This document has been replaced by the standard
DNVGL-ST-N001
which may be accessed through https://my.dnvgl.com/
This document may still be valid for some existing projects.

This Guideline was updated as part of the first stage of the harmonisation between the
GL Noble Denton and DNV heritage marine services requirements.
Refer also to DNVGL-SE-0080 Noble Denton marine services – Marine Warranty Survey
for further details.
All references to GL Noble Denton apply to the legal entity trading under the DNV GL or GL Noble Denton
name which is contracted to carry out the scope of work and issues a Certificate of Approval, or provides a
marine related advisory or assurance service.

Once downloaded this document becomes UNCONTROLLED.
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PREFACE

This document has been drawn with care to address what are considered to be the primary issues in relation to the contents based on the experience of the GL Noble Denton Group of Companies (“the Group”). This should not, however, be taken to mean that this document deals comprehensively with all of the issues which will need to be addressed or even, where a particular matter is addressed, that this document sets out a definitive view for all situations. In using this document, it should be treated as giving guidelines for sound and prudent practice, but guidelines must be reviewed in each particular case by the responsible organisation 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 guidance given is sound and comprehensive.

Reasonable precaution has been taken in the preparation of this document to seek to ensure that the content is correct and error free. However, no company in the Group

- shall be liable for any loss or damage incurred resulting from the use of the information contained herein or
- shall voluntarily assume a responsibility in tort to any party or
- shall owe a duty of care to any party other than to its contracting customer entity (subject always to the terms of contract between such Group company and subcontracting customer entity).

This document must be read in its entirety and is subject to any assumptions and qualifications expressed therein as well as in any other relevant communications by the Group in connection with it. Elements of this document contain detailed technical data which is intended for analysis only by persons possessing requisite expertise in its subject matter.

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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 load-outs 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.

1.2.2 This Revision 2 supersedes Revision 1 dated 22 June 2013. The main changes are shown in Section 2.9
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 load-outs 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 https://www.dnvgl.com/rules-standards/noble-denton-maa-rules-and-guidelines.html.

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 Revision 1 superseded Revision 0 dated 6 Dec 2010. Main changes were:
   - Additional definitions in Section 3
   - Updates to the Approval Process in Section 4
   - Minor changes in the information required for design spectra in Section 6.5.1, for moored vessels in Sections 6.6.2 and 6.6.3 and for moorings in Section 6.7.1
   - Updates to moorings for Weather-Restricted Operations in Section 7.3
   - Changes in wave frequency motions in Section 8.5.1
   - New warning about vortex shedding in deep water in Section 8.7
   - Minor changes in analysis techniques in Section 9.4.3 and Table 9-2
   - Changes to redundancy requirements in Section 10.2.4
   - Section 12.9.3 deleted (proof loading is not in the latest OCIMF guidelines)
   - New Section 12.9.4 to include shore based winches for load-out
   - Changes to shore mooring points and bollard strength in Section 14.6.1 to 14.6.4.
   - Sections 10.4.8, 12.6.4 and 14.6.5 to 14.6.6 have been moved from “Guidelines for Load-outs”, 0013/ND and mitigation measures added to Section 10.4.8.
   - Additional requirements for inshore moorings in Sections 14.6 and 14.7.
   - Appendix A added with information required for approval
2.9 This Revision 2 supersedes Revision 1 dated 22 June 2013. Main changes (denoted by a line in the right hand margin) are:
- POSMOOR '96 acceptable only if having POSMOOR notation in Section 5.2.4
- Additional references in Section 5.3.4 and 5.3.5
- Changes in wave specification in Sections 7.7.1 and 7.7.2
- Deletion of Section 8.6.3 about semi-submersible motions.
- Clarification of winching policy in Section 9.3.2
- Line touchdown horizontal clearance to pipeline/cable in Sections 11.1.5 and 11.3.2
- Guidance when the as laid mooring deviates from the analysis in Section 11.2.3
- Survey requirements for composite moorings, or mooring line fitted with buoy in Section 11.6.3
- Clarification on safety factors for damaged cases when mooring loads are held on winches in Section 14.6.5.

2.10 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.

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

2.12 Electronic versions of GL Noble Denton Guidelines are available on:
Care should be taken when referring to any GL Noble Denton Guideline document that the latest revision is being consulted.

