GENERAL GUIDELINES FOR MARINE PROJECTS

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<tr>
<th>Date</th>
<th>Revision</th>
<th>Prepared by</th>
<th>Authorised by</th>
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<tr>
<td>22 Jun 13</td>
<td>0</td>
<td>RLJ</td>
<td>Technical Policy Board</td>
</tr>
</tbody>
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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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### CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 SUMMARY</td>
<td>5</td>
</tr>
<tr>
<td>2 INTRODUCTION</td>
<td>6</td>
</tr>
<tr>
<td>3 DEFINITIONS</td>
<td>7</td>
</tr>
<tr>
<td>4 THE APPROVAL PROCESS</td>
<td>11</td>
</tr>
<tr>
<td>4.1 Role of the Marine Warranty Surveyor</td>
<td>11</td>
</tr>
<tr>
<td>4.2 Certificate of Approval</td>
<td>11</td>
</tr>
<tr>
<td>4.3 GL Noble Denton Approval</td>
<td>11</td>
</tr>
<tr>
<td>4.4 Scope of Work Leading to an Approval</td>
<td>12</td>
</tr>
<tr>
<td>4.5 Limitation of Approval</td>
<td>12</td>
</tr>
<tr>
<td>4.6 Repetitive &amp; Unattended Operations</td>
<td>13</td>
</tr>
<tr>
<td>5 HEALTH, SAFETY AND ENVIRONMENT</td>
<td>14</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>14</td>
</tr>
<tr>
<td>5.2 Jurisdiction</td>
<td>14</td>
</tr>
<tr>
<td>5.3 Responsibilities</td>
<td>14</td>
</tr>
<tr>
<td>5.4 Risk Management</td>
<td>14</td>
</tr>
<tr>
<td>5.5 Qualification and Training</td>
<td>14</td>
</tr>
<tr>
<td>5.6 Safety Plan</td>
<td>15</td>
</tr>
<tr>
<td>5.7 Contingency and Emergency Planning and Procedures</td>
<td>15</td>
</tr>
<tr>
<td>5.8 Security and Tracking System</td>
<td>15</td>
</tr>
<tr>
<td>6 ORGANISATION, PLANNING AND DOCUMENTATION</td>
<td>16</td>
</tr>
<tr>
<td>6.1 Introduction</td>
<td>16</td>
</tr>
<tr>
<td>6.2 Organisation and Communication</td>
<td>16</td>
</tr>
<tr>
<td>6.3 Quality Assurance and Administrative Procedures</td>
<td>16</td>
</tr>
<tr>
<td>6.4 Technical Procedures</td>
<td>17</td>
</tr>
<tr>
<td>6.5 Technical Documentation</td>
<td>17</td>
</tr>
<tr>
<td>6.6 Documentation and Certification</td>
<td>19</td>
</tr>
<tr>
<td>7 METOCEAN CRITERIA &amp; FORECASTS</td>
<td>22</td>
</tr>
<tr>
<td>7.1 Introduction</td>
<td>22</td>
</tr>
<tr>
<td>7.2 Metocean Criteria (Unrestricted Operations)</td>
<td>22</td>
</tr>
<tr>
<td>7.3 Weather Restricted Operations</td>
<td>24</td>
</tr>
<tr>
<td>7.4 Weather / Metocean Forecasts</td>
<td>26</td>
</tr>
<tr>
<td>7.5 Benign Weather Areas</td>
<td>27</td>
</tr>
<tr>
<td>8 WEIGHT CONTROL</td>
<td>29</td>
</tr>
<tr>
<td>8.1 Introduction</td>
<td>29</td>
</tr>
<tr>
<td>8.2 Weight Class</td>
<td>29</td>
</tr>
<tr>
<td>8.3 Reserves</td>
<td>29</td>
</tr>
<tr>
<td>8.4 Weight Control Reports &amp; Audits</td>
<td>29</td>
</tr>
<tr>
<td>8.5 Weight and Buoyancy Control</td>
<td>30</td>
</tr>
<tr>
<td>9 STRUCTURAL STRENGTH</td>
<td>31</td>
</tr>
<tr>
<td>9.1 General</td>
<td>31</td>
</tr>
<tr>
<td>9.2 Structural Steel</td>
<td>31</td>
</tr>
<tr>
<td>9.3 Fillet welds</td>
<td>32</td>
</tr>
<tr>
<td>9.4 Doubler Plates</td>
<td>32</td>
</tr>
<tr>
<td>9.5 Bolted Connections for seafastenings</td>
<td>32</td>
</tr>
<tr>
<td>9.6 Light-weight Metallic and Composite Structures</td>
<td>32</td>
</tr>
<tr>
<td>9.7 Structural Concrete</td>
<td>32</td>
</tr>
<tr>
<td>9.8 Compressed Air</td>
<td>33</td>
</tr>
<tr>
<td>10 BUILDING / CONSTRUCTION BASIN</td>
<td>34</td>
</tr>
<tr>
<td>11 TOW-OUT FROM DRY-DOCK / BUILDING BASIN</td>
<td>35</td>
</tr>
<tr>
<td>11.1 Mooring and handling lines</td>
<td>35</td>
</tr>
</tbody>
</table>
11.2 Underkeel clearance for leaving basin
11.3 Side Clearances
11.4 Underkeel Clearance Outside Basin
11.5 Towage and marine considerations

12 TEMPORARY BALLASTING AND COMPRESSED AIR SYSTEMS
   12.1 General
   12.2 Redundancy
   12.3 Inlets
   12.4 Pipework
   12.5 Umbilicals

13 USE OF DP VESSELS
   13.1 Background
   13.2 DP Equipment Classes
   13.3 System Design & Capability
   13.4 DP2 or DP3 Class
   13.5 Operational Requirements
   13.6 Vessel Clearances
   13.7 Jack-Ups
   13.8 Information Required for Approval

14 DECOMMISSIONING
   14.1 General

REFERENCES

APPENDIX A - FILLET WELD STRESS CHECKING

APPENDIX B - BOLTED CONNECTIONS

TABLES
Table 6-1 Principal Vessel Documentation
Table 7-1 Return Periods
Table 7-2 Value of JONSWAP $\gamma$, ratio of $T_p:T_z$ and $T_p:T_1$ for each integer value of $K$
Table 7-3 Metocean Reduction Factors
Table 7-4 Northern & Southern Boundaries of Benign Weather Areas by Month
Table 9-1 Load Factors for use with AISC 14th Edition
Table 13-1 DP Equipment Classes

FIGURES
Figure 6-1 Example of document organogram
Figure 7-1 Map Showing Benign Weather Areas
Figure A-1 Effective Throat Dimension $'a'$ for Concave and Convex Fillet Welds
Figure A-2 Normal and Shear Stresses acting on the plane of Weld Throat
Figure A-3 Bracket connected by double Fillet Weld
Figure A-4 Stresses and Forces acting on Fillet Weld
1 SUMMARY

1.1 These guidelines have been developed by GL Noble Denton to present material that is common to more than one of the other GL Noble Denton guidelines for the approval of marine projects.

1.2 They include:

- The approval process for marine warranty
- Health Safety and Environment
- Organisation, planning and documentation
- Metocean criteria (design and operating) and forecasts
- Weight control
- Structural strength
- Building/construction basins
- Tow-out from dry-dock/building basin
- Temporary ballasting & compressed air systems
- Use of Dynamic Positioning (DP) vessels
- Decommissioning of platforms and topsides.
2 INTRODUCTION

2.1 This document is a prime reference for the specific guidelines developed by GL Noble Denton for application to marine projects, listed in Section 2.3. It contains items that were previously duplicated in more than one guidelines.

2.2 The specific Guidelines are intended to lead to an approval by GL Noble Denton. Such approval does not imply that compliance with national codes and legislation, or the requirements of other regulatory bodies, harbour authorities and/or any other parties would be given.

2.3 This report should be read in conjunction with the specific GL Noble Denton Guideline documents, particularly:

b. 0013/ND “Guidelines for Load-Outs”, Ref. [2]
c. 0015/ND “Guidelines for Concrete Gravity Structure Construction & Installation”, Ref. [3]
d. 0016/ND “Seabed and Sub-seabed data required for approvals of Mobile Offshore Units (MOUs)”, Ref. [4]
e. 0021/ND “Guidelines for the Approval of Towing Vessels”, Ref. [5]
g. 0028/ND “Guidelines for Steel Jacket Transportation & Installation”, Ref. [7]
h. 0029/ND “Guidelines for Submarine Pipeline Installation”, Ref. [8]
i. 0030/ND “Guidelines for Marine Transportations”, Ref. [9]
j. 0031/ND “Guidelines for Float-Over Installations /Removals”, Ref. [10]
l. 0035/ND “Guidelines for Offshore Wind Farm Infrastructure Installation”, Ref. [12].

2.4 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.

2.5 Designers and installers of innovative designs or installation methods are recommended to discuss the procedures and design with the relevant GL Noble Denton office at an early stage of the project to ensure that it will be approvable without changes.

2.6 Please contact the Technical Policy Board Secretary at TPB@nobledenton.com with any queries or feedback.
### 3 DEFINITIONS

Referenced definitions are underlined.

