanent Mooring		
Intact Condition	n/a	1.50
Redundancy Check	n/a	1.00
Mobile Mooring		
Intact Condition	1.00	0.80
Redundancy Check	Not required	Not required

Table 10-3 Design Safety Factors for Holding Capacity of Anchor Piles and Suction Piles

	Permanent Moorings		Mobile Moorings	
Analysis Condition	Axial Loading	Lateral Loading	Axial Loading	Lateral Loading
Intact Condition	2.00	1.60	1.50	1.20
Redundancy Check	1.50	1.20	1.20	1.00

Table 10-4 Design Safety Factors for Holding Capacity of Gravity and Plate Anchors

Analysis Condition	Gravity Anchors				Plate Anchors	
	Permanent Moorings		Mobile Moorings		Permanent Moorings	Mobile Moorings
	Axial	Lateral	Axial	Lateral		
Intact Condition	2.00	1.60	1.50	1.20	2.00	1.50
Redundancy Check	1.50	1.20	1.20	1.00	1.50	1.20

10.5.3 Anchor forces may be reduced by friction between the grounded portion of the mooring line and the seabed. Guidance on mooring line seabed friction is given in Annex A.10.4.5 of ISO 19901-7:2005, Ref. [2]

10.5.4 Anchor holding capacity for mobile moorings may be determined by referring to manufacturer's datasheets for the size and type of anchor under consideration taking into account the seabed soil type determined by location survey findings.

10.5.5 Where seabed conditions are unknown, or of a type not characterised by typical manufacturer data, anchor capacity should be demonstrated by proof loading; normally, to the maximum intact tension determined in the mooring analysis.

10.5.6 For permanent moorings and those utilising VLAs (Vertical Load Anchors), e.g. DENLA / StevManta or pile anchors, detailed soil data and a full geotechnical assessment will generally be required.

10.5.7 It is generally accepted that modern drag embedment anchors (e.g. Stevpris Mk V and Bruce FFTS) are capable of resisting significant uplift forces. It is considered acceptable that this vertical load capacity is utilised, provided that the calculation is based on recognised guidelines, e.g. Appendix D of API RP 2SK 3rd Edition (2005), Ref. [3].

10.5.8 If traditional drag embedment anchors (not specifically designed to resist vertical uplift forces) are used, it must be shown that sufficient mooring line is deployed to prevent uplift in the intact case. In the single line failure case it is generally acceptable to have some uplift, provided that the vertical force at the anchor is much less than the submerged weight of the anchor.

11 CLEARANCES

11.1 GENERAL

11.1.1 The clearances stated below are given as guidelines to good practice. The specific requirements and clearances should be defined for each project and operation, taking into account particular circumstances such as:

- water depth
- proximity of subsea assets
- survey accuracy
- the station keeping ability of the anchor handling vessel
- seabed conditions and slope
- estimated anchor drag during embedment
- single mooring line failure
- the probable weather conditions during anchor installation

11.1.2 Field operators and subsea asset owners may have their own requirements which differ from those stated below, and should govern if more conservative. Agreement should be obtained from such operators and/or owners in advance if the moorings will be close to their assets.

11.1.3 If any of the clearances specified below are impractical because of the proposed mooring configuration or seabed layout a risk assessment shall be carried out to determine the necessary precautions. The results of the risk assessment shall be agreed with the relevant GL Noble Denton office.

11.1.4 Moorings should be designed and laid in such a way that there is positive clearance with any subsea asset during installation.

11.1.5 The following Table 11-1 summarises the minimum clearances described in the Sections below. The minimum clearances are based on the worst intact configuration accounting for external loads.