2.13 Please contact the Technical Standards Committee Secretary at TSC@dnvgl.com with any queries or feedback.
# DEFINITIONS

Referenced definitions are underlined.

<table>
<thead>
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<th>Term or Acronym</th>
<th>Definition</th>
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</thead>
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<tr>
<td>Alpha Factor</td>
<td>The maximum ratio of operational criteria / design environmental condition to allow for weather forecasting inaccuracies. See Section 7.4.8 of 0001/ND, Ref. [1]</td>
</tr>
<tr>
<td>Approval</td>
<td>The act, by the designated GL Noble Denton representative, of issuing a 'Certificate of Approval'.</td>
</tr>
<tr>
<td>ATA</td>
<td>Automatic Thruster Assist</td>
</tr>
<tr>
<td>Barge</td>
<td>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).</td>
</tr>
<tr>
<td>Certificate of Approval</td>
<td>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.</td>
</tr>
<tr>
<td>Client</td>
<td>The company to which GL Noble Denton is contracted to perform marine warranty or consultancy activities.</td>
</tr>
<tr>
<td>Cold Stacking</td>
<td>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.</td>
</tr>
<tr>
<td>Competent person</td>
<td>Someone who has sufficient training and experience or knowledge and other qualities that allow them to assist you properly. The level of competence required will depend on the complexity of the situation and the particular help required.</td>
</tr>
<tr>
<td>DNV</td>
<td>Det Norske Veritas</td>
</tr>
<tr>
<td>DP</td>
<td>Dynamic Positioning</td>
</tr>
<tr>
<td>FLS</td>
<td>Fatigue Limit State</td>
</tr>
<tr>
<td>FOI</td>
<td>Floating Offshore Installation</td>
</tr>
<tr>
<td>FOS</td>
<td>Factor of Safety</td>
</tr>
<tr>
<td>GL Noble Denton</td>
<td>The legal entity trading under the DNV GL or GL Noble Denton name which is contracted to carry out the scope of work and issues a Certificate of Approval, or provides a marine related advisory or assurance service.</td>
</tr>
<tr>
<td>HAZID</td>
<td>Hazard Identification</td>
</tr>
<tr>
<td>Hot Stacking</td>
<td>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.</td>
</tr>
<tr>
<td>IACS</td>
<td>International Association of Classification Societies.</td>
</tr>
<tr>
<td>Inshore Mooring</td>
<td>A mooring operation in relatively sheltered coastal waters, but not at a quayside.</td>
</tr>
<tr>
<td>Insurance Warranty</td>
<td>A clause in the insurance policy for a particular venture, requiring the approval of a marine operation by a specified independent survey house.</td>
</tr>
<tr>
<td>Load-out</td>
<td>The transfer of a major assembly or a module onto a barge, e.g. by horizontal movement or by lifting.</td>
</tr>
<tr>
<td>Term or Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------</td>
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</tr>
<tr>
<td>LS2 (ULS)</td>
<td>A design condition where the loading is dominated by low probability environmental / storm loads. e.g. at the 10- or 50-year return period level or, for weather-restricted operations, where an Alpha factor according to Section 7.3.8 of 0001/ND, Ref. [1], is to be applied.</td>
</tr>
<tr>
<td>MBL</td>
<td>The minimum allowable value of breaking load for a particular sling, grommet, wire or chain etc.</td>
</tr>
<tr>
<td>Mobile Mooring</td>
<td>Mooring system, generally retrievable, intended for deployment at a specific location for a short-term duration, such as those for mobile offshore units.</td>
</tr>
<tr>
<td>MODU</td>
<td>Mobile Offshore Drilling Unit</td>
</tr>
<tr>
<td>Moored Vessel</td>
<td>Within the scope of this document refers to any structure which is being moored.</td>
</tr>
<tr>
<td>Mooring System</td>
<td>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.</td>
</tr>
<tr>
<td>MOU</td>
<td>Mobile Offshore Unit</td>
</tr>
<tr>
<td>n/a</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>NMD</td>
<td>Norwegian Maritime Directorate.</td>
</tr>
<tr>
<td>OCIMF</td>