<table>
<thead>
<tr>
<th>Term or Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/50 weight estimate</td>
<td>The value representing the median value in the probability distribution of weight</td>
</tr>
<tr>
<td>AISC</td>
<td>American Institute of Steel Construction</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>ASD</td>
<td>Allowable Stress Design (effectively the same as WSD)</td>
</tr>
<tr>
<td>ASOG</td>
<td>Activity Specific Operations Guidelines (for DP – See Section 13.5.1 k)</td>
</tr>
<tr>
<td>Assured</td>
<td>The Assured is the person who has been insured by some insurance company, or underwriter, against losses or perils mentioned in the policy of insurance.</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 Pontoon, Ship or Vessel where appropriate).</td>
</tr>
<tr>
<td>Benign (weather) area</td>
<td>An area with benign weather as described in Section 7.5</td>
</tr>
<tr>
<td>BL / Breaking Load</td>
<td>Certified minimum breaking load of wire rope, chain or shackles.</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>Classification</td>
<td>A system of ensuring ships are built and maintained in accordance with the Rules of a particular Classification Society. Although not an absolute legal requirement, the advantages (especially as regards insurance) mean that almost all vessels are maintained in Class.</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>Design environmental condition</td>
<td>The design wave height, wind speed, current and other relevant environmental conditions specified for the design of a particular transportation or operation.</td>
</tr>
<tr>
<td>DP</td>
<td>Dynamic Positioning or Dynamically Positioned</td>
</tr>
<tr>
<td>EPC</td>
<td>Engineering, Procurement and Construction</td>
</tr>
<tr>
<td>FMEA or FMECA</td>
<td>Failure Modes and Effects Analysis or Failure Modes, Effects and Criticality Analysis</td>
</tr>
<tr>
<td>Term or Acronym</td>
<td>Definition</td>
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</tr>
<tr>
<td>GL Noble Denton</td>
<td>The legal entity trading under the GL Noble Denton name which is contracted to carry out the scope of work and issues a Certificate of Approval, or provides advice, recommendations or designs as a consultancy service.</td>
</tr>
<tr>
<td>HAZID</td>
<td>Hazard Identification Study</td>
</tr>
<tr>
<td>HAZOP</td>
<td>Hazard and Operability Study</td>
</tr>
<tr>
<td>HIRA</td>
<td>Hazard Identification Risk Assessment</td>
</tr>
<tr>
<td>IACS</td>
<td>International Association of Classification Societies</td>
</tr>
<tr>
<td>IMO / International Maritime Organization</td>
<td>The United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships</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>ISM / International Safety Management.</td>
<td>The ISM Code provides an International standard for the safe management and operation of ships and for pollution prevention.</td>
</tr>
<tr>
<td>JSA</td>
<td>Job Safety Analysis</td>
</tr>
<tr>
<td>Load-in</td>
<td>The transfer of a major assembly or a module from a barge, e.g. by horizontal movement or by lifting.</td>
</tr>
<tr>
<td>Load-out</td>
<td>The transfer of a major assembly or a module from land onto a barge by horizontal movement or by lifting</td>
</tr>
<tr>
<td>LRFD</td>
<td>Load and Resistance Factor Design</td>
</tr>
<tr>
<td>LS1 / Limit State 1</td>
<td>A design condition where the loading is gravity dominated; also used when the exclusions of Section 9.2.5 apply.</td>
</tr>
<tr>
<td>LS2 / Limit State 2</td>
<td>A design condition where the loading is dominated by environmental / storm loads, e.g. at the 10- or 50-year return period level or, for weather-restricted operations, where a Metocean Reduction Factor according to Section 7.3.3 is to be applied.</td>
</tr>
<tr>
<td>MBL / Minimum Breaking Load</td>
<td>The minimum allowable value of breaking load for a particular sling, grommet, wire or chain etc.</td>
</tr>
<tr>
<td>Metocean Reduction Factor</td>
<td>The maximum ratio of operational criteria / design criteria to allow for weather forecasting inaccuracies. See Table 7-3.</td>
</tr>
<tr>
<td>MODU</td>
<td>See MOU</td>
</tr>
<tr>
<td>MOU / Mobile Offshore Unit.</td>
<td>For the purposes of this document, the term may include Mobile Offshore Drilling Units (MODUs), and non-drilling mobile units such as accommodation, construction, lifting or production units including those used in the offshore renewables sector.</td>
</tr>
<tr>
<td>MWS</td>
<td>Marine Warranty Surveyor (see Section 4.1)</td>
</tr>
<tr>
<td>Term or Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------</td>
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</tr>
<tr>
<td>NDT / Non Destructive Testing</td>
<td>Ultrasonic scanning, magnetic particle inspection, eddy current inspection or radiographic imaging or similar. May include visual inspection.</td>
</tr>
<tr>
<td>NMD</td>
<td>Norwegian Maritime Directorate</td>
</tr>
<tr>
<td>Operation Criteria</td>
<td>The metocean limits used when assessing weather forecasts to determine the acceptability of proceeding with (each phase of) an operation beyond the next Point of No Return.</td>
</tr>
<tr>
<td>Operation Duration</td>
<td>The planned duration of the operation <strong>excluding</strong> a contingency period from 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).</td>
</tr>
<tr>
<td>Operational Reference Period</td>
<td>The <strong>Operation Duration</strong>, <strong>including</strong> a contingency period</td>
</tr>
<tr>
<td>Platform</td>
<td>The completed steel or concrete structure complete with topsides</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>QRA</td>
<td>Quantified Risk Analysis</td>
</tr>
<tr>
<td>RCS / Recognized Classification Society</td>
<td>Member IACS with recognized and relevant competence and experience in specialised vessels or structures, and with established rules and procedures for classification / certification of such vessels /structures under consideration.</td>
</tr>
<tr>
<td>Reduced exposure operation /towage /transportation</td>
<td>A weather-unrestricted operation which has an exposure sufficiently short (typically under 30 days) for the design extremes to be reduced. Applicable only to towages or transportations, See Section 7.2.2.3 and Section 6.5 of 0030/ND, Ref. [9].</td>
</tr>
<tr>
<td>Restricted operation</td>
<td>See Weather-restricted operation.</td>
</tr>
<tr>
<td>SOLAS</td>
<td>International Convention for the <strong>Safety Of Life At Sea</strong>. An international treaty concerning the safety of merchant and other ships and MOUs.</td>
</tr>
<tr>
<td>Statement of Acceptability</td>
<td>See Section 4.2.5</td>
</tr>
<tr>
<td>Structure</td>
<td>The object to be transported and installed, or a sub-assembly, component or module.</td>
</tr>
<tr>
<td>Survey</td>
<td>Attendance and inspection by a <strong>GL Noble Denton</strong> 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 <strong>GL Noble Denton</strong> 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</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>TRN / Technical Review Note</td>
<td>Notes issued by the MWS in which MWS questions and comments are recorded for installation contractor action.</td>
</tr>
<tr>
<td>Term or Acronym</td>
<td>Definition</td>
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<tr>
<td>----------------</td>
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</tr>
<tr>
<td>Vessel</td>
<td>A marine craft designed for the purpose of transportation by sea or construction activities offshore. See Barge</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 favourable weather forecast (generally less than 72 hours), taking contingencies into account. The design environmental condition need not reflect the statistical extremes for the area and season. A suitable factor should be applied between the design weather conditions and the operational weather limits and the design weather conditions (see Section 7.3.3)</td>
</tr>
<tr>
<td>Weather unrestricted operation</td>
<td>An operation with an operational reference period greater than the reliable limits of a favourable weather forecast (generally less than 72 hours). The design weather conditions must reflect the statistical extremes for the area and season. The design weather is typically a 10 year seasonal storm, but subject to Section 7.2.2.</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>
<tr>
<td>WSD</td>
<td>Working Stress Design (effectively the same as ASD)</td>
</tr>
</tbody>
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4 THE APPROVAL PROCESS

4.1 ROLE OF THE MARINE WARRANTY SURVEYOR

4.1.1 An Insurance Warranty is a clause in the insurance policy for a particular marine project, requiring the approval of one or more marine operations by Marine Warranty Surveyors from a specified independent survey house, or one from a list of such survey houses. In most cases the Assured employs the survey house though occasionally an insurance broker or underwriter may do so.

4.1.2 The requirement is normally satisfied by the issue of one or more Certificates of Approval. Responsibility for interpreting the terms of the Warranty so that an appropriate Scope of Work can be defined rests with the Assured who may be the operator, owner or his contractor. The scope may include acceptance of procedures and equipment in advance of the issue of the Certificates of Approval and may also be extended to cover consultancy work as described in Section 4.3.1.

4.1.3 The surveyor may also attend during an operation to monitor the operations and agree any changes in procedures. In these cases he has no executive authority on the project but when necessary he shall submit recommendations to the assured’s representative to ensure that the project is run in a safe and proper manner.

4.2 CERTIFICATE OF APPROVAL

4.2.1 A Certificate of Approval is the formal document issued by the Warranty Surveyor when, in his or her judgement and opinion, all reasonable checks, preparations and precautions have been taken to keep risks within acceptable limits, and an operation may proceed. It is the main deliverable of the approval process.

4.2.2 The Certificate of Approval for a marine operation such as float-out, towage or installation will normally be issued when:

- all preparations including engineering reviews, acceptance of procedures /manuals, seafastening and ballasting are complete,
- marine equipment such as tugs and towing connections have been inspected,
- a readiness meeting has been held, and
- the actual and forecast weather are suitable for the operation to begin.

4.2.3 Agreement is required on the end-point of each Certificate of Approval.

4.2.4 The Warranty Surveyor may be unable to issue a Certificate of Approval due to inadequate procedures or equipment for the likely conditions. Similarly failure to follow the procedures and conditions in the Certificate of Approval could lead to it being withdrawn. In the event of a loss, the lack of a valid Certificate of Approval could invalidate the insurance warranty and prevent or reduce payment by underwriters for any loss.

4.2.5 A Statement of Acceptability may be issued when the client requires documentary proof that GL Noble Denton has completed the necessary reviews of procedures and supporting calculations and that subject to any stated limitations on the Statement of Acceptability, the procedures are considered acceptable. No surveys or site checks are required for a Statement. A Statement of Acceptability covers only the acceptability of the submitted documents. It does not imply approval of any proposed operation.

4.3 GL NOBLE DENTON APPROVAL

4.3.1 GL Noble Denton may act as a Warranty Surveyor, giving Approval to a particular 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 but an individual Warranty Surveyor must not approve his/her own work, e.g. as towmaster, without the agreement of the client who should normally seek the underwriter’s acceptance.

NOTE: When working on aspects of a project where conflict could occur it is normal practice that these are under the control of separate line management and that appropriate disclosures are made.
4.3.2 In accordance with the definition in Section 3, GL Noble Denton is the legal entity trading under the GL Noble Denton name which is contracted to carry out the scope of work and issues a Certificate of Approval, or provides advice, recommendations or designs as a consultancy service.

4.3.3 GL Noble Denton approval may be sought where an operation is the subject of an Insurance Warranty, or where an independent third party review is required.

4.4 SCOPE OF WORK LEADING TO AN APPROVAL

4.4.1 Details of scopes of work, including surveys, reviews and calculations required, are given in the relevant GL Noble Denton guidelines specific for that work.

4.4.2 Early involvement of GL Noble Denton in agreeing criteria at the initial planning or design stage will often save the time and expense of changing designs after construction has started.

4.4.3 In some cases risk assessments can be used to justify project-specific deviations from the standard criteria provided that GL Noble Denton agree that the results are acceptable. When such risk assessments show increased risk levels the operation may be approved subject to disclosure to and agreement by the underwriters.

4.5 LIMITATION OF APPROVAL

4.5.1 A Certificate of Approval is issued for a particular towage, voyage or operation only and is not to be deemed or considered to be a general statement of seaworthiness of vessels.

4.5.2 A Certificate of Approval is issued based on external conditions observed by the attending surveyor of the structure, hull(s), machinery and equipment, without removal, exposure or testing of parts.

4.5.3 Any alterations to the surveyed items or agreed procedures after issue of the Certificate of Approval may render the Certificate invalid unless the changes are accepted by GL Noble Denton in writing. Any changes to the agreed procedure should be submitted through a Management of Change system. This should normally include a risk assessment and all information relevant to demonstrate the acceptability of the change.

4.5.4 No responsibility is accepted by GL Noble Denton for the way in which a transportation is conducted after departure, or for the way in which an operation is conducted after commencement, this being solely the responsibility of the appropriate manager, master or superintendent.

4.5.5 The Certificate covers the surveyed items within the agreed scope of work only. It does not, for instance, cover any other cargo on board a vessel or barge, or any damage to the surveyed cargo as a consequence of inadequacy of any other cargo or its seafastenings, unless specifically included in the scope of work.

4.5.6 Fatigue damage is excluded from any GL Noble Denton approval, unless specific instructions are received from the client to include it in the scope of work.

4.5.7 The Certificate of Approval for any operation does not cover any moorings used:
   - prior to the start of a transportation or operation,
   - at any intermediate shelter port or arrival port,
   - after completion of a transportation or operation,

   unless specifically approved by GL Noble Denton. If approval of moorings is required, other than for the operation itself, specific approval should be requested.

4.5.8 A Certificate of Approval for installation applies to the safety of the structure and associated equipment during the defined installation period. It does not imply that the completed jacket, platform or other installation will be fit for purpose.

4.5.9 The safety of personnel will not be specifically addressed unless our Client requests this and the detailed requirements are included in the scope of work.

4.5.10 A Statement of Acceptability covers the acceptability of submitted documents only. It does not imply approval of any proposed operation.
4.6 REPETITIVE & UNATTENDED OPERATIONS

4.6.1 Attendance by a surveyor is not normally required for all repeats of identical operations unless specified by the insurance warranty or client, provided that GL Noble Denton is kept informed of any variations, problems and potential problems. The attendances will be agreed at the start of each project and will typically include:
   a. The first unique event
   b. After significant changes in procedures for the operations
   c. After change of vessel
   d. After change of Person in Charge or OIM
   e. An additional 10% of repetitive operations, randomly selected.

4.6.2 **Certificates of Approval** for any towage or transport, for which a GL Noble Denton surveyor does not attend the departure, will normally be issued in advance after the vessel or barge and towing vessel(s) have been surveyed. It will be validated by email or other means after the actual departure weather and weather forecast have been agreed by the relevant GL Noble Denton office.

4.6.3 **Statements of Acceptability** will normally be issued in advance, when required, for unattended lifts, load-outs or other operations when the procedures and calculations have been accepted.
5 HEALTH, SAFETY AND ENVIRONMENT

5.1 INTRODUCTION
This Section contains general guidelines on safety and emergency issues. This subject must be managed by the client or his nominated contractor in accordance with local jurisdiction, as well as appropriate guidelines and specifications regarding health, safety and the environment (HSE). GL Noble Denton’s Scope of Work includes HSE issues only where explicitly stated.

5.2 JURISDICTION
In addition to Approval by GL Noble Denton, construction and marine operations will be subject to national and international regulations and standards on personnel safety and protection of the environment. It should also be noted that a marine operation can involve more than one nation’s area of jurisdiction, and that for barges and vessels the jurisdiction of the flag state will apply.

5.3 RESPONSIBILITIES
5.3.1 The owner of the structure will have the overall responsibility for planning and execution of the construction and marine operations, and hence also the safety of personnel, facilities and environment. The owner may delegate the execution and follow-up of these issues to a nominated third party such as an EPC-contractor.

5.3.2 If a part of the marine operations is to be carried out near other facilities or their surroundings, safety zones shall be defined by the owner.

5.4 RISK MANAGEMENT
5.4.1 Risk management should be applied to the project to reduce the effects of hazards and to limit the overall risk. The preferred approach is achieved by addressing the following functions:
   a. Identification of potential hazards
   b. Preventative measures to avoid hazards wherever possible
   c. Controls to reduce the potential consequences of unavoidable hazards
   d. Mitigation to reduce the impact of risk, should hazards occur.