Table 11-1 Summary of Minimum Mooring Clearances

Condition	Minimum Clearance	0032/ND Reference Section
Allowance for anchor placing inaccuracy	50 m (typical)	11.2.1
Anchor horizontal distance from a subsea asset	100 m	11.2.2
Horizontal distance to pipeline or asset in line of anchor drag	300 m	11.2.2
Line horizontal to subsea wellhead, manifold or other asset	100 m	11.3.1
Line/Vessel horizontal to platform*	10 m	11.3.2
Line above pipeline ≥40m WD	10 m	11.4.1
Line above pipeline <40m WD	25% WD, but not less than 5 m	11.4.1
Line to line	20 m (30 m - if repositioning by winching)	11.5.1

* This is only for platforms which project above Water Level (WL)

11.2 HORIZONTAL ANCHOR CLEARANCES

11.2.1 Adequate clearance shall be maintained between anchors and any associated laydown pennants (where applicable) and seabed infrastructure. Allowance must be made for inaccuracies and unpredictability in the laying and embedment of drag anchors (typically 50m in the most critical direction).

11.2.2 Anchors should not be placed within 100m of a subsea asset. Additionally where the drag path of the anchor is towards the asset, drag embedment anchors should be located more than 300m radially from the point where the anchor line crosses the pipeline, cable or subsea structure as shown in the following Figure 11.1. These distances must be maintained throughout the mooring life.

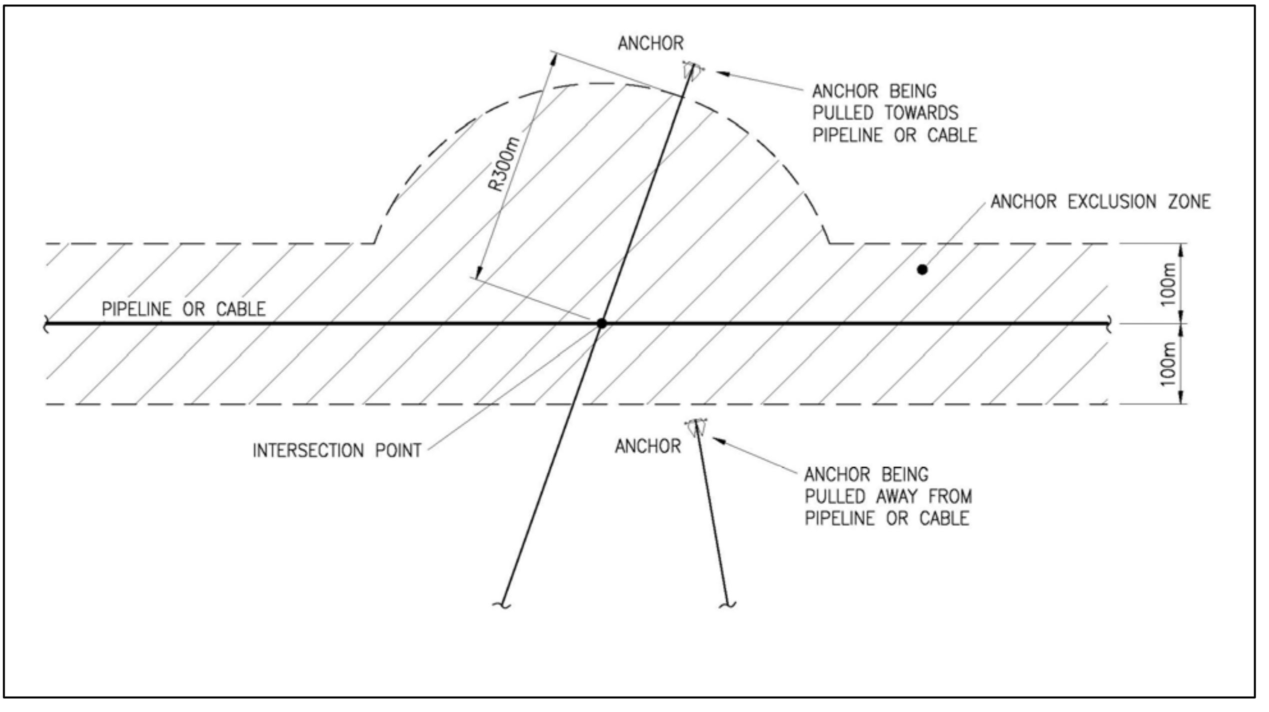

Figure 11.1 Minimum Horizontal Anchor Clearances from Pipelines or Cables

11.3 HORIZONTAL WIRE OR CHAIN CLEARANCES

11.3.1 Moorings shall never be run over subsea assets, other than pipelines or cables, or within 100m horizontally from them.