<td>Oil Companies International Marine Forum.</td>
</tr>
<tr>
<td>Operation Duration</td>
<td>The planned duration of the operation from the forecast prior to the Point of No Return to a condition when the operations /structures can safely withstand a seasonal design storm (also termed “safe to safe” duration); this excludes the contingency period.</td>
</tr>
<tr>
<td>Operational Reference Period</td>
<td>The Operation Duration, plus the contingency period</td>
</tr>
<tr>
<td>Permanent Mooring</td>
<td>Mooring system normally used to moor floating structures deployed for long-term operations, such as those for a floating production system.</td>
</tr>
<tr>
<td>PNR / Point of No Return</td>
<td>The last point in time, or a geographical point along a route, at which an operation could be aborted and returned to a safe condition.</td>
</tr>
<tr>
<td>PSA</td>
<td>Petroleum Safety Authority Norway</td>
</tr>
<tr>
<td>QTF / Quadratic Transfer Function</td>
<td>Refers to the matrix that defines second order mean wave loads on a moored vessel in bi-chromatic waves. When combined with a wave spectrum the mean wave drift loads and low frequency loads can be calculated.</td>
</tr>
<tr>
<td>Quayside Mooring</td>
<td>A mooring that locates a moored vessel alongside a quay (usually at a sheltered location).</td>
</tr>
<tr>
<td>RAO / Response Amplitude Operator</td>
<td>Defines the moored vessel’s (first order) response in regular waves and allows calculation of moored vessel wave frequency (first order) motion in a given sea state using spectral analysis techniques.</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>Check of the failure load case associated with the applicable extreme (survival) environment, e.g. the one leg damaged case.</td>
</tr>
<tr>
<td>Semi-Submersible Unit</td>
<td>A floating structure normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns, connected to submerged pontoons.</td>
</tr>
<tr>
<td>Term or Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SLS / Serviceability Limit State</td>
<td>A design condition where the structure is required to fulfil its primary operational function.</td>
</tr>
<tr>
<td>Survey</td>
<td>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.</td>
</tr>
<tr>
<td>Surveyor</td>
<td>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.</td>
</tr>
<tr>
<td>SWL / Safe Working Load</td>
<td>SWL is a derated value of WLL, following an assessment by a competent person of the maximum static load the item can sustain under the conditions in which the item is being used.</td>
</tr>
<tr>
<td>TA</td>
<td>Thruster Assist</td>
</tr>
<tr>
<td>UKCS</td>
<td>United Kingdom Continental Shelf</td>
</tr>
<tr>
<td>ULS / Ultimate Limit State</td>
<td>See LS2 (ULS)</td>
</tr>
<tr>
<td>VLA</td>
<td>Vertical Load Anchors.</td>
</tr>
<tr>
<td>Weather-restricted operation</td>
<td>A marine operation which can be completed within the limits of an operational reference period with a weather forecast not exceeding the operational criteria. The operational reference period (which includes contingencies) is generally less than 72 hours. The design environmental condition need not reflect the statistical extremes for the area and season. An alpha factor shall be accounted for in defining the design environmental condition. See Section 7.4.8 of 0001/ND, Ref. [1].</td>
</tr>
<tr>
<td>Weather-unrestricted operation</td>
<td>An operation with an operational reference period greater than the reliable limits of a weather forecast. The operational reference period (which includes contingencies) is generally more than 72 hours. The design weather conditions must reflect the statistical extremes for the area and season. The design weather is defined in Section 7.3 of 0001/ND, Ref. [1].</td>
</tr>
<tr>
<td>WLL / Working Load Limit</td>
<td>The maximum force which a product is authorized to sustain in general service when the rigging and connection arrangements are in accordance with the design. See SWL.</td>
</tr>
</tbody>
</table>
4 THE APPROVAL PROCESS