5.4.2 Each major marine operation should be subject to detailed hazard studies. Those taking part should include the personnel and organisations involved in the design of structures and systems, as well as those involved in the marine operation.

5.4.3 Each major system essential to the performance and safety of marine operations including, for example, the power generation and the ballast and compressed air systems should be subjected to a rigorous study.

5.4.4 A variety of techniques including HAZID, HAZOP, FMECA, HIRA, JSA and Tool Box Talks may be used as appropriate to monitor and control such hazards and to model their potential effects.

5.4.5 QRA techniques may be used to compute the particular level of risk applicable to any operation, to compare levels of risk between alternative proposals or between known and novel methods, and to enable rational choices to be made between alternatives.

5.4.6 Ideally, each of the various studies outlined above should be managed by a competent independent person familiar with the overall concept, but outside the team carrying out the relevant system or structure design or operational management.

5.4.7 It is good practice that no major activity is carried out on a site without an approved Method Statement, and that the Risk Assessment process is part of that approval procedure, and that the Risk Assessment itself forms an appendix to the Method Statement.

5.5 QUALIFICATION AND TRAINING
5.5.1 Operation supervisors shall possess thorough knowledge and have experience from similar operations. Other key personnel shall have knowledge and experience within their area of responsibility. Before the start of an operation, all personnel involved shall be briefed by the supervisors regarding responsibilities, communication, safety, and step by step procedures and tasks.
5.5.2 Adequate training appropriate to each individual’s function and situation should be given, including job training, site safety training and briefings, marine safety and survival training.

5.5.3 A qualification matrix is recommended for correct tracking and control of personal qualifications.

5.5.4 Computer simulation and training, and/or model tests can give valuable information for the personnel carrying out the operation.

5.6 SAFETY PLAN
5.6.1 A safety plan shall be included in the procedure manual for each operation. This plan consists of the safety rules that apply to minimise the following risks encountered during each operation:
   a. Risks inherent from the metocean conditions
   b. Risks incurred by construction, transportation, installation and commissioning activities
   c. Risks to the environment
   d. Risks due to simultaneous operations (SIMOPS) – see IMCA, Ref. [25]
   e. Risks due to working on live assets, etc.

5.7 CONTINGENCY AND EMERGENCY PLANNING AND PROCEDURES
5.7.1 Each operation is considered to progress from a condition of security to another condition of security. Contingency planning is required so that, in the event that an operation cannot be completed in the time and manner intended, an alternative condition of security can be achieved.

5.7.2 Contingency and emergency planning should form part of the operational procedures. Plans should be developed for all foreseeable emergencies, which can include:
   a. Severe weather
   b. Planned precautionary action in the event of forecast severe weather
   c. Structural parameters approaching pre-set limits
   d. Stability parameters approaching pre-set limits
   e. Failure of mechanical, electrical or control systems
   f. Fire
   g. Collision
   h. Leakage
   i. Pollution
   j. Structural failure
   k. Mooring failure
   l. Human error
   m. Man overboard
   n. Personnel accidents or medical emergencies
   o. Terrorism and sabotage.

5.7.3 The procedures should detail alarm signals, reporting, communication, organisation and required equipment such as escape routes, personnel rescue means and fire fighting equipment.

5.7.4 Fire and evacuation alarms should be periodically tested, and drills should carried out periodically, or as required by safety legislation.

5.8 SECURITY AND TRACKING SYSTEM
5.8.1 Where necessary, a suitable security and tracking system should be in use to record personnel on the structure or vessels, to track their whereabouts, and if required, to restrict access to certain areas to authorised personnel only.

5.8.2 The contractor is responsible for accident reporting to the owner and regulatory bodies. Any incidents, accidents or near-misses relevant to the safety of the structure or future marine operations shall also be reported to GL Noble Denton.
6 ORGANISATION, PLANNING AND DOCUMENTATION

6.1 INTRODUCTION

This Section suggests the requirements for the organisation and documentation systems that should be set up for the performance of marine operations to allow the Marine Warranty Surveyor to approve them in a timely and economic manner.

6.2 ORGANISATION AND COMMUNICATION

6.2.1 An appropriate Project organisation chart shall be set up, illustrating how the marine operations integrate with the rest of the project. Key responsibilities shall be clearly defined, and the responsibilities and reporting lines shown on the organisation chart.

6.2.2 Organisation charts shall be drawn up for each marine operation showing the reporting lines into the project organisation and those responsible. Such reporting lines may include:

- a. Client's representative
- b. Overall project management
- c. Operation management
- d. Towing vessels
- e. Mooring systems and marine spread
- f. Ballast system operation
- g. Weather forecasting
- h. Support services
- i. Advisory panel providing expertise as required
- j. Safety
- k. Statutory, regulatory and approving bodies
- l. Emergency response.

6.2.3 In each case the responsibilities and duties of each function shall be clearly defined to minimise uncertainties and overlapping responsibilities.

6.2.4 During on-going marine operations the site team should be limited to those persons with defined roles during the operation. Back-up services, including emergency services, contingency assistance and technical advisory services shall be identified and appropriately located.

6.2.5 Communication systems, including radio channels, telephone, telefax numbers, e-mail addresses and out-of-hours numbers shall be identified and checked for accuracy.

6.2.6 Where personnel changes occur during the course of an operation because of shift changes, these shall be identified. Every effort should be made to avoid changes of key personnel during critical stages of the operation.

6.2.7 Where transfer of responsibility is involved, times of and procedures for hand-over from one organisation to another (e.g. from fabrication to marine operations, from on-shore to offshore) shall be identified.

6.2.8 When continuous operations using more than 1 shift are not standard practice then special provision to prevent fatigue must be made for operations that could continue beyond normal working hours. This includes provision of suitably experienced and briefed alternate personnel with good hand-overs at each shift change.

6.3 QUALITY ASSURANCE AND ADMINISTRATIVE PROCEDURES

6.3.1 A quality management system in accordance with the current version of ISO 9001, Ref. [29], or equivalent should be adopted and be in place.
6.4 TECHNICAL PROCEDURES

6.4.1 Technical procedures shall be in place to control engineering related to the marine activities.

6.4.2 The objective of these procedures is to define applicable technical standards to ensure agreement and uniformity, with bridging documents where necessary, on matters such as:
   a. International and national standards and legislation
   b. Certifying authority/regulatory body standards
   c. Marine warranty surveyor guidelines
   d. Project criteria
   e. Design basis
   f. Metocean criteria
   g. Calculation procedures
   h. Change management.

6.5 TECHNICAL DOCUMENTATION

6.5.1 An integrated document numbering system for the entire project is suggested, including documents produced by client, contractors, sub-contractors and vendors.

6.5.2 Documents relating to marine operations should be grouped into levels according to their status, for example:
   a. Criteria and design basis documents
   b. Procedures and operations manuals
   c. Supporting documents, including engineering calculations, equipment specifications and systems operating manuals.

6.5.3 Procedure documents, intended to be used as an active tool during marine operations should include a section which clearly shows their references to higher and lower level documents, and should list all inter-related documents. A document organogram is often helpful as shown in the following Figure.
6.5.4 Essential elements to be included in or referred to by a marine operation document include:

a. Introduction
b. Reference documents
c. Outline execution plan
d. Organogram and lines of command
e. Job-descriptions for key personnel
f. Safety plan
g. Authorities and permits including notification and approval requirements
h. Contractual approvals and hand over
i. Environmental criteria, including design and operational criteria
j. Operational bar chart, showing the anticipated duration of each activity, inter-related activities, key decision points, hold points
k. Specific step-by-step instructions for each phase of the operation including sequence, timing, resources and check lists
l. Reference to related drawings and calculations, e.g. environmental loads, moorings, ballast, stability, bollard pull
m. Contingency and emergency plans
6.5.5 Documents referred to by a marine operation procedure document should be available and accessible on board or on site close to the operation for reference by those involved.

6.5.6 The top level procedure document should define the On-Scene Commander in the event of an emergency situation and the interfaces between the various parties involved.

6.6 DOCUMENTATION AND CERTIFICATION

6.6.1 The applicable documentation and certificates shown in Table 6-1 shall be valid for the marine equipment proposed. Some documentation is mandatory to comply with international legislation and standards. The documentation and certification requirements for any particular structure, vessel or operation should be determined in advance. Where new documentation is needed, the issuing authority and the Rules to be applied should be identified.

Table 6-1 Principal Vessel Documentation

<table>
<thead>
<tr>
<th>Document / Certificate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridging Document</td>
<td>Recommended when the vessel’s operations are managed by more than one party. It outlines the vessel’s Safety Management System interface with that of the other parties and contains a responsibility matrix to provide clear guidance on operating principles and procedures for compliance and to ensure that the management onus is allocated. Should be signed by all concerned parties for acceptance.</td>
</tr>
<tr>
<td>Cargo Securing Manual</td>
<td>Provides guidance and specifies arrangements on stowage and securing of cargo. It accounts for the types of cargo and transverse, longitudinal and vertical forces which may arise during adverse weather and sea conditions that are likely to be experienced during the voyage. Approved by the Flag State.</td>
</tr>
<tr>
<td>Certificate for Civil Liability for Bunker Oil Pollution</td>
<td>Required for vessels over 1,000 gt. (gross tonnage). Generally issued by a P&amp;I (Protection &amp; Indemnity) Club.</td>
</tr>
<tr>
<td>Class (Hull and machinery)</td>
<td>Vessels and their machinery, built and maintained in accordance with the Rules of a Classification Society will be assigned a class in the Society’s Register Book, and issued with the relevant Certificates, which will indicate the character assigned to the vessel and machinery. Issued by the Classification Society. While it is desirable for vessel to be classed for insurance and condition purposes it is not generally a legal requirement for it to be classed as long as it has a valid load-line or load-line exemption certificate. In addition to Class Certificates the most recent Class Status report detailing the present status and list of outstanding class requirements shall be submitted.</td>
</tr>
<tr>
<td>Customs clearance</td>
<td>Issued by Customs confirming that so far as they are concerned the vessel is free to sail. Issued after light dues have been paid, and on production of various other mandatory documentation.</td>
</tr>
<tr>
<td>Garbage Management Plan</td>
<td>A plan for management of waste. It may be documented within the vessel’s Safety Management System and should be approved by the Vessel Operator /Manager.</td>
</tr>
<tr>
<td>g.t. / gross tonnage</td>
<td>See Tonnage Certificate</td>
</tr>
<tr>
<td>International Oil Pollution Prevention (IOPP)</td>
<td>Certifies that the vessel complies with international oil pollution regulations (MARPOL Annex 1). Unless stated otherwise, all vessels over 400 gt must comply with the requirements of the code. Issued by the Flag State, or the appointed Classification Society.</td>
</tr>
<tr>
<td>ISM Document of Compliance</td>
<td>Certificate issued to the Vessel Operator /Manager stating that the Company complies with the requirements of the ISM Code and is endorsed for the type of ship for which this applies. (Note: The vessel must belong to one of the stated types.)</td>
</tr>
<tr>
<td>Document / Certificate</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Lifesaving Appliances</td>
<td>Normally covered under Cargo Ship Safety Equipment Certificate. Where temporary equipment, e.g. liferafts or fire fighting equipment, is placed on a structure not in possession of a Cargo Ship Safety Equipment Certificate, it is expected that each item will be individually certified, with an in-date inspection.</td>
</tr>
<tr>
<td>Load Line</td>
<td>Issued after a vessel has been marked with her assigned load line marks. The Certificate gives details of the dimensions related to the freeboard, and the various special marks, e.g. TF (Tropical Fresh), WNA (Winter North Atlantic) etc. The vessel must be periodically inspected, to confirm that no changes have occurred to the hull or superstructure which would render invalid the data on which the assignment of freeboard was made. Issued by the Flag State, or appointed Classification Society.</td>
</tr>
<tr>
<td>Load Line Exemption</td>
<td>Where a vessel or structure is exempt from some or all of the provisions of the above, it may be issued with a Load Line Exemption Certificate, which will include any qualifying provisions. Issued by the Flag State, appointed Classification Society, or Port Authority.</td>
</tr>
<tr>
<td>MODU /MOU certificate</td>
<td>This may be a substitute for the Ship Safety Construction, Ship Safety Equipment and Safety Radio certificates</td>
</tr>
<tr>
<td>Navigation Lights and Shapes</td>
<td>Normally covered under Cargo Ship Safety Equipment Certificate. Where temporary lights are placed on a structure not in possession of a Cargo Ship Safety Equipment Certificate, it is expected that they will be individually certified, or in possession of a manufacturer’s guarantee of compliance.</td>
</tr>
<tr>
<td>Panama Canal documentation</td>
<td>For transit through the Panama Canal, drawings are required showing the extent of visibility from the bridge, and the extension of bilge keels, if fitted.</td>
</tr>
<tr>
<td>Registry</td>
<td>The Certificate of Registry is required by all commercial vessels. It contains the details from the Flag State Register in which the vessel has been registered, including principal dimensions, tonnage, and ownership. Issued by the Flag State Register.</td>
</tr>
<tr>
<td>Safe Manning document</td>
<td>A document issued by Flag State, showing the minimum safe manning for a vessel</td>
</tr>
<tr>
<td>Safety Management Certificate (SMC)</td>
<td>A document issued to a ship which signifies that the Company and its shipboard management operate in accordance with the approved Safety Management System. Issued by the Flag State, or appointed Classification Society.</td>
</tr>
<tr>
<td>Safety Radio Certificate</td>
<td>Issued by the Flag State after survey of the vessel’s radio installation, declaring that it is satisfactory for the intended service.</td>
</tr>
<tr>
<td>Ship Safety Construction</td>
<td>Covers the hull, machinery and equipment of a ship over 500 gt (gross tonnage) and shows that the ship complies with the construction and safety regulations applicable to the ship and the voyages she is to be engaged in. Issued by the Flag State, or appointed Classification Society.</td>
</tr>
<tr>
<td>Ship Safety Equipment</td>
<td>This is a record of the safety equipment carried on the vessel (over 500 gt), in compliance with SOLAS, including lifesaving appliances, fire fighting equipment, lights and shapes, pilot ladders, magnetic compass etc. Issued by the Flag State, or appointed Classification Society.</td>
</tr>
<tr>
<td>Ship Sanitation Control Certificate or Exemption Certificate (replaces De-rat)</td>
<td>Competent authorities use this document, which carries a six month period of validity, to identify and record all areas of ship-borne public health risks (not limited to rodents), together with any required control measures to be applied.</td>
</tr>
<tr>
<td>SOPEP</td>
<td>Shipboard Oil Pollution Emergency Plan - Class approved</td>
</tr>
<tr>
<td>Document / Certificate</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SPS (Special Purpose Ship) certificate</td>
<td>This may be a substitute for the Ship Safety Construction, Ship Safety Equipment and Safety Radio certificates</td>
</tr>
<tr>
<td>Tonnage Certificate</td>
<td>Shows the Tonnage as obtained by measurement, and is a measure of volume rather than weight. 1 ton equals 2.83 cu.m (100 cu.ft). Measured by a surveyor appointed by the Flag State.</td>
</tr>
<tr>
<td>Transportation or towing manual</td>
<td>A manual providing the Master with the key information that he needs, including the cargo and route. See Appendix G of 0030/ND, Ref. [9], for more details.</td>
</tr>
<tr>
<td>Trim and Stability booklet</td>
<td>A booklet setting out the vessel’s stability particulars, and allowing the actual draught, trim and stability characteristics and limitations to be determined for any cargo arrangement. Usually prepared by designers, and must be approved by the Flag State or a delegated Classification Society.</td>
</tr>
</tbody>
</table>
7 METOCEAN CRITERIA & FORECASTS