11.3.2 In the absence of code specific requirements minimum horizontal clearances of 10m should be maintained both above and below the water line between the line and any structure that projects above the water level (structures that are fully submerged are classed as subsea assets).

11.4 LINE VERTICAL CLEARANCES

11.4.1 In the absence of code specific requirements minimum vertical clearances of 10m over pipelines should be maintained at any tension in the intact condition. In shallow water depths of less than 40m the minimum clearance should not be less than 25% of the water depth, but not be less than 5.0m. Any reduction in clearance to less than that specified shall be based on a documented risk assessment (GL Noble Denton present) and provision for constant monitoring of the clearances during the operation of the unit.

11.4.2 A reduced vertical clearance may be justified for fibre rope due to the greatly reduced weight of the material provided that the fibre rope connections are maintained clear of the thrash zone and the pipeline / umbilical / subsea infrastructure.

11.4.3 Temporary lay-down of an anchor wire or fibre rope (but not chain) over a pipeline, umbilical, spool or cable may be acceptable subject to all of the following being submitted to review:

- Evidence that there is no other practicable anchor pattern that would avoid the lay-down.
- The status of a pipeline or spool (e.g. trenched, live, rock-dumped, on surface) and its contents (e.g. oil, gas, water) and internal pressure.
- Procedures clearly stating the maximum duration that the anchor wire/fibre rope is in contact with the pipeline, umbilical, spool or cable and the reason for the contact.
- Written evidence that the pipeline owner accepts laying down of the anchor wire over their pipeline, umbilical spool or cable and has contingency measures in place in case of damage and a possible hydrocarbon leak.
- Evidence that the anchor wire will be completely slack i.e. no variation in tension.
- Evidence that the seastate during the lay-down will be restricted to an acceptable value.
- Documentation demonstrating that the anchor wire or its weight will not overstress or damage the coating on the pipeline, umbilical, spool or cable.

11.5 LINE-LINE CLEARANCES

11.5.1 Crossed mooring lines are generally not acceptable except:

a. Where crossing points are visible and contact avoided / wear mitigated with suitable protection;

b. Where a minimum line-line clearance requirement of 20 m (or 30 m if repositioning by winching), can be demonstrated for the combinations of tensions and vessel motions that are most critical from the clearance perspective. This would normally apply to independently moored vessels.

11.6 INSTALLING ANCHORS

11.6.1 Whenever an anchor is run out over a pipeline, flowline or umbilical, the anchor shall be securely stowed on the deck of the anchor handling vessel. In circumstances where either gravity anchors or closed stern tugs (tugs without stern rollers) are used, and anchors cannot be stowed on deck, the anchors shall be double secured through the additional use of a safety strap or similar.

11.6.2 At no time shall an anchor wire come in contact with a pipeline, cable or subsea structure while running out or retrieving an anchor.

12 MOORING EQUIPMENT

12.1 MOORING INTEGRITY

12.1.1 Whilst the selection of a mooring system to meet code requirements is imperative to ensure the overall safety of a moored structure, it should be borne in mind that inappropriate selection of materials (connections and jewellery, etc) and inadequate inspection and maintenance programmes are likely to be the primary factors in most failures.

12.1.2 Care shall be taken such that all mooring hardware is used in strict accordance with the manufacturer's recommendations and best industry practice.

12.1.3 Experience is required to assess the suitability of a proposed mooring system for a long term application. Reference should be made to the principal findings from Noble Denton's Phase 1 and Phase 2 Mooring Integrity Joint Industry Projects (JIPs). See Refs [12] and [13].

12.2 CERTIFICATION

12.2.1 All components of a mooring system should be certified and their certificates available for inspection by an attending surveyor.

12.3 ANCHORS

12.3.1 Anchors should be of a type approved by a recognised classification society and suitable for the seabed composition at the location. In particular, at locations where the seabed is hard, anchors capable of taking the full load through the fluke tips alone should be used.

12.3.2 Where applicable, anchors should be correctly configured for the seabed composition at the location, e.g. fluke angle should be set as per manufacturer's recommendations.