4.1 GENERAL

4.1.1 Further information on the approval process appears in DNVGL-SE-0080 - Noble Denton marine services – Marine Warranty Survey, Ref [10].

4.2 SCOPE OF WORK LEADING TO A MOORING 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 moored 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, Ref. [12].

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. [12], 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 later versions of, 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.

5.2.3 DNV OS E301, Position Mooring (POSMOOR E301), Ref. [5], is considered by GL Noble Denton to be an acceptable alternative to ISO 19901-7 when used in conjunction with DNV RP C205, Ref. [8].

5.2.4 DNV Rules for the Classification of Mobile Offshore Units, Part 6, Chapter 2: Position Mooring (POSMOOR ‘96), Ref. [9] 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 for MOUs with existing POSMOOR notation under the Rules for the Classification of Mobile Offshore Units Ref. [9].

5.2.5 Compliance with this guideline alone may not be adequate to meet regional requirements where local legislations stipulate the criteria to be complied with.

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

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, 5.3.5 and 10 of this Guideline.

5.3.3 BS6349-6 “Design of Inshore Moorings and Floating Structures”, Ref. [4], (now withdrawn), 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. [13], 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. The guidelines are not suitable for a moored vessel that cannot leave its quayside mooring under extreme conditions.

5.3.5 DNV-OS-H101, Ref. [6], & DNV-OS-H102, Ref. [7] provide guidance for the assessment of quayside mooring and strength requirements for mooring lines, quayside bollards as well as onboard mooring attachments.
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 14.6).

6.4.2 Further details of seabed and geotechnical data requirements are given in GL Noble Denton Guideline 0016/ND, Ref. [2], “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 peak period, together with a parametric wave spectrum, e.g. JONSWAP spectrum and peak enhancement factor
   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 MOORED 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 Moored vessel condition:
   a. Intended draught(s)
   b. Details of loading condition - displacement, VCG, LCG, mass moments of inertia or radii of gyration in roll, pitch and yaw.

6.6.3 Environmental loading and response characteristics (for all relevant draughts and water depths):
   a. Wind load coefficients
   b. Current load coefficients
   c. Quadratic Transfer Functions (QTFs) and low frequency added mass and damping
   d. One of the following wave-frequency response characteristics:
      - Response Amplitude Operators (RAOs) or
      - Wave Load RAOs 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 and load-cell calibration.
   c. Position and capacity of on board 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.
   d. Documented thruster capacities taking into account reductions due to thruster-thruster, thruster-hull and thruster-current interactions.

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 nominal diameter, minimum breaking load, dry and wet weight per unit length and for chain or wire the axial stiffness (EA, where E = Young’s modulus and A = cross section area) or for fibre ropes the applicable load-extension curve.
   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
   h. Anchor position and mooring pre-tension.

6.7.2 If GL Noble Denton is undertaking a mooring analysis, details of any Operator or Drilling Contractor preferred or standard anchor pattern and pre-tension 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>
<thead>
<tr>
<th>Table 7-1</th>
<th>Environmental Return Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mooring Type</strong></td>
<td><strong>Mooring Duration</strong></td>
</tr>
<tr>
<td></td>
<td>&lt; 6 months</td>
</tr>
<tr>
<td>Quayside / Inshore</td>
<td>10 year[1]</td>
</tr>
<tr>
<td>Offshore - Mobile near another asset</td>
<td>10 year</td>
</tr>
<tr>
<td>Offshore - Permanent</td>
<td>n/a</td>
</tr>
<tr>
<td>Offshore - Mobile in Open Location</td>
<td>5 year</td>
</tr>
</tbody>
</table>

[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 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 mooring for a weather-restricted operation (as defined in Section 3) 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 Factors relating to Weather-Restricted Operations are covered in Section 7.3 of 0001/ND, Ref. [1], “General Guidelines for Marine Projects”

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 19901-1 gust spectrum, Ref. [11], would be applicable to Section 7.5.2 b 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 take account of mean spring tide, the return period storm surge, fluvial (river) and wind-driven components, including variations with depth.

7.7 WAVES
7.7.1 For mobile moorings it is generally acceptable to consider a single extreme significant wave height and a range of associated peak periods corresponding to the relevant return period for a location.
7.7.2 For permanent moorings a number of H_s-T_p combinations along the 100 year return period contour line shall be considered in the analysis. If a contour plot is not available, a sensitivity study by varying peak period for the 100 year return period seastate 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.
7.7.3 Long crested waves shall be assumed for analysis unless otherwise documented.

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 shall 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 is 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 moored vessel at the draught(s) under consideration. Line tensions should be evaluated for all possible moored 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 moored 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, Ref. [8].
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 moored 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. Effects from wave/current interaction have to be included together with viscous effects if relevant.
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 moored 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 moored vessel lead to a wave frequency motion response of the vessel. The wave frequency motion is generally calculated either from the wave spectrum and moored vessel’s motion RAOs or from the wave force RAOs and frequency dependent added mass and damping. Both the motion RAOs and wave force RAOs can be calculated from a diffraction analysis. The motion RAOs can also be determined from model tests. The RAOs should be determined at the relevant moored 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. [11]. 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 14.5.1).