7.1 INTRODUCTION
7.1.1 This Section refers to the metocean criteria applicable for marine operations and transportations.
7.1.2 It may be impractical and/or uneconomic to design marine operations for extreme conditions. However, if the operational design levels are set too low the waiting time for acceptable conditions could be excessive.
7.1.3 A set of limiting metocean criteria should be established dependent on the duration of each discreet operation, which may be a weather-restricted or a weather-unrestricted operation as defined in Section 3. Reference may be made to ISO 19901-1, Ref. [30], for weather-unrestricted operations.
7.1.4 Weather-unrestricted operations are addressed in Section 7.2. For weather-restricted operations see Section 7.3 and for weather/metocean forecasts see Section 7.4.

7.2 METOCEAN CRITERIA (UNRESTRICTED OPERATIONS)

7.2.1 DESIGN AND OPERATIONAL CRITERIA
7.2.1.1 For each specific phase of marine construction and for critical operations in a marine operation, the design and operational metocean criteria shall be defined. Design (metocean) criteria are generally used for analysis to a recognised standard (using relevant safety factors). For weather-restricted operations the operational (metocean) criteria are reduced below the criteria used for design to allow for weather forecasting inaccuracies (see Section 7.3.3).

NOTE: Operating limits for personnel transfers, assisting vessels, ROV's, etc. are usually derived from past experience of similar operations (often with built-in safety factors). In some cases these can be more limiting than the design criteria.

7.2.2 RETURN PERIODS
7.2.2.1 For design criteria for moorings see Section 7 of 0032/ND, Ref. [11]. The return periods for any marine operation, apart from moorings, should be related to its operational reference period, as defined in Section 3. As general guidance, the following criteria may be applied provided that the independent extremes are considered concurrently:

<table>
<thead>
<tr>
<th>Duration of use</th>
<th>Design environmental criteria (for independent extremes - see Section 7.2.2.2 for joint probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3 days</td>
<td>Specific weather window. The Metocean Reduction Factors in Section 7.3.3 should be considered when selecting the design criteria.</td>
</tr>
<tr>
<td>3 days to 1 month</td>
<td>10 year return independent extremes, seasonal, or using a reduced exposure towage/transportation computation (as defined in Section 3) with a minimum of the 1 year seasonal return</td>
</tr>
<tr>
<td>1 month to 1 year</td>
<td>10 year return independent extremes, seasonal</td>
</tr>
<tr>
<td>More than 1 year</td>
<td>50 year return independent extremes, all year</td>
</tr>
</tbody>
</table>

7.2.2.2 If conditions are determined using the joint probability of different parameters, then the return period should be increased by a factor of 4 i.e. 10 years to say 50 years and 50 years to 200 years, unless the loadings are dependent on a single parameter in which case the value of that parameter shall be taken from a joint probability combination in which it is maximised.

7.2.2.3 For towages or transportations, the design extremes may be reduced below the 10 year seasonal return, to give the same probability of encounter as a 30 day exposure to a 10 year seasonal storm. In this case the “adjusted” design extremes are defined in terms of the 10% risk level (see Section 6.4 of 0030/ND, Ref. [9]. The design extremes shall not be reduced below the 1 year seasonal return.

7.2.2.4 Directionality of the environment may be considered.
7.2.3 WIND

7.2.3.1 The design wind speed shall generally be the 1 minute mean velocity at a reference height of 10m above sea level. A longer or shorter averaging period may be used for design depending upon the nature of the operation, the structure involved and the response characteristics of the structure to wind.

7.2.3.2 The relationship between wind velocity at the reference and actual elevations above sea level and between different averaging periods can be found in ISO 19901-1 "Metoean design and operational considerations", Ref. [30].

7.2.4 WAVES

7.2.4.1 The design maximum wave shall be the most probable highest individual wave in the design seastate, assuming an exposure of 3 hours. The determination of the height, period and crest elevation of the maximum wave should be determined from an appropriate higher-order wave theory and account for shallow water effects.

7.2.4.2 Seastates shall include all relevant spectra up to and including the design storm seastate for the construction site or towage route. Long-crested seas shall be considered unless there is a justifiable basis for using short-crested seas or these are more critical. Consideration should be given to the choice of spectrum.

7.2.4.3 In the simplest method the peak period ($T_p$) for all seastates considered, should be varied as:

$$\sqrt{(13.9) < T_p < \sqrt{(30.0)}}$$

where $H_{sg}$ is in metres, $T_p$ in seconds. The effects of swell should also be considered if not already covered in this peak period range. A reduced range of $T_p$ may be used if the route specific data and natural periods allow.

However, this method incorrectly assumes that all periods are equally probable. As a result this method should generally produce higher design responses than would be the case when using the more robust $H_{sg}$-$T_p$ method described in the following Section 7.2.4.4.

7.2.4.4 In the alternative method, a contour is constructed within the $H_{sg}$-$T_p$ plane that identifies equally probable combinations of $H_{sg}$ & $T_p$ for the design return period subject to the constraints of the wave breaking. This contour should also cover swell. $H_{sg}$-$T_p$ combinations from around the contour should be tested in motion response calculations to identify the worst case response (there is no need to consider a range of $T_p$ with each $H_{sg}$).

7.2.4.5 The relationship between the peak period $T_p$ and the zero-up crossing period $T_z$ is dependent on the spectrum. For a mean JONSWAP spectrum ($\gamma=3.3$) $T_p/T_z = 1.286$; for a Pierson-Moskowitz spectrum ($\gamma=1$) $T_p/T_z = 1.41$.

7.2.4.6 The following Table 7-2 indicates how the characteristics of the JONSWAP wave energy spectrum vary over the range of recommended seastates. The constant, $K$, varies from 13 to 30 as shown in the equation in Section 7.2.4.3 above. $T_i$ is the mean period (also known as $T_m$).

<table>
<thead>
<tr>
<th>Constant $K$</th>
<th>$\gamma$</th>
<th>$T_p/T_z$</th>
<th>$T_p/T_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>5.0</td>
<td>1.24</td>
<td>1.17</td>
</tr>
<tr>
<td>14</td>
<td>4.3</td>
<td>1.26</td>
<td>1.18</td>
</tr>
<tr>
<td>15</td>
<td>3.7</td>
<td>1.27</td>
<td>1.19</td>
</tr>
<tr>
<td>16</td>
<td>3.2</td>
<td>1.29</td>
<td>1.20</td>
</tr>
<tr>
<td>17</td>
<td>2.7</td>
<td>1.31</td>
<td>1.21</td>
</tr>
<tr>
<td>18</td>
<td>2.4</td>
<td>1.32</td>
<td>1.23</td>
</tr>
<tr>
<td>19</td>
<td>2.1</td>
<td>1.34</td>
<td>1.24</td>
</tr>
<tr>
<td>20</td>
<td>1.8</td>
<td>1.35</td>
<td>1.25</td>
</tr>
<tr>
<td>21</td>
<td>1.6</td>
<td>1.36</td>
<td>1.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constant $K$</th>
<th>$\gamma$</th>
<th>$T_p/T_z$</th>
<th>$T_p/T_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1.4</td>
<td>1.37</td>
<td>1.27</td>
</tr>
<tr>
<td>23</td>
<td>1.3</td>
<td>1.39</td>
<td>1.28</td>
</tr>
<tr>
<td>24</td>
<td>1.1</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>25</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>26</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>27</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>28</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>29</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
<tr>
<td>30</td>
<td>1.0</td>
<td>1.40</td>
<td>1.29</td>
</tr>
</tbody>
</table>
7.2.4.7 For operations involving phases sensitive to extreme sea states, such as temporary on-bottom stability or green water assessment, the maximum wave height and associated period should be used.

7.2.4.8 For precise operations sensitive to small fluctuations of the sea level even under calm sea state conditions, the occurrence of long period, small amplitude swell on the site should be checked and its effects on the operations evaluated.

7.2.4.9 Attention should also be paid to areas prone to strong currents acting against the waves which would amplify the steepness of the sea state (i.e. reduce the wave encounter period that drives dynamic response).

7.2.5 CURRENT
7.2.5.1 The design current shall be the rate at mean spring tides, taking account of variations with depth and increases caused by the design storm and storm surge.

7.2.5.2 Currents may be divided into two different categories:
   a. Tidal currents
   b. Residual currents that remain when the tidal component is removed, including river outflows, surge, wind drift, loop and eddy currents.

7.2.5.3 Tidal currents may be predicted reliably, subject to long term measurement (at least one complete lunar cycle at the same season of the year as the actual planned operation). Residual currents may only be reliably predicted or forecast using sophisticated mathematical models.

7.2.6 OTHER PARAMETERS
7.2.6.1 Other factors including the following may be critical to the design or operations and should be addressed:
   a. Water level including tide and surge
   c. Sea icing, icing on superstructure
   d. Exceptionally low temperature
   e. Large temperature differences
   f. Water density and salinity
   g. Bad visibility.

7.3 WEATHER RESTRICTED OPERATIONS
7.3.1 GENERAL
7.3.1.1 A marine operation with an operational reference period (as defined in Section 3) generally less than 72 hours may be classed as a weather-restricted operation. The design environmental conditions for such an operation may be set independent of extreme statistical data, provided that:
   • The statistics indicate an adequate frequency and duration of the required weather windows
   • Dependable weather forecasts are received at appropriate intervals
   • The start of the operation is governed by an acceptable weather forecast, covering the operational reference period
   • Adequate marine and contingency procedures are in place.