12.4 CHAIN

12.4.1 Mooring chain shall be manufactured in accordance with an appropriate standard for offshore mooring chain (such as an IACS classification society) and certified by an IACS member or other recognised certification body accepted by GL Noble Denton.

12.5 WIRE ROPE

12.5.1 Wire rope mooring components for offshore mooring shall comply with the requirements of Section 11.1.2 of ISO 19901-7, Ref. [2] (Stationkeeping Systems) and be certified by an IACS member or other recognised certification body accepted by GL Noble Denton.

12.6 FIBRE ROPE

12.6.1 In general, contact between fibre rope and the seabed should be avoided in normal operating conditions.

12.6.2 Given the nonlinear stiffness characteristics of fibre ropes, it is essential that appropriate data is obtained on the stiffness characteristics under load.

12.6.3 Minimum breaking strength of fibre ropes shall be certified in accordance with a standard industry practice (such as API RP 2SM) by bodies approved by an IACS member or other recognised certification body accepted by GL Noble Denton.

12.7 CONNECTORS

12.7.1 Mooring chains should be composed of continuous lengths of chain where practicable.

12.7.2 Where it is necessary to use in-line connectors, the mooring pattern should be designed, so as to ensure that no connecting hardware is subjected to thrashing against the seabed. If this is not possible this should be risk assessed on a case by case basis and suitable contingency measures put in place in case of failure at this location.

12.7.3 Only classification society approved Long Term Mooring (LTM) connectors should be used where a double locking mechanism has been employed to restrain the main load bearing pins of the connector.

12.8 BUOYS (SURFACE AND SUBSURFACE)

12.8.1 Spring buoys should be designed in accordance with the requirements of a recognised design code. Guidance on spring buoy design is given in Section 11.1.5 of ISO 19901-7, Ref. [2], (Stationkeeping Systems).

12.8.2 It should be ensured that any subsurface buoy is supplied with a suitable submersion rating for the intended application.

12.8.3 For long term applications, the dynamic response of the buoy and the resulting fatigue implications for all connections should be addressed. Experience has shown that such analyses are complex and time consuming and do not necessarily predict possible failure modes which may be experienced in the field.

12.8.4 Where buoys are used to provide clearances, means to detect their loss should be provided e.g. tension monitoring (this should reveal a loss), transponders, etc. The operating procedures should document the loss monitoring procedure and the remedial actions required. Suitable spares should also be readily available and stored in a convenient location.

12.9 VESSEL CONNECTION POINTS

12.9.1 Where vessel connections are to fairleads / winches / windlasses that make up part of a classed mooring system for a vessel, e.g. under POSMOOR notation, it is acceptable to assume that these have adequate strength (as the capacities of these are specified under the class rules in relation to the MBL of the vessel's mooring lines).

12.9.2 Vessel connections points (including windlasses, winches, fairleads, Smit brackets, bollards, bitts etc) should generally be designed for a load equal to 1.1 times the MBL of the connected mooring line. The foundation structure must also be demonstrated to be suitable for the same design loads.

12.9.3 Where design calculations and/or certificates are unavailable, it may be acceptable to demonstrate adequate connection capacity through proof loading. OCIMF, Ref. [11], gives some guidance on suitable levels of proof loading for common vessel connections (e.g. double bitts, panama chocks etc). Proof loading is potentially hazardous and a detailed, risk assessed procedure, will be required before commencing such proof loading operations.

12.9.4 Notwithstanding any class requirements, winches/windlasses should have a stall capacity sufficiently in excess (typically 20%) of the maximum line tensions in the limiting operating environment to allow the vessel to safely move to the standby/survival condition (as applicable).

12.10 FENDERING

12.10.1 When a vessel is to be moored against another structure such as a quayside, adequate fendering shall be provided to prevent damage to the vessel and structure.

12.10.2 In cases where fendering must restrain the vessel (e.g. when the vessel is blown on to the quay), fenders shall be considered to be structural elements of the mooring system and shall be subject to the same redundancy requirements as mooring lines.

12.10.3 It must be demonstrated that the maximum analysed load upon any fender when multiplied by the appropriate safety factor (see Table 10-1) does not exceed the static reaction force rating of the fender.