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 moored vessel / mooring system, at periods close the natural periods 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.

8.7 DEEP STRUCTURE VORTEX SHEDDING
8.7.1 For deep structures anchored to mooring systems in areas that are subjected to large current variations during the warranted installation phases, whether or not of tidal nature, a check should be made that the mooring response is safe with respect to potential in-line and transverse vortex shedding that can generate vortex induced motions.
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 and directions along the mooring lines from anchor to moored vessel (downline weather conditions)]:
   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 or its mooring is in close proximity to another installation (other than a quay) or specific operational constraints upon the vessel offset exist (e.g. a connected drilling riser), the moored 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. [12], and Table 1 therefrom is reproduced below:

<table>
<thead>
<tr>
<th>Type of Mooring</th>
<th>Limit State</th>
<th>Conditions to be Analyzed</th>
<th>Analysis Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Mooring</td>
<td>LS2 (ULS)</td>
<td>Intact / Redundancy Check</td>
<td>Dynamic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transient(^{[1]})</td>
<td>Quasi-Static or Dynamic</td>
</tr>
<tr>
<td></td>
<td>FLS</td>
<td>Intact</td>
<td>Dynamic</td>
</tr>
<tr>
<td></td>
<td>SLS</td>
<td>No guidance given</td>
<td>No guidance given</td>
</tr>
<tr>
<td>Mobile Mooring</td>
<td>LS2 (ULS)</td>
<td>Intact / Redundancy Check</td>
<td>Quasi-static or Dynamic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transient(^{[1],[2]})</td>
<td>Quasi-static or Dynamic</td>
</tr>
<tr>
<td></td>
<td>FLS</td>
<td>Not required</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>SLS</td>
<td>No guidance given</td>
<td>No guidance given</td>
</tr>
</tbody>
</table>

**NOTES**

\(^{[1]}\) Applicable only if another installation is in close proximity to the moored vessel or its 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. [12], 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”. GL Noble Denton’s policy on line tension adjustments (whatever code is used) is as follows:

a. Line adjustments to maintain moored 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 load cases.

c. Line adjustments following line failure ARE NOT permitted.

d. Line adjustments to optimise tensions in particular load cases, e.g. between windward and leeward lines ARE NOT permitted.

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

a. Line adjustments are only performed in the intact case.

b. Due consideration is made regarding 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.

f. Winch load cells are calibrated and are maintained to measure mooring loads within 5% accuracy.

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 moored 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 line dynamics resulting from the line inertia force due to 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 can be 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>
<thead>
<tr>
<th>Type of Analysis</th>
<th>Quasi-Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Time</td>
</tr>
<tr>
<td>Quayside / Inshore</td>
<td>✓ ✓</td>
<td>× ✓</td>
</tr>
<tr>
<td>Short Term Offshore Open Location</td>
<td>✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Short Term Offshore alongside a Fixed Installation</td>
<td>✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Short Term Offshore Vessel alongside a Floating Offshore Installation</td>
<td>×</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Long Term Offshore</td>
<td>×</td>
<td>✓ ✓ ✓</td>
</tr>
</tbody>
</table>

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. [8].

9.4.9 Care should be taken when modelling offshore mooring systems with excessive line length deployed on the seabed. Generally the maximum deployed line length used in the calculations should be limited to the suspended length at a line tension equal to the line MBL plus 500 m.

9.4.10 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.

9.4.11 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, Ref. [12].
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 moored 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.

10.2.4 The approach of simply doubling the safety factor requirements to compensate for lack of redundancy is not acceptable for mooring systems. For example, in systems including chain and associated connectors, mooring failures are not always directly related to a design overload. The appropriate factor should be determined following a case by case review taking into account the age and condition of all the mooring line components.