7.3.1.2 A marine operation with an operational reference period greater than 72 hours may exceptionally be classed as a weather-restricted operation, provided that:
   • An acceptable weather forecast service is contracted and is available for advice at any time
   • Dependable weather forecasts are received at appropriate intervals
   • Management resources of interested parties are always available with the right authority level to monitor any operation decisions
   • Adequate marine and contingency procedures are in place
A risk assessment has been carried out and the results accepted by GL Noble Denton. The quality of data available and weather forecasts for the area and season should influence the assessment of overall risk.

7.3.2 IMPACT ON DESIGN
7.3.2.1 During design the following should be considered:
   a. Measures to minimize the duration of critical activities, without compromising the safety of the operation, in order to provide more margin on the weather window
   b. Re-design of the operation and/or structure so that higher metocean conditions can be safely sustained
   c. Contingency situations, and back-up and stand-by measures
   d. Whether delays to previous activities could push the operation into an unfavourable season.

7.3.3 MARGINS ON WEATHER
7.3.3.1 To undertake any operation, the Operational Criteria™ shall be less than the Design Criteria. The margin is a matter of judgement, dependent on factors specific to each case.

7.3.3.2 Unless agreed otherwise with GL Noble Denton, for marine operations with Operational Reference Periods of less than 72 hours the maximum forecast wave height for each phase of the operation shall not exceed the design wave height for that phase multiplied by the applicable factor from Table 7-3 below. The forecast wind and current shall be similarly considered when their effects on the operation or structure are significant. Forecasts, especially for Operational Reference Periods over 24 hours, should have a high confidence level.

<table>
<thead>
<tr>
<th>Table 7-3</th>
<th>Metocean Reduction Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>Weather Forecast Provision</td>
</tr>
<tr>
<td>1</td>
<td>No project-specific forecast (i.e. public domain forecast only)</td>
</tr>
<tr>
<td>2</td>
<td>One project-specific forecast source</td>
</tr>
<tr>
<td>3</td>
<td>Two project-specific forecast sources</td>
</tr>
<tr>
<td>4</td>
<td>One project-specific forecast source plus in-field wind and wave monitoring (e.g. wave rider buoy) without regular feedback to forecast source</td>
</tr>
<tr>
<td>5</td>
<td>Two project-specific forecast sources plus in-field wind and wave monitoring (e.g. wave rider buoy) without regular feedback to forecast source</td>
</tr>
<tr>
<td>6</td>
<td>as #4 but with regular feedback to forecast sources</td>
</tr>
<tr>
<td>7</td>
<td>as #5 but with regular feedback to forecast sources</td>
</tr>
<tr>
<td>8</td>
<td>Two project-specific forecast sources plus in-field wind and wave monitoring &amp; offshore meteorologist</td>
</tr>
<tr>
<td>9</td>
<td>Two project-specific forecast sources plus in-field wind and wave monitoring &amp; offshore meteorologist</td>
</tr>
</tbody>
</table>

7.3.3.3 The Operational Reference Period (as defined in Section 3) shall include a contingency duration determined with due allowance for the nature and criticality of the individual operations in the Operational Reference Period (safe to safe).
7.3.4 OPERATION DURATION AND OPERATIONAL REFERENCE PERIOD

7.3.4.1 When defining the Operational Reference Period (weather window) required for a weather-critical marine operation, the schedule should be as realistic as possible. The Operational Reference Period should be the best-estimate Operation Duration plus contingencies for:

a. Inaccuracy in operation schedule. For schedules based on field experience gained from previous similar operations it is possible that a lower contingency can be justified.

b. Technical / mechanical / operational delays. For operations using vulnerable or critical equipment extra contingency should be allowed.

c. Inaccuracy in the timing and length of window predicted by the metocean forecast. Extra contingency can be necessary for operations where metocean conditions are difficult to predict because of the area or the time of the year.

7.3.4.2 For situations where a contingency duration has not been defined, the contingency duration shall be at least the Operation Duration (as defined in Section 3) with a minimum of 6 hours. Where subsea operations are required the contingency shall be at least twice the Operation Duration.

7.3.4.3 The forecast window duration should be in excess of the Operational Reference Period.

7.3.5 POINT OF NO RETURN (PNR)

7.3.5.1 Weather-restricted operations may be divided into sequences where the operation can be aborted and brought to a safe condition within the remainder of the existing weather window.

7.3.5.2 The Point of No Return (PNR) should be defined as the last point in time, or a geographical point along a route, at which an operation can be aborted and returned to a safe condition.

7.3.5.3 For the critical operation period between any PNR and the structure reaching a safe condition, the reliability of the weather window and forecast is crucial.

7.4 WEATHER / METOCEAN FORECASTS

7.4.1 GENERAL

7.4.1.1 Project specific forecasts shall be obtained before and during all marine operations. The forecast shall be issued at suitable regular intervals dependent on the operation, and at least every 12 hours. Wherever possible a second forecast should be obtained from an independent source before critical operations.

7.4.1.2 For complex and/or longer weather-restricted operations, the forecaster(s) should preferably be present at site to check the local situation and provide regular weather briefings. Reference may be made to the Handbook of Forecasting Services, Ref. [36].

7.4.2 FORECAST PARAMETERS

7.4.2.1 The forecast should cover short, medium term and outlook periods and include relevant parameters such as:

a. Synopsis, barometric pressure, temperature
b. Wind direction and velocity
c. Waves and swell - significant and maximum height, direction and period
d. Visibility, rain, snow, sleet, icing and sea ice
e. Confidence level of the forecast and each of the key parameters.

7.4.2.2 Other conditions such as current, tide and surge can be relevant to certain operations. Such conditions can require real time measurement as well as regular forecasting before and during operations. Attention should be paid to local current phenomenon, for instance:

a. Loop-eddy currents in the Gulf of Mexico
b. Soliton currents in the South China Sea.
7.4.3 ON SITE MONITORING

7.4.3.1 Where operations are sensitive to local environmental conditions, or to changes in these, means for on-site monitoring should be considered (see Table 7-3).

7.5 BENIGN WEATHER AREAS

7.5.1 Areas considered benign are shown in the following Table 7-4 and Figure 7-1 for different months. In general they have the following characteristics:

a. virtually free of monsoons, Tropical Revolving Storms or Tropical Cyclones
b. exceeding Beaufort Force 5 for <20% of any month (in a “typical” year)
c. However these areas may experience sudden vicious squalls and very rare tropical storms or cyclones.

Table 7-4 Northern & Southern Boundaries of Benign Weather Areas by Month

<table>
<thead>
<tr>
<th>Basin</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Atlantic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20'N</td>
<td>15'N</td>
<td>10'N</td>
<td>9'N</td>
<td></td>
<td></td>
<td>13'N</td>
<td>15'N</td>
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<tr>
<td>Red Sea</td>
<td>23'N</td>
<td>coast</td>
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<td></td>
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<tr>
<td>Arabian Gulf</td>
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<tr>
<td>Arabian Sea (see Note 1)</td>
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<tr>
<td>Bay of Bengal</td>
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<tr>
<td>Northeast Pacific (see Note 2)</td>
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<td></td>
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</tr>
<tr>
<td>Northwest Pacific to 160°W</td>
<td>4'N</td>
<td>8'N</td>
<td>4'N</td>
<td>7'N</td>
<td>5'N</td>
<td>4'N</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>South Atlantic</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>South Indian</td>
<td>7'S</td>
<td>9'S</td>
<td>8'S</td>
<td>6'S</td>
<td>5'S</td>
<td>7'S</td>
<td>15'S</td>
<td>5'S</td>
<td>7'S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW Pacific from 125°E to 130°W</td>
<td>8'S</td>
<td>10'S</td>
<td>8'S</td>
<td>7'S</td>
<td>23'S</td>
<td>8'S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Southeast Pacific to 130°W</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23'S</td>
</tr>
</tbody>
</table>

Key: All year boundary | Intermediate boundary | Maximum area boundary

Note 1: The boundary between the Arabian Sea and Bay of Bengal is assumed to be 75°E.
Note 2: The Northeast Pacific is from 160°W to the American coast but 88°W for May to November inclusive.
Note 3: The equator is the Southern boundary for areas in the Northern hemisphere and the Northern boundary for areas in the Southern hemisphere.
Figure 7-1 Map Showing Benign Weather Areas
8 WEIGHT CONTROL

8.1 INTRODUCTION
8.1.1 A Not To Exceed (NTE) weight shall be defined for any part or all of the structure for any phase when too high a weight could be critical.

8.1.2 In addition to any in-place design and operational considerations, the following factors may control the not-to-exceed weight:
   a. Draught and stability for float-out, towages, matings and installation
   b. Allowable stresses in the structure for marine operations.
   c. Crane, load-out trailers or other equipment or ground-bearing limitations, e.g. for load-out or installation.

8.1.3 Weight control shall be performed by means of a well-defined and documented system, complying with the ISO International Standard ISO 19901-5 – Petroleum and Natural Gas Industries – Specific requirements for offshore structures – Part 5: Weight control during engineering and construction, Ref. [31].

8.1.4 Ref. [31] states (inter alia) that:
   - “Class A (weight control) will apply if the project is weight- or CoG-sensitive for lifting and marine operations or during operation (with the addition of temporaries), or has many contractors with which to interface. Projects may also require this high definition if risk gives cause for concern”.
   - “Class B (weight control) shall apply to projects where the focus on weight and CoG is less critical for lifting and marine operations than for projects where Class A is applicable”.
   - “Class C (weight control) shall apply to projects where the requirements for weight and CoG data are not critical”.

8.2 WEIGHT CLASS
8.2.1 Unless it can be shown that a particular structure and all its marine operations are not weight or CoG sensitive, then Class A weight control definition is required, as shown in Section 4.2 of ISO 19901-5, Ref. [31].

8.3 RESERVES
8.3.1 For calculation purposes conservative values of weight and CoG should be used. It should be noted that some calculation results, e.g. transportation motions, may be more critical with a lower value of weight and lower CoG.

8.3.2 Where an operation is likely to be CoG sensitive, the extremes of the CoG envelope shall be considered in calculations.

8.3.3 An adequate reserve shall be added to the 50/50 weight estimate, as defined in Ref. [31] to suit each particular operation considering the weight and CoG sensitivity and the maturity of the project design. In general, the reserve applied to the final 50/50 weight estimate should be not less than 5%.

8.3.4 Where structures or components are weighed, a reserve of not less than 3% should be applied to the final weighed weight, unless it can be demonstrated that the weighing method and equipment have an overall accuracy better than this figure.

8.4 WEIGHT CONTROL REPORTS & AUDITS
8.4.1 Prior to any structure being weighed, a predicted weight and CoG report shall be issued, so that the weighed weight and CoG can immediately be compared with the predicted results. Any significant discrepancies and their effects on the final weight shall be investigated.

8.4.2 If any changes take place after weighing or final weight calculation the effect of any weight changes on the operational procedures shall be assessed, and the procedures modified if necessary.
8.4.3 The final derived weight and CoG values shall be submitted. A statement may be required from a responsible engineer confirming that the structure and the lifting equipment, seafastenings, etc. remain adequate for the final weight and CoG.

8.4.4 When the installation of a large number of nominally identical items is to be approved, the weight control programme should be documented to show the effects of all potential variations on the final weights and the results certified by a competent person.

8.4.5 During construction afloat, periodic draught measurements and weight control audits and inclining tests shall be carried out when a particular structure and its marine operations are weight or CoG sensitive, particularly prior to critical operations such as deck mating.

8.4.6 See Section 14.1.2 for weight control for decommissioning/removal.

8.5 WEIGHT AND BUOYANCY CONTROL

8.5.1 Where the balance between weight and buoyancy is critical to the draught, stability or floating behaviour, the dimensional and buoyancy control and monitoring shall be maintained to an appropriate degree of accuracy.
9 STRUCTURAL STRENGTH

9.1 GENERAL

9.1.1 The structural strength of the final structure in the installed condition is the responsibility of the assured and would normally be verified and accepted by the certifying authority. The Marine Warranty Surveyor takes no responsibility for the installed condition unless the Marine Warranty Survey scope specifically addresses this case e.g. for jack-up site approval.

9.1.2 Although a Marine Warranty Surveyor does not certify the final structure he shall ensure that the load cases relevant to load-out, construction afloat, towage, transportation and installation are suitably addressed in the design.

9.1.3 The loadings used for structural strength assessment should be determined in accordance with the requirements of the applicable Code(s), Standard(s) and Guideline(s). It is important to recognise that the metocean design criteria used to determine the loads applicable to Weather-Restricted operations will be greater than the Operation Criteria limits that apply to (each phase of) the operation. This is due the requirement to apply a metocean reduction factor in accordance with Section 7.3.3.