12.10.4 The pressure exerted by a fender on the hull of the vessel and the quay shall be calculated, and it shall be demonstrated that this pressure is not in excess of that which the vessel's structure and the quay are designed to resist.

12.10.5 The rated energy absorption capacity of the fendering shall be at least twice the energy associated with the vessel's peak velocity due to the environment or wake induced motion from passing traffic.

12.10.6 Structural elements of fendering (e.g. pressure membranes) shall be protected (e.g. with sacrificial elements such as tyres) such that they are not damaged through contact with the vessel or quayside.

12.10.7 Moveable fenders shall be restrained to prevent excessive movement. Restraints shall be designed to resist a load equal to the maximum analysed load on the fender multiplied by the maximum coefficient of friction between the fender and vessel.

12.10.8 Particular care should be taken where it is intended to employ a spacer barge as a fender. These arrangements have historically proven to have high failure potential and should, therefore, always be the subject of careful design and independent scrutiny.

12.10.9 Fenders should be arranged to avoid the possibility of a vessel “hang up” against the quayside. The fender arrangement should be subject to a local site inspection. This is particularly relevant for loadout operations where “hung up” barges may suddenly come free as the load of a module is being transferred from the quayside to a barge.

13 PROCEDURAL CONSIDERATIONS

13.1 GENERAL

13.1.1 The planning and preparation for mooring a vessel should be carried out sufficiently in advance of the operation such that the analyses described in this document can be carried out.

13.1.2 Non-standard mooring operations such as quayside moorings of MODUs shall be risk assessed to confirm that all factors relating to the security of the vessel have been taken into account and that the level of risk is controlled. The risk assessment shall be submitted for approval by GL Noble Denton. The risk assessment should also take into account political or crime related security risks associated with the location.

13.1.3 Prior to designing a mooring spread a mooring analysis needs to be carried out and the factors detailed in Sections 7, 8 and 9 are to be taken into account.

13.2 ANCHOR PROOF LOADING

13.2.1 After installation, anchors should be proof load tested to ensure adequate embedment. Proof loads should be maintained for at least 15 minutes.

13.2.2 For mobile moorings in open locations, proof loads will generally be to the maximum expected operating tension at a location.

13.2.3 For mobile moorings in proximity to other installations, proof load is expected to be the maximum intact tension identified in a mooring analysis.

13.2.4 Mooring test loading for permanent moorings shall be in accordance with Section 10.4.6.2 of ISO 19901-7, Ref [2].

13.3 MANNING

13.3.1 The level of manning shall be sufficient in terms of numbers, skill competency and experience to operate all the relevant machinery and to manage the mooring system and emergency systems, on a twenty-four hour basis, without the need for any personnel to work excessively long hours. The numbers shall be sufficient to take appropriate action in the case of any emergency to ensure the safety and security of the crew, the vessel and the location infrastructure (including port facilities, moored vessels and environmental considerations).

13.3.2 Where appropriate shore-side assistance should be available on a 24-hour basis with direct lines of communication to the moored vessel.

13.4 INSPECTION, MONITORING AND MAINTENANCE

13.4.1 Where practicable, an inspection, monitoring and maintenance programme should be in place to ensure that all mooring components are in a serviceable condition and that their certified MBLs remain valid. Discard criteria shall be documented and applied in line with recognised industry standards

14 DOCUMENTATION

14.1 LEADING TO APPROVAL

14.1.1 For GL Noble Denton to issue approval, the following documentation must be provided.

14.2 OFFICE REVIEW

14.2.1 Mooring analysis report detailing:

a. Location and Vessel Data (see Sections 6 and 7);

b. Environmental Loads and Motions (see Section 8);

c. Mooring Analysis Results (see Sections 9, 10, 11 and 12).

14.2.2 Mooring plan detailing vessel location and mooring arrangement.

14.2.3 Supporting procedures and risk assessments (particularly where the mooring is weather restricted or is not fully redundant).

14.3 ON SITE

14.3.1 Certification for all mooring components including vessel and shore connection points. These certificates shall be issued or endorsed by bodies approved by an IACS member or other recognised certification bodies accepted by GL Noble Denton. If the certification is old, on site inspection by a competent person should have been carried out to check the present condition of connection points, etc.