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 moored vessel itself or with the anchor racks/bolsters, as the resulting abrasive wear can damage both the mooring line(s) and the moored 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, Ref. [12].
Table 10-1  Line Tension Limits and Design Safety Factors

<table>
<thead>
<tr>
<th>Analysis Condition</th>
<th>Analysis Method</th>
<th>Line Tension Limit (percent of MBL)</th>
<th>Design Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact</td>
<td>Quasi-Static</td>
<td>50%</td>
<td>2.00</td>
</tr>
<tr>
<td>Intact</td>
<td>Dynamic</td>
<td>60%</td>
<td>1.67</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>Quasi-Static</td>
<td>70%</td>
<td>1.43</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>Dynamic</td>
<td>80%</td>
<td>1.25</td>
</tr>
<tr>
<td>Transient - one line broken</td>
<td>Quasi-Static</td>
<td>95%</td>
<td>1.05</td>
</tr>
</tbody>
</table>

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 (the benefit of any reduction in diameter should not be included in the calculations).

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.

10.4.8 Safety factors used in the mooring design for temporary operations, e.g. barge mooring during load-out, may be reduced on a case by case basis, subject to the acceptance of the risk mitigation measures by GL Noble Denton. Mitigation measures can include the provision of standby tugs or use of weather restrictions.

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. [12], should be considered applicable in the absence of other code specific requirements:

Table 10-2  Drag Anchor Holding Capacity Design Safety Factors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quasi-Static</th>
<th>Dynamic Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Mooring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intact Condition</td>
<td>n/a</td>
<td>1.50</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>n/a</td>
<td>1.00</td>
</tr>
<tr>
<td>Mobile Mooring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intact Condition</td>
<td>1.00</td>
<td>0.80</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>Not required</td>
<td>Not required</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Analysis Condition</th>
<th>Permanent Moorings</th>
<th>Mobile Moorings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Axial Loading</td>
<td>Lateral Loading</td>
</tr>
<tr>
<td></td>
<td>Axial Loading</td>
<td>Lateral Loading</td>
</tr>
<tr>
<td>Intact Condition</td>
<td>2.00</td>
<td>1.60</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>1.50</td>
<td>1.20</td>
</tr>
</tbody>
</table>
Table 10-4   Design Safety Factors for Holding Capacity of Gravity and Plate Anchors

<table>
<thead>
<tr>
<th>Analysis Condition</th>
<th>Gravity Anchors</th>
<th></th>
<th>Plate Anchors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permanent Moorings</td>
<td>Mobile Moorings</td>
<td>Permanent Moorings</td>
<td>Mobile Moorings</td>
</tr>
<tr>
<td></td>
<td>Axial</td>
<td>Lateral</td>
<td>Axial</td>
<td>Lateral</td>
</tr>
<tr>
<td>Intact Condition</td>
<td>2.00</td>
<td>1.60</td>
<td>1.50</td>
<td>1.20</td>
</tr>
<tr>
<td>Redundancy Check</td>
<td>1.50</td>
<td>1.20</td>
<td>1.20</td>
<td>1.00</td>
</tr>
</tbody>
</table>

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, Ref. [12].

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. It is generally acceptable to have some uplift in the redundancy check case for design conditions including dynamic components, provided that there is no uplift on the anchor for line tensions corresponding to mean environmental loads acting on the unit.
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>
<thead>
<tr>
<th>Condition</th>
<th>Minimum Clearance</th>
<th>0032/ND Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowance for anchor placing inaccuracy</td>
<td>50 m (typical)</td>
<td>11.2.1</td>
</tr>
<tr>
<td>Anchor horizontal distance from a subsea asset</td>
<td>100 m</td>
<td>11.2.2</td>
</tr>
<tr>
<td>Horizontal distance to pipeline or asset in line of anchor drag</td>
<td>300 m</td>
<td>11.2.2</td>
</tr>
<tr>
<td>Line horizontal to subsea wellhead, manifold or other asset</td>
<td>100 m</td>
<td>11.3.1</td>
</tr>
<tr>
<td>Line touchdown horizontal to pipeline/cable</td>
<td>50 m</td>
<td>11.3.2</td>
</tr>
<tr>
<td>Line/Vessel horizontal to platform*</td>
<td>10 m</td>
<td>11.3.3</td>
</tr>
<tr>
<td>Line above pipeline ≥40m WD</td>
<td>10 m</td>
<td>11.4.1</td>
</tr>
<tr>
<td>Line above pipeline &lt;40m WD</td>
<td>25% WD, but not less than 5 m</td>
<td>11.4.1</td>
</tr>
<tr>
<td>Line to line</td>
<td>20 m (30 m - if repositioning by winching)</td>
<td>11.5.1</td>
</tr>
<tr>
<td>Line to pre-laid buoyant risers/support structures during installation</td>
<td>10 m</td>
<td>11.4.4</td>
</tr>
</tbody>
</table>