9.2 STRUCTURAL STEEL

9.2.1 The primary structure and any critical temporary works like lifting attachments, spreader bars and seafastenings shall be of high quality structural steelwork with full material certification and NDT inspection certificates showing appropriate levels of inspection. It shall be assessed using the methodology of a recognised and applicable offshore code including the associated load and resistance factors for LRFD codes or safety factors for ASD/WSD codes.

9.2.2 Traditionally AISC has also been considered a reference code, e.g. by API RP2A. Although specifically not recommended by API 22nd edition, if the ANSI / AISC 360-10 American National Standard “Specification for Structural Steel Buildings” of June 2010 (in the AISC 14th edition) is used, the allowables shall be compared against member stresses determined using a load factor on all loads (dead, live, environmental, etc.) of no less than those detailed in the following Table 9-1.

<table>
<thead>
<tr>
<th>Table 9-1 Load Factors for use with AISC 14th Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Limit State 1 (LS1):</td>
</tr>
<tr>
<td>Limit State 2 (LS2):</td>
</tr>
</tbody>
</table>

Note: The load factor of 0.75 for the WSD/LS2 case arises because the basic allowable stress in AISC WSD 14th edition is 0.6*yield and the traditional 1/3 increase to 0.8*yield (i.e. to 0.6*yield*4/3) for environmental load cases is not included. As an alternative, the load is multiplied by 3/4 and used with the standard allowable of 0.6*yield in order to achieve the safety levels that have been used and accepted over many years.

9.2.3 Stress in fillet welds for brackets loaded by a force acting in a direction parallel to the weld bead shall be assessed using the method presented in Appendix A. The allowables shall be compared against member stresses determined using a load factor on both dead and live loads of no less than

- LS1: 1.40
- LS2: 1.05

9.2.4 Any load case may be treated as a gravity-load dominated limit state (LS1).
9.2.5 The infrequent load cases, generally limited to survival and damaged cases, including design cases for weather-restricted operations where a metocean reduction factor according to Table 7-3 is to be applied, may be treated as an LS2, environmental load dominated, case. This does not apply to:

- Steelwork subject to deterioration and/or limited initial NDT unless the condition of the entire loadpath has been verified, for example the underdeck members of a barge or vessel.
- Steelwork subject to NDT prior to elapse of the recommended cooling and waiting time as defined by the Welding Procedure Specification (WPS) and NDT procedures. In cases where this cannot be avoided by means of a suitable WPS, it may be necessary to increase the strength or impose a reduction on the design/permissible seastate.
- Steelwork supporting sacrificial bumpers and guides.
- Spreader bars, lift points and primary steelwork of lifted items.
- Structures during a load-out.

9.2.6 The design of non-tubular connections shall be in accordance with an appropriate standard such as AISC Ref. [13], using a consistent safety format and factors.

9.3 FILLET WELDS
9.3.1 Appendix A gives the requirements for checking fillet welds.

9.4 DOUBLER PLATES
9.4.1 Doubler plates are generally recommended for use:

a. when attaching seafastenings or sacrificial anodes to permanent steel work subject to fatigue or if the permanent structure could be damaged when the attachments are burnt off after use.

b. To avoid welding onto other welds.

9.4.2 Doubler plates are generally NOT recommended for use when tension can cause overstress in the doubler plate or the structure to which it is attached.

9.5 BOLTED CONNECTIONS FOR SEAFASTENINGS
9.5.1 Appendix B gives the requirements for bolted connections for seafastenings which involving cyclic loading due to the dangers of progressive collapse.

9.6 LIGHT-WEIGHT METALLIC AND COMPOSITE STRUCTURES
9.6.1 Different light weight metallic and composite materials will have their own advantages, disadvantages and problems. The designers or manufacturers shall specify any handling /connection requirements which must appear in the relevant procedures and towing /transportation manuals.

9.6.2 Tugger line systems are very important while handling lightweight alloy items in order to avoid any impact with sea-fastening, grillage or offshore structures which may cause plastic deformations.

9.6.3 A structural assessment of an innovative structure and/or material cargo during temporary stages may not always be available for GL Noble Denton to review due to confidentiality concerns. In this case, after agreement with the Insurance Underwriter and the Client, GL Noble Denton may accept an official document from the designer stating maximum allowable loads from the seafastenings and allowable accelerations for the structure /cargo to keep within allowable stresses during transport or installation. Alternatively one of the parties may confirm that they will take responsibility in case of blade damage during load-out, transport or installation.

9.7 STRUCTURAL CONCRETE
9.7.1 The strength of concrete and its reinforcement including any pre- or post-tensioning shall comply with a recognised and appropriate concrete design code, such as those listed in ISO 19903, Ref [32]. Any time-dependent properties of the materials shall be taken into account.
9.8 COMPRESSED AIR

9.8.1 Compressed air may be used to resist hydrostatic head on internal or external walls during ballasting, for reducing draft, or for reducing overall bending moments by air cushions in skirt cells under well controlled conditions. However its absence should not, in general, result in structural collapse i.e. it should be used only to increase structural safety factors.

9.8.2 Where the requirements of Section 9.8.1 cannot be met, then a risk assessment shall be carried out to determine possible causes and probabilities of loss of compressed air. Mitigating measures to reduce the risks to an acceptable level shall be agreed with GL Noble Denton.
10 BUILDING / CONSTRUCTION BASIN

10.1 The surrounding walls of any building / construction basin shall be designed in accordance with accepted civil and geotechnical engineering practice, guidelines, codes and standards.

10.2 Where materials are used whose stability characteristics can be affected by a change in pore water pressure, suitable monitoring devices shall be installed and the data retrieved and analysed by competent geotechnical engineers to ensure continuing stability of the walls throughout the period of the platform construction.

10.3 Meteorological design criteria for the basin design shall be at least the 100 year independent extremes.

10.4 Consideration shall be given to the design of the basin walls, including but not limited to the following:
   a. The integrity of the walls shall remain stable when subjected to:
      - The highest astronomical tide, plus
      - Storm surge, plus
      - Maximum wave crest height, corrected for shoaling and run-up if applicable.
   b. The walls shall be of adequate height to prevent overtopping, except by spray, in the above conditions.
   c. Walls shall be protected against the effects of collision, scour (including propeller scour) and wave action.
   d. The effects of ice loading shall be considered when applicable.
   e. Mooring and winching loads.
   f. Equipment /crane loads on the edges and around the edges of the basin.

10.5 Pumping capacity shall be adequate for maximum seepage, rainfall (including run-off from surrounding land) and spray overtopping and allow for loss of pumps or power sources.
11 TOW-OUT FROM DRY-DOCK / BUILDING BASIN

11.1 MOORING AND HANDLING LINES
11.1.1 If the structure is to remain afloat at moorings inside the dock or basin, then the moorings shall be designed in accordance with 0032/ND, Ref. [11], taking into account the weather criteria of Section 7.2.2.

11.1.2 Handling lines and winching equipment shall be designed to withstand the design loads arising, assuming that handling operations are weather-restricted operations. All wires shall be designed to a safety factor on certified breaking load of not less than 3.0. Connections to the structure and to the shore shall be designed in accordance with 0032/ND, Ref. [11].

11.2 UNDERKEEL CLEARANCE FOR LEAVING BASIN
11.2.1 If the unit is likely to be at moorings in the dock or basin at maximum draught for any significant time, the effects of siltation and negative surge shall be considered.

11.2.2 When moored in, or leaving the dock or basin, the unit shall have a minimum underkeel clearance, using tidal rise if necessary, of at least 0.5 metres for a period adequate for float-out, including contingencies. This would normally be of the order of 3 hours before, to 3 hours after high water. The planned float-out operation, excluding contingencies, should normally be planned to be completed before high water.

11.2.3 Compressed air may be used to reduce draught if required, subject to the requirements of Section 9.8.

11.2.4 A tide gauge shall be installed on site to check that actual tidal levels correspond to those predicted.

11.2.5 At least 4 visible draught scales shall be painted on or fixed to the structure

11.3 SIDE CLEARANCES
11.3.1 Depending on the positional control of the unit during the exit of the basin, the channel width at full depth should normally be not less than:

$$1.2 \times B \quad \text{when inside the basin, and}$$

$$2.0 \times B \quad \text{when out of the basin},$$

where B = maximum structure dimension, normal to the direction of travel.

11.3.2 The required channel width may be reduced if the unit is winched out along a fendered guide.

11.3.3 The required channel width may need to be increased if tugs are used.

11.4 UNDERKEEL CLEARANCE OUTSIDE BASIN
11.4.1 Once outside the building basin the minimum underkeel clearance shall be as required by Section 14.20 of 0030/ND, Ref. [9] until final emplacement.

11.5 TOWAGE AND MARINE CONSIDERATIONS
11.5.1 Tugs, towage and marine considerations for tow out of dock shall be in accordance with 0030/ND, Ref. [9].

11.5.2 An exclusion zone for marine traffic should be agreed with the Port Authority and any other relevant authorities.
12.1 GENERAL

12.1.1 Regardless of any requirement to change draught during construction, towage or installation operations, floating structures should be fitted with a means of pumping out water from all compartments. Any special cases where this does not apply shall be agreed with GL Noble Denton and may be subject to a specific risk assessment.

12.1.2 All ballasting procedures shall, wherever possible, be reversible so that, in case of emergency, the unit can be returned to a safe draught within 24 hours. If this is not feasible (for instance if there is an unstable phase during submersion before installation) then a risk assessment shall be carried out to demonstrate the acceptability of the system and procedures and submitted for GL Noble Denton approval.

12.2 REDUNDANCY

12.2.1 The design of the ballasting system shall be such that the failure of any one valve to open or close, or the fracture of any pipe, will not cause flooding of the unit, or failure to flood when required.

12.2.2 All remotely controlled valves shall be capable of operation by a secondary, preferably manual system. Any automatic or radio controlled system shall have a manual override system.

12.2.3 The secondary valve operation system may be by ROV, provided that ROV access and a suitable ROV are available at all stages of the operation. The time for the ROV to get to and operate the valve shall ensure that the valve can be operated before the flow through it is critical.

12.2.4 Sufficient redundancy of pumps, power supplies, cross-over pipework and instrumentation shall be provided so that essential operations can continue in the event of failure of any one component or system.

12.3 INLETS

12.3.1 All internal and external inlets shall be adequately protected to prevent damage by entering debris and cables. All internal compartments must be cleaned of debris before immersion or towage starts.

12.3.2 Except when in use for inlet or discharge, all openings to sea shall be protected by a double barrier.

12.3.3 Any external valves and pipework shall be protected against collision and fouling by towlines, mooring lines or handling wires.

12.4 PIPEWORK

12.4.1 All essential pipework shall be of permanent-type construction and hydrostatically tested to a minimum of 1.3 times the design pressure.

12.4.2 Temporary flexible hoses are not generally permitted. Where their use cannot be avoided, for instance for supply of back-up compressed air from a compressor barge alongside, then a risk assessment shall be carried out to demonstrate the acceptability of the system and submitted for GL Noble Denton approval.

12.5 UMBILICALS

12.5.1 If umbilicals are necessary to provide power and/or hydraulic services during any marine operation, adequate back-up capability shall be provided, and fail-safe systems shall be incorporated into critical controls.
13 USE OF DP VESSELS

13.1 BACKGROUND

13.1.1 A DP (Dynamic Positioning) control system automatically maintains a vessel’s position by using its propulsion units. The position and heading (either absolute or relative to another vessel) are determined from a number of independent reference systems including DGPS, taut wire, laser based (e.g. Fanbeam or CyScan), radar (e.g. Artemis, RadaScan, RADius), acoustic transponders (e.g. ultra or super-short baseline or long base line). The position of each sensor on the vessel needs to be known so that corrections due to trim, heel etc can be made. The results from each reference system are factored to allow for possible system errors and these factors are constantly adjusted in the light of discrepancies from the positions calculated by each other system in operation.

13.1.2 The forces on the vessel from wind, waves and currents are also constantly calculated using the results from other sensors and these, together with the offset from the required position, are used to calculate and control the required thrust vector for each propeller or thruster to maintain position.

13.1.3 Unknown forces on the vessel, or erroneously calculated forces, can arise from many causes including:

a. Mooring or fender loads from vessels alongside
b. Collisions with other vessels or structures
c. Horizontal forces caused when a load is lowered onto stabbing guides on another structure or vessel.
d. Forces from towing (including ploughs or trenchers)
e. Helicopter down-draught affecting wind measurement sensors
f. Horizontal reactions from the seabed on a jack-up leg when the leg engages with the seabed.
   