14.3.2 Details of manning and emergency response plan.

15 SPECIAL CONSIDERATIONS FOR INSHORE AND QUAYSIDE MOORINGS

15.1 BACKGROUND

15.1.1 The engineering, design, verification and execution of inshore and especially quayside moorings is very frequently underestimated leading to a gap between the strict requirements for approval and what the client / contractor may wish to provide. The default standards used often fall below the requirements of a 10 year return period design to recognised codes.

15.2 LOCATIONS WITHIN HARBOUR LIMITS

15.2.1 The intended location of the unit within the port area should be established with the Port Authority. In some cases the Port Authority will have determined this well in advance and it will not be subject to change. In some Ports, where commercial shipping forms the core of their business, the berth selected by the Port may be subject to change. In all cases discussions should be held with the Port Authority to determine the berth likely to be selected and its characteristics and those of any likely alternatives.

15.2.2 If the Port Authority is reluctant to commit to a particular berth the importance of the details of the berth in the project planning and design should be emphasised in discussions with the Port Authority. In order to avoid delays it may be necessary to undertake analyses for not only the most probable berth but also a number of contingencies.

15.2.3 The potential for surge due to passing traffic, particularly if moored in a river or canal, should be assessed. The unit may experience surge up and down the berth and may be drawn off it.

15.2.4 The Port Authority should be requested to issue a Notice to Mariners requesting passing marine traffic to reduce their speed to limit any effect of surge on the moorings.

15.3 CONTINGENCY ARRANGEMENTS

15.3.1 Details of tug capacity and shore-based manpower, their availability, call out times, phone numbers and port emergency procedures should all be provided for review and taken into account in the risk assessment (see Sections 13.1.2 and 13.3).

15.4 MOORING CONSIDERATIONS

15.4.1 Even very small magnitude motions induced by waves or long period swell, can result in very large tensions on the short, stiff mooring lines commonly utilised in quayside moorings. This effect should be evaluated closely (see Section 8.5.4).

15.4.2 Motions will also increase the likelihood of abrasion damage particularly in fibre ropes. Chafe chain, stretchers and adequate protection should be employed to minimise chafe points. Chafe points should be regularly inspected and if significant damage is found the damaged components should be replaced as a matter of priority. Thus, adequate contingency spares are required at the site of the mooring.

15.4.3 Wind loads shall take account of all construction phases and can be increased due to scaffolding, wind and weather protection, etc.

15.4.4 It is often impossible to properly tension and adjust moorings at quayside. It is therefore necessary to take account of large variations in working tension in the mooring analysis. A suitable method for achieving and verifying the design pretension should be considered during mooring design. In practice a smaller number of high capacity, lines with similar lengths and pretensions is better than multiple small ones in an asymmetric arrangement.

15.4.5 In some cases a mooring is simply not feasible without some means of adjustment and this can be somewhat difficult and expensive to provide if it is not available on the vessel. It, however, represents a wise investment given the likely value of the moored object.

15.4.6 Quayside moorings will often necessitate the use of multiple connections, strops etc to make up the mooring lines. These need to be reviewed carefully to ensure that there are no unforeseen failure modes. All connections shall be properly matched and all soft rope to hard tackle connections shall have properly fitted hard eyes.

15.4.7 Adequate fendering is hard to achieve on larger vessels, semi-submersibles, etc. because the loads involved can be large. Spacer barges, in particular, have a poor record in operation and proposals to use spacer barges should always be carefully engineered. If possible, some means of holding the vessel off the quay as well as the fenders should be provided. Laying offshore anchors on a semi-submersible moored at the quayside can provide an additional contingency.

15.4.8 Inshore and especially quayside moorings will typically require a careful local study of environmental design extremes. Usually it is not feasible to design the mooring to resist the omni-directional extremes so some form of directional metocean study is required. It is rare to have available a full set of data on current and tides, and it may be necessary to take some local measurements to determine the actual current at the quayside.

15.4.9 Quayside moorings typically have short natural periods. Therefore the wind and wave excitation frequencies need to be carefully established.