* 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](image)

11.2.3 If the as-installed line bearing deviates more than +/- 5deg from the design spread, the spread shall be re-assessed to confirm compliance with adopted code factor of safety. The anchor installation tolerance should not be more than 50m radially towards the fairlead or 100m radially outwards from the design anchor position. Where line crosses a subsea structure/pipeline, the impact of the final anchor position shall be assessed irrespective of the installation tolerance achieved.

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 When mooring lines cross pipelines or cables, the distance between the touchdown and the asset should not be less than 50m.

11.3.3 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.

11.4.4 Clearance between mooring lines and buoyant sections of risers or riser support structures such as mid water arches during the installation of permanent moorings systems shall not be less than 10m for the design environmental conditions. The clearances shall be established based on as-installed and surveyed position and giving due consideration to the maximum motions of the moored vessel under design environmental conditions.

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 moored vessel motions that are most critical from the clearance perspective. This would normally apply to independently moored vessels. The clearance may be reduced to 30% of water depth for shallow water operations.

11.5.2 During positioning of the moored vessel, or during weather restricted operations such as lifting, reduced clearance not less than 50% of the clearance outlined in Sec 11.5.1 may be agreed by GL Noble Denton on a case by case basis after careful consideration of, as a minimum;

- Operational procedures,
- Tension measurement and accuracy
- Ranges of tension on the crossed lines
- Material of the mooring lines/condition
- Consequences of failure/breach of clearance
- Environmental conditions (wind, wave direction and visibility),
- Backup systems (thrusters, tugs) and fenders

11.5.3 Crossing of synthetic mooring lines with wire ropes or chain is not acceptable.

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.
11.6.3 For composite moorings, or mooring lines fitted with buoys to provide vertical clearance with subsea assets, the as-laid mooring anchor position/crossing location shall be surveyed to confirm that the design clearances are not breached after test tensioning and any resulting anchor drag.
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 [14] and [15].

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. [12], (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.

12.6.4 New synthetic lines/ropes should be pre-stretched.

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. [12], (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 MOORED VESSEL CONNECTION POINTS

12.9.1 Where moored 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 The structure and foundations of moored vessel connections points (including windlasses, winches, fairleads, Smit brackets, bollards, bitts etc.) should generally be designed for an ultimate holding capacity not less than 1.1 times the required MBL of the connected mooring line.

12.9.3 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 moored vessel to safely move to the standby /survival condition (as applicable).

12.9.4 Shore winches should have a brake holding at least 20% higher than the maximum line tensions expected. Winch foundations should be designed for a load in excess of the brake holding capacity required.

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 moored vessel and structure.

12.10.2 In cases where fendering must restrain the moored 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 moored vessel and the quay shall be calculated, and it shall be demonstrated that this pressure is not in excess of that which the moored 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 moored 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 moored 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 moored 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 moored vessel “hang up” against the quayside. The fender arrangement should be subject to a local site inspection. This is particularly relevant for load-out 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 moored 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 temporary moorings, e.g. for load-outs, proof loading should be to at least the stall capacity of the winch. In some cases greater loads can be required to ensure adequate embedment.

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

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

13.2.5 Mooring test loading for permanent moorings shall be in accordance with Section 10.4.6.2 of ISO 19901-7, Ref. [12].

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 moored 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 SPECIAL CONSIDERATIONS FOR INSHORE AND QUAYSIDE MOORINGS

14.1 BACKGROUND
14.1.1 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.

14.2 LOCATIONS WITHIN HARBOUR LIMITS
14.2.1 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.

14.2.2 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.

14.2.3 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.

14.2.4 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.

14.3 LOAD-OUT MOORINGS
14.3.1 Barge mooring during a load-out operation can be considered as weather restricted operation if adequate arrangements are available at site to secure the barge alongside complying with the design conditions required as per Section 7.2.2 when a bad weather is forecast.

14.3.2 If the barge with the structure loaded out is to be moored alongside for more than 72 hours, the system shall be analysed against the requirements of Section 7.2.2 and should comply with the strength requirements in Section 10.4, Section 12.9 and Section 14.6.