   On extracting legs, there will be a similar loss of an unknown restraining force from the soil.

In each case the control system will tend to react against the unknown force, often producing detrimental effects. In these cases the gain for the relevant measuring system may need to be reduced, or other procedures implemented before a loss of position occurs.

13.2 DP EQUIPMENT CLASSES

13.2.1 The following Table shows IMO definitions (from Ref. [28]). The table also shows operations which were formerly associated with NMD consequence class requirements for the 3 main classes of DP. These former NMD requirements were intended to be a useful guide for the choice of IMO Equipment Class depending on the severity consequences that would follow a loss of position.
Table 13-1 DP Equipment Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>IMO Definition</th>
<th>Former NMD requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loss of position may occur in the event of a single fault. (This class is unlikely to be suitable for most operations approved by a MWS)</td>
<td>Operations where loss of position keeping capability may cause damage or pollution of small consequence.</td>
</tr>
<tr>
<td>2</td>
<td>Redundancy so that no single fault in an active system will cause the system to fail. Loss of position should not occur from a single fault of an active component or system such as generators, thruster, switchboards, remote controlled valves etc., but may occur after failure of a static component such as cables, pipes, manual valves etc.</td>
<td>Operations where loss of position keeping capability may cause personnel injury, pollution, or damage with large economic consequences.</td>
</tr>
<tr>
<td>3</td>
<td>As for Class 2 but which also has to withstand fire or flood in any one compartment without the system failing. Loss of position should not occur from any single failure including a completely burnt fire sub division or flooded watertight compartment.</td>
<td>Operations where loss of position keeping capability may cause fatal accidents, or severe pollution or damage with major economic consequences.</td>
</tr>
</tbody>
</table>

13.2.2 Vessels with DP1 class should not operate within a 500 m statutory exclusion zone unless suitable provision has been in its vessel-specific CAMO (Critical Activity Mode of Operation) and its ASOG (Activity Specific Operations Guidelines).

13.3 SYSTEM DESIGN & CAPABILITY

13.3.1 Any vessel operating on DP should comply with the following:

a. The DP system should be designed, equipped and operated in accordance with IMO MSC/Circ.645 – “Guidelines for Vessels with Dynamic Positioning Systems”, Ref. [28].

b. The required DP equipment class for a pipelay vessel should be in accordance with DNV-OS-F101, Ref. [15], Section 10, Clause C500.

c. The vessel’s DP FMEA should meet the standards of detail and analysis in the following industry guidance:
   - IMCA M 166 “Guidance on Failure Modes and Effects Analysis”, Ref. [22],
   - IMCA M 178 “FMEA Management Guide”, Ref. [23]
   - MTS “DP Vessel Design Philosophy Guidelines”, Ref. [34].

d. A DP Capability Analysis should be provided which meets the standards contained in IMCA M 140 “Specification for DP Capability Plots”, Ref. [20].

e. There should be a valid CMID (Common Marine Inspection Document), IMCA M 149, Ref. [21], from a recognized independent auditing organization.

f. The vessel should have an Annual DP Trials programme which meets the standards given in IMCA M 190 “Guidance for Developing and Conducting Annual DP Trials Programmes for DP Vessels”, Ref. [24], and should provide historical evidence of having conducted Annual DP Trials.

13.4 DP2 OR DP3 CLASS

13.4.1 Vessels with DP class notations equivalent to IMO Equipment Class 3 should offer a higher level of fault tolerance than vessels with DP class notations equivalent to IMO DP Equipment Class 2.

13.4.2 Vessels with DP Class 3 equivalent notations should be used in operations where the consequences of a loss of position are considered to have a reasonable potential to result in death, substantial structural damage or significant environmental pollution. As a general guide, operations in this
category could include drilling, diving support, and heavy lift operations, and accommodation support where the DP accommodation vessel is linked by gangway to the offshore structure.

13.4.3 The above general guide does not preclude the use of DP Class 2 vessels for these operations provided that they have been subjected to a full and detailed risk assessment and appropriate additional risk reduction measures agreed with GL Noble Denton.

13.5 OPERATIONAL REQUIREMENTS

13.5.1 Any vessel operating on DP shall comply with the following:

a. The vessel should be operated in accordance with the guidance given in MTS “DP Operations Guidance”, Ref. [33], IMCA M103, “The Design and Operation of Dynamically Positioned Vessels”, Ref. [18], and IMCA M 220 “Guidance on Operational Activity Planning”, Ref. [26].

b. Where a DP Class 2 or 3 vessel is used, the vessel should be operated in such a way that it will not lose position if the vessel suffers its worst case failure. The vessel’s environmental limits should be determined by inspection of the DP capability analysis for the vessel’s worst case failure such that the vessel should not be operated in environmental conditions which exceed the environmental envelope calculated for worst case failure.

c. The procedures should identify the phases of the operations which are most vulnerable to failures and the contingency actions can be taken to mitigate the consequences.

d. The vessel’s procedures should give the maximum weather limitations for operating on DP for all expected types of operation.

e. The vessel’s key DP personnel should comply with the competency guidelines given in IMCA M117, “The Training and Experience of Key DP Personnel”, Ref. [19].

f. The operator of the vessel shall demonstrate that the audit and annual trials recommendations do not preclude the planned operations.

g. DP Mobilisation trials and checks shall be carried out before arrival at the location. The mobilisation trials should be used to verify the integrity and performance of the vessel’s DP system, including power generation, distribution and power management, propulsion and rudders, auxiliaries, DP control system, position references and sensors.

h. DP Location Arrival tests and checks shall be completed on arrival at the location and prior to commencement of operations. The location arrival tests should include full functional tests of the DP system and check that the DP system is set up properly prior to the start of operations.

i. The DP vessel shall be equipped with suitable position reference and sensors in accordance with the vessel’s DP class notation. Position reference systems should be selected with due consideration to operational requirements, with regard to restrictions caused by the manner of deployment, expected performance in working situations and potential conflicts when using a combination of absolute and relative systems.

j. Consideration should be given to improving the maintenance of safe working separations between DP vessels and fixed structures incorporating rotating laser measuring systems (e.g. CyScan or Fanbeam), or radar distance measurement (e.g. RadaScan or RADius) into vessel DP systems.

k. It is desirable that any DP vessel is operated in accordance with its vessel specific CAMO and its ASOG. The CAMO sets out the most fault tolerant configuration for the DP system and its associated plant and equipment. The CAMO should be implemented during all critical DP activities undertaken by the vessel. The ASOG sets out the operational, environmental and equipment performance limits for the vessel and the specific activity the vessel is undertaking. These limits are set according to the level of risk. Where the risks are high, the limits are at their most stringent. The limits may be relaxed where the risks are low. (Refer to MTS “DP Operations Guidance”, Ref. [33], for details.).
13.6 VESSEL CLEARANCES

13.6.1 For vessels with DP class notations equivalent to IMO Equipment Class 2 and 3 there should always be an adequate clearance distance between the DP vessel and the nearest point on the adjacent offshore structure, whether above or below the surface. As a general rule the clearance distance should not be less than 10 metres. In exceptional circumstances it may be acceptable for the clearance distance to be reduced to 5 metres or less but only after a full and detailed risk assessment and the implementation of additional risk reduction measures agreed with GL Noble Denton.

13.7 JACK-UPS

13.7.1 Jack up vessels that are operated in DP should have DP control system features and DP operational procedures which minimise the horizontal reaction forces at touchdown and lift off so that, as far as is possible, the thruster forces balance the wind drag and current forces. This reduces the potential for the horizontal forces or moments to be transferred from the vessel through the legs to the seafloor. See IMCA M 223, Ref. [27], for more details.

13.7.2 An alternative is to leave a location under manual control. When leaving from alongside a surface or subsea structure, the procedures shall mitigate the risk of collision, especially if the current and/or wind and waves are pushing the jack-up towards the structure.

13.8 INFORMATION REQUIRED FOR APPROVAL

13.8.1 The following initial information should be submitted if approval of DP operations is required. When inadequate documents are submitted a vessel visit may be required.

   a. Detailed DP system description showing compliance with Sections 13.3.1 a & b and 13.4.
   b. FMEA showing compliance with Section 13.3.1 c.
   c. A DP Capability Analysis showing compliance with Section 13.3.1 d.
   d. CMID showing compliance with Section 13.3.1 e.
   e. Evidence of having conducted Annual DP Trials showing compliance with Section 13.3.1 f.
   f. Operating procedures showing compliance with Sections 13.5.1 a to d. Ideally these should include the CAMO and ASOG.
   g. Nautical Institute (or similar) DP Operator certificates and evidence of competence assurance of key DP personnel showing compliance with Section 13.5.1 e.
   h. Trials reports and close outs for annual trials showing compliance with Section 13.5.1 f.
   i. Records of checklists showing compliance with Section 13.5.1 g & h.
   j. Details of position reference systems showing compliance with Section 13.5.1 i & j.
14 DECOMMISSIONING

14.1 GENERAL

14.1.1 The same requirements should apply for decommissioning/platform removal work as for installation which are covered in:

a. 0015/ND “Guidelines for Concrete Gravity Structure Construction & Installation”, Ref. [3]
c. 0028/ND “Guidelines for Steel Jacket Transportation & Installation”, Ref. [7]
d. 0029/ND “Guidelines for Submarine Pipeline Installation”, Ref. [8]
e. 0031/ND “Guidelines for Float-Over Installations /Removals”, Ref. [10].

14.1.2 However there can be differences in approach for:

- Weight control - due to lack of suitable records
- Structural conditions - due to corrosion and wear
- HAZMAT and other hydrocarbon residues
- Reduced value of the equipment for which more damage may be acceptable.

Any such differences should be discussed on a case-by-case basis and agreed with GL Noble Denton.

14.1.3 When the operations are not covered in the GL Noble Denton guidelines then reference may be made to DNV-RP-H102 “Marine Operations During Removal of Offshore Installations”, Ref. [16].
REFERENCES

[5] GL Noble Denton 0021/ND “Guidelines for the Approval of Towing Vessels”.
[12] GL Noble Denton 0035/ND “Guidelines for Offshore Wind Farm Infrastructure Installation”
[18] IMCA M 103 The Design and Operation of Dynamically Positioned Vessels
[19] IMCA M 117 The Training and Experience of Key DP Personnel
[20] IMCA M 140 Specification for DP Capability Plots
[22] IMCA M 166 Guidance on Failure Modes and Effects Analysis
[23] IMCA M 178 FMEA Management Guide
[24] IMCA M 190 Guidance for Developing and Conducting Annual DP Trials Programmes for DP Vessels
[25] IMCA M 203 Guidance on Simultaneous Operations (SIMOPS)
[26] IMCA M 220 Guidance on Operational Activity Planning
[27] IMCA M 223 Guidance for the Positioning of Dynamically Positioned (DP) Jack-up Vessels On and Off the seabed
[28] IMO MSC/Circ.645 Guidelines for Vessels with Dynamic Positioning Systems
[29] ISO 9001 “Quality Management Systems — Requirements”
[34] Marine Technology Society (MTS) “DP Vessel Design Philosophy Guidelines Part 2”

APPENDIX A - FILLET WELD STRESS CHECKING

A.1 The effective length of a fillet weld, \( l \), should be taken as the length over which the fillet is full-size. This may be taken as the overall length of the weld reduced by twice the effective throat thickness \( a \). Provided that the weld is full size throughout its length, including starts and terminations, no reduction in effective length need be made for either the start or the termination of the weld.

A.2 The effective throat thickness, \( a \), of a fillet weld should be taken as the height of the largest triangle (with equal or unequal leg) that can be inscribed within the fusion faces and the weld surface, measured perpendicular to the outer side of this triangle, see Figure A.1.

\[ \text{Figure A-1 Effective Throat Dimension 'a' for Concave and Convex Fillet Welds} \]

A.3 A uniform distribution of stress is assumed on the throat section of the weld, leading to the normal and shear stresses shown in Figure A.2.

\[ \sigma_{\perp} = \text{normal stress perpendicular to the throat} \]
\[ \sigma_{\parallel} = \text{normal stress parallel to the axis of the weld} \]
\[ \tau_{\perp} = \text{shear stress (in the plane of the throat) perpendicular to the axis of the weld} \]
\[ \tau_{\parallel} = \text{shear stress (in the plane of the throat) parallel to the axis of the weld} \]

\[ \text{Figure A-2 Normal and Shear Stresses acting on the plane of Weld Throat} \]
A.4 The normal stress $\sigma_\parallel$ parallel to the axis is not considered when verifying the design resistance of the weld.

A.5 The two stress conditions perpendicular to the axis of the weld, $\sigma_\perp$ and $\tau_\perp$ may be considered to be equal in magnitude in the case where the load $P$ acting on the bracket is applied parallel to the axis of the weld. This can be seen in the assumption in Figure A-3 that the load vectors should be drawn with the symmetry that is illustrated.

A.6 The design resistance of the fillet weld will be sufficient if the following is satisfied:

$$\left(\sigma_\perp^2 + 3\times(\tau_\perp^2 + \tau_{\perp\perp}^2)\right)^{0.5} \leq \gamma_m \times \sigma_{yield}$$  \hspace{1cm} \text{Eqn 1}

Where:

- $\sigma_{yield}$ is the yield stress of the material
- $\gamma_m$ is the appropriate material factor selected

A.7 **Fillet Welded Bracket** For a bracket subjected to a load $P$ parallel to the weld line as shown in Figure A.3 and where the base structure to which the bracket is welded is adequately stiff the bending load applied to the weld line can be considered to vary linearly and the shearing load at the weld to be constant, as shown in the figure.

A.8 In this case the maximum perpendicular load per unit weld length, $f_\perp$, can be described as shown in Eqn 2.

$$f_\perp = 6 \times P \times h \times \frac{1}{l^2}$$  \hspace{1cm} \text{Eqn 2}

A.9 The uniform shear load per unit weld length, $f_h$, is given by

$$f_h = \frac{P}{l}$$  \hspace{1cm} \text{Eqn 3}

![Figure A-3 Bracket connected by double Fillet Weld](image-url)
A.10 **Double Fillet**  For a double fillet weld as shown in Figure A.4 the force $f_v$ may be considered as being resisted by a combination of normal and shear stresses acting on the throat of the weld as illustrated in the diagram. The applied load also produces a shear stress on the weld throat of $\tau_\parallel$ acting at right angles to the other shear stress $\tau_\perp$.

A.11 These stresses can be combined to form the von Misses equivalent stress (see Eqn 1). The equations for $\sigma_\perp$, $\tau_\perp$ and $\tau_\parallel$ are given in Eqn 4 and Eqn 5.

\[
\sigma_\perp = \tau_\perp = \frac{3}{\sqrt{2}} \frac{P \times h}{a \times l^2}
\]

\[
\tau_\parallel = \frac{P}{2 \times a \times l}
\]

\[
f_v = 6. P. h/l^2
\]

*Stresses and Resultant Forces*

A.12 The resulting limiting value for the weld throat thickness, $a$, is given in Eqn 6.

\[
a \geq \left(\frac{P}{\gamma_m \times \sigma_{yield} \times l}\right) \times \sqrt{18 \times \left(\frac{h}{l}\right)^2 + \frac{3}{4}}
\]

*Figure A-4  Stresses and Forces acting on Fillet Weld*
A.13 **Single Fillet**: For a bracket with a single fillet weld of length \( l \) the resulting limiting value for the weld throat thickness, \( a \), is given in Eqn 7.

\[
a \geq \left( \frac{P}{\gamma_m \times \sigma_{\text{yield}} \times l} \right) \times \sqrt{72 \times \left( \frac{h}{l} \right)^2 + 3}
\]

**Eqn 7**

A.14 **Selection of Yield Stress and Material Factor**: The yield stress used should be the lowest of the yield stress values of the weld itself and the two parts of metal welded together.

A.15 The material factor, \( \gamma_m \), shall be taken as 1.0.

Note: The **applied loads** shall be increased by the following factors:

- 1.40 for LS1 checks where the loading is gravity dominates; also used when the exclusions of 9.2.5 apply.
- 1.05 for LS2 checks where the loading is dominated by environmental / storm loads.

APPENDIX B - BOLTED CONNECTIONS

B.1 AIM AND SCOPE

B.1.1 This Appendix offers guidance on the selection of standards suitable for use when designing and specifying a bolted connection for marine seafastenings. In addition bolt installation and tightening requirements are discussed. Due to the difficulty of inspecting the adequacy of a bolted connection after it has been made up the significance of correct preparation, installation and accurate documentation is emphasised.

B.1.2 In bolted connections for use with marine seafastenings it is essential that there is not only adequate design and properly detailed construction drawings but also correct supervision and documentation to confirm that a bolted connection has been made correctly.

B.1.3 Bolts that are not torqued up correctly or that need lock nuts should not be used for connections involving cyclic loading (e.g. seafastening) due to the dangers of progressive collapse.

B.2 GENERAL CONSIDERATIONS

B.2.1 This Appendix is aimed at situations where bolted connections are used in a marine environment to form a temporary connection between steel items for seafastening purposes. Traditionally cargo seafastenings have consisted of welded connections. However in some circumstances bolts are more convenient for securing cargo items as they can be removed more quickly. It is assumed that the cargo items are small in comparison to the ship or barge and that the fastening will not be required to transmit forces resulting from flexure of the supporting vessel or that if they do so these forces have been accurately determined and included in the design.

B.2.2 Due to the typically cyclic nature of forces applied to marine seafastening connections, bolted connections which are to be used in this manner should be designed as “slip critical”, that is the load is carried by means of friction between the faying (or touching) surfaces of the items connected. The purpose of the bolts is thus to provide the necessary clamping force between the faying surfaces to ensure the friction load can be carried without slip. In this way the bolts themselves are not required to carry shear or edge bearing forces. It follows that correct installation and pretensioning of the bolts is essential.

B.3 CODES AND GUIDELINES

B.3.1 A suitable internationally recognised standard should be used for the design of slip critical bolted connections. Such a code is the AISC Specification for Structural Buildings (Ref. [13]) which deals with the design of connections in Chapter J. Section J3-8 deals with slip-critical connections. This code provides for the use of both the Load and Resistance Factor Design (LRFD) and the Allowable Strength Design (ASD) methodology. In this note the design of bolts will be illustrated using the LRFD approach.

B.3.2 Helpful guidance in the design and specification of bolted connections is given in the AISC Design Guide 17 on “High Strength Bolts”, Ref. [14].

B.3.3 Specifications for bolts, washers, holes, assembly, etc. and much useful information for the design of slip-critical bolted connections is also provided in the Research Council on Structural Connections (RCSC); “Specification for Structural Joints Using High-Strength Bolts”, see Ref. [35].

B.4 BOLTED CONNECTION DESIGN STRENGTH

B.4.1 Load Resistance Factor Design (LRFD) The following summary of some of the main requirements for bolted joint design is based on the LRFD approach presented in AISC (Ref. [13]). In LRFD design when a structure or structural component ceases to fulfil the intended purpose in some way, it is said to have exceeded a limit state.

B.4.2 The design strength $\Phi R_n$ is the nominal strength $R_n$ multiplied by the resistance factor $\Phi$. The design strength of each structural component or assembly must equal or exceed the factored load, which is the relevant load or load combination comprising the sum of the nominal loads multiplied by load factors. The load factors reflect uncertainty in individual load magnitudes.
B.4.3 For marine seafastenings the load factors to be used should be those provided in Table 9-1 of these guidelines. The load factor recommended for the LS1 limit state is 1.60 and this is the appropriate value to use for the analysis of slip critical joints. The factored load must be smaller than the design resistance:

\[
\text{Factored Load} = 1.6 \times \text{Load} < \Phi \cdot R_n
\]

NOTE: The requirement that bolted connections be designed using the LS1 load factor applied to the extreme loads is to account for the criticality and sensitivity of pretensioned and slip-critical joints and the fact that the design load has a significant probability of being exceeded.

B.4.4 High Strength Bolts in Slip-Critical Connections Chapter J3-8 of AISC, Ref. [13], describes how for high strength bolts in slip critical connections the design slip resistance is \( \Phi \cdot R_n \), where \( R_n \) is the nominal strength of the joint and \( \Phi \), the resistance factor, with values given in the following table.

<table>
<thead>
<tr>
<th>Type of holes</th>
<th>( \Phi ) (LRFD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For standard size and short-slotted holes perpendicular to the direction of the load</td>
<td>1.0</td>
</tr>
<tr>
<td>For over-sized and short-slotted holes parallel to the direction of the load</td>
<td>0.85</td>
</tr>
<tr>
<td>For long-slotted holes</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The nominal strength of the joint, \( R_n \), is defined in J3-8 in AISC, Ref. [13], as:

\[
R_n = \mu \cdot D_u \cdot h_f \cdot T_b \cdot N_s
\]

where:

\( \mu \) = mean slip coefficient for Class A or B surfaces as applicable, and determined as follows, or as established by tests.

<table>
<thead>
<tr>
<th>Type of surface</th>
<th>( \mu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot dipped galvanised or roughened surfaces)</td>
<td>0.3</td>
</tr>
<tr>
<td>For Class B surfaces (unpainted blast-cleaned steel surfaces with Class B coatings on blast-cleaned steel)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

\( D_u \) = 1.13; a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension. The use of other values may be approved by the engineer of record.

\( T_b \) = minimum fastener tension (see Table J3.1 or J3.1M of AISC, Ref. [13])
\( h_f \) = factor for fillers, determined as follows:

<table>
<thead>
<tr>
<th>Number of Fillers</th>
<th>( h_f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where there are no fillers or where bolts have bee added to distribute loads in the filler</td>
<td>1.0</td>
</tr>
<tr>
<td>Where bolts have not been added to distribute the load in the filler: for one filler between connected parts</td>
<td>1.0</td>
</tr>
<tr>
<td>for two or more fillers between connected parts</td>
<td>0.85</td>
</tr>
</tbody>
</table>

\( N_s \) = number of slip planes required to permit the connection to slip.

**B.4.5 Combined Tension and Shear in Slip Critical Connections** When a slip-critical connection is subjected to an applied tension that reduces the net clamping forces the available slip resistance per bolt as given above shall be multiplied by a factor \( k_s \) as follows:

\[
k_s = 1 - T_u / (D_u.T_b.N_b)
\]

[LRFD type analysis] (see AISC, Ref. [13], J3-9)

\( k_s \) = 1 - \( T_u / (D_u.T_b.N_b) \)

where:

\( N_b \) = number of bolts carrying the applied tension

\( T_u \) = tension force due to LRFD load combinations

\( T_b \) = minimum fastener tension given in Table J3.1 or J3.1M

**B.4.6 Fatigue** Given the cyclic nature of the loadings arising from vessel motion in a seaway, the fatigue limit state of the bolts and the connected parts shall be considered for voyages of more than 2 days i.e. approximately when the number of cycles could exceed 20,000 cycles. For further guidance on fatigue, see Appendix 3 of AISC, Ref. [13], Chapter 7 of AISC, Ref. [14] and 5.5 of RCSC, Ref. [35].

**B.4.7** For connections that experience tension, account shall be taken of the increase in the nominal bolt loads due the effects of prying; alternatively the connected parts shall be shown to be of sufficient thickness that prying forces are not significant. AISC, Ref. [14], provides useful guidance on prying. Consideration of fatigue is particularly important for bolts in tension where relative stiffness effects can cause the cyclic load/stress range to be more pronounced than some expect, even without the consideration of prying. To ensure that the actual tensile fatigue is adequately addressed by the calculations, it is essential to ensure good fit-up of the mating surfaces and proper pretension of all the bolts. Any yielding of the bolts under extreme loading would reduce the pretension and significantly reduce the fatigue life.

**B.4.8** Where the load range is variable, the damage should be assessed using the Palmgren-Miner summation method.
B.4.9 **Installation and inspection of Bolted Assemblies** Pre-installation verification should be carried-out according to Section-7 RCSC, Ref. [35], during which tension calibration must be used to confirm both the suitability of the complete fastener assembly and the pretensioning procedure. According to these recommendations a representative sample of not fewer than three complete fastener assemblies of each combination of diameter, length, grade and lot to be used in the work shall be checked at the site of installation in a tension calibrator to verify that the pretensioning method develops a pretension that is equal to or greater than that specified. Minimum bolt pretensions are specified in Table 7.1 of RCSC, Ref. [35].

B.4.10 It is essential that bolted assemblies be correctly stored, matched and made-up and that the correct pretension is introduced into the bolts, (see RCSC, Ref. [35], Installation, Section-8.2).

B.4.11 Attention should be paid to providing correctly hardened washers where necessary (e.g. when oversize or slotted holes are used; when high strength bolts are used with low yield material; when Direct Tension Indicators “DTI” used in the pretensioning method), see RCSC, Ref. [35], Section 8.2.4, etc.).

B.4.12 Faying surfaces in slip-critical joints must meet the requirements in RCSC Specification (see Ref. [35]) Sections 3.2 and 3.2.2. It is assumed due to the nature of the application that surfaces will