15.5 SHORE MOORING POINTS / BOLLARDS / WINCHES

15.5.1 The capacity of shore mooring points and winches, including their foundations, should be demonstrated by certification or by design. Where these are unavailable, proof loading may be undertaken to demonstrate capacity. Proof loads should be a minimum of 1.25 times the maximum intact tension for that line calculated in the mooring analysis. Proof loading operations can be potentially very hazardous and should be carefully planned taking into account the possibility of catastrophic failure of connection points. A suitable, risk assessed, proof testing procedure should be available.

15.6 PROCEDURES

15.6.1 Procedures should detail and quantify, where applicable,

- mooring tension monitoring, inspection, line adjustment and
- emergency response arrangements, including spare equipment and availability of tugs and shore-based manpower as described in Section 15.3.
- mooring line tending arrangements to account for predicted variations in tidal height
- safe access to vessels accounting for potentially significant tidal variations.

15.7 COLD STACKING

15.7.1 Approval for cold stacking can only be given when it can be demonstrated that all of the factors mentioned in this document have been taken into account and it can be demonstrated by a risk assessment accepted by GL Noble Denton that cold stacking presents no substantially increased risk to the unit. It is clear, however, that moorings on cold stacked units still require regular inspection and it should be documented that steps have been put in place for this to be carried out.

15.8 ICE LOADING

15.8.1 For locations where loading from drifting ice is expected on a moored structure the impact on mooring line tensions shall be assessed.

15.8.2 Mooring lines employed in locations where sea ice is expected shall be qualified by the manufacturers for the range of temperatures expected in the region. The mooring lines shall be resistant to abrasion.

16 SPECIAL CONSIDERATIONS FOR PERMANENT MOORINGS

16.1 GENERAL

16.1.1 Requirements for permanent moorings are fairly comprehensively covered in the industry standard codes referred to previously.

16.1.2 Additional considerations over mobile moorings are likely to include the following with further information available in the Mooring Integrity JIP OTC papers, Ref. [12] and [13]:

- Fatigue (axial, bending and torsion)
- Marine growth and how to r remove it for inspection to take place
- Wear and corrosion including , microbial induced corrosion (MIC)
- Mooring line failure detection and instrumentation
- Spring buoy failure detection.

REFERENCES

[1] ISO IS 19901-1: Petroleum and Natural Gas Industries — Specific Requirements for Offshore Structures — Part 1: Met ocean Design and Operating Conditions.

[2] ISO IS 19901-7: Petroleum and Natural Gas Industries — Specific Requirements for Offshore Structures — Part 7: Stationkeeping Systems for Floating Offshore Structures and Mobile Offshore Units.

[3] API RP 2SK 3rd Edition (2005): Design and Analysis of Station keeping Systems for Floating Structures.

[4] DNV RP C205 (2007): Environmental Conditions and Environmental Loads. Det Norske Veritas,

[5] DNV OS E301 (2008): Position Mooring. Det Norske Veritas

[6] DNV Rules for Classification of Mobile Offshore Units, Part 6, Chapter 2 (1996): Position Mooring (POSMOOR).

[7] BS 6349-6 (1989): Maritime Structures — Design of Inshore Moorings and Floating Structures.

[8] GL Noble Denton 0013/ND “Guidelines for Loadouts”

[9] GL Noble Denton 0016/ND “Seabed and Sub-seabed Data Required for Approvals of Mobile Offshore Units (MOU)”

[10] IMCA M 179 (2005): Guidance on the Use of Cable Laid Slings and Grommets.

[11] OCIMF Mooring Equipment Guidelines, Second Edition 1997

[12] “Floating Production Mooring Integrity JIP – Key Findings” Martin G. Brown, Tony D. Hall, Douglas G. Marr, Max English and Richard O. Snell, OTC 17499, 2005

[13] “Phase 2 Mooring Integrity JIP – Summary of Findings” Martin G. Brown, Andrew P. Comley, Morten Eriksen, Ian Williams, Philip Smedley, Subir Bhattacharjee, OTC 20613, 2010

All GL Noble Denton Guidelines can be downloaded from **www.gl-nobledenton.com**