14.3.3 Mooring calculations for load-out conditions should take into account the wind area of the loaded out structure. Simplified calculation procedures using spread sheets without taking into consideration the relative stiffness of the mooring lines are acceptable only if it can be shown that at least one mooring line capable of providing the required restraint for a specific environment direction is available in the direction considered without exceeding the allowable loads.

14.4 CONTINGENCY ARRANGEMENTS
14.4.1 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).

14.5 MOORING CONSIDERATIONS
14.5.1 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).

14.5.2 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.

14.5.3 Wind loads shall take account of all construction phases and can be increased due to scaffolding, wind and weather protection, etc.
14.5.4 It is often impossible to properly tension and adjust moorings at a 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 are better than multiple small ones in an asymmetric arrangement.

14.5.5 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 moored vessel. It, however, represents a wise investment given the likely value of the moored object.

14.5.6 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.

14.5.7 Adequate fendering is hard to achieve on larger moored 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 moored 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.

14.5.8 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.

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

14.6 SHORE MOORING POINTS / BOLLARDS / WINCHES

14.6.1 The capacity of shore mooring points and winches, including their foundations, should be demonstrated by certification or by design. The ultimate load capacity should be greater than 1.1 times the worst case combined loading from all the connected mooring lines with the loads factored according to Table 10-1.

14.6.2 When safe working load is defined without reference to the ratio of ultimate load capacity to safe working load or working load limits, a factor no greater than 1.60 may be applied to the defined safe working load to derive an estimate of the ultimate load capacity.

14.6.3 When this data is not available proof loading may be undertaken to demonstrate the capacity of the bollard and its foundation. Proof loads shall be a minimum of 1.375 times the maximum combined un-factored line tension expected on the bollard. However, the proof load shall not exceed 1.25 times the safe working load defined by the manufacturer, where this is available. The bollard and its foundation on inspection following the proof loading shall not exhibit signs of damage or cracks.

14.6.4 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. Displacement controlled loading is generally preferred.

14.6.5 If the mooring load is to be held on a winch brake, then the winch brake capacity, with the outer wrap on the drum, should exceed the maximum mooring intact load multiplied by a minimum factor of 1.2, and be greater than the maximum line tension for redundancy check cases. Where winches are used, tension monitoring devices / meters shall be used.

14.6.6 In cases where existing shore-side mooring equipment is being used, wires and winches may sometimes be offered which have a breaking load greater than the barge equipment to which they are connected. Great care is needed in such situations, and the wire loadings should be controlled and monitored.

14.7 SEA ANCHORS

14.7.1 Where sea anchors are laid for load-out or other inshore /quayside moorings they shall be checked against drag by a holding test at the design load.
14.8 PROCEDURES
14.8.1 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 14.2.4.
- mooring line tending arrangements to account for predicted variations in tidal height
- safe access to moored vessels accounting for potentially significant tidal variations.

14.9 COLD STACKING
14.9.1 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.

14.10 ICE LOADING
14.10.1 For locations where loading from drifting ice is expected on a moored structure the impact on mooring line tensions shall be assessed.
14.10.2 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.
15 SPECIAL CONSIDERATIONS FOR PERMANENT MOORINGS

15.1 GENERAL

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

15.1.2 Additional considerations over mobile moorings are likely to include the following with further information available in the Mooring Integrity JIP OTC papers, Ref. [14] and [15]:

- Fatigue (axial, bending and torsion)
- Marine growth and how to 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

[2] GL Noble Denton 0016/ND “Seabed and Sub-seabed Data Required for Approvals of Mobile Offshore Units (MOU)”
[8] DNV-RP-C205 Environmental Conditions and Environmental Loads

APPENDIX A - INITIAL INFORMATION REQUIRED FOR MOORING APPROVAL

A.1 OFFICE REVIEW
A.1.1 Mooring analysis report detailing:
   a. Location and Moored 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).
A.1.2 Mooring plan detailing moored vessel location and mooring arrangement.
A.1.3 Supporting procedures and risk assessments (particularly where the mooring is weather-restricted or is not fully redundant).

A.2 ON SITE
A.1.4 Certification for all mooring components including moored 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.
A.1.5 Details of manning and emergency response plan (see Sections 10.2.3 and 14.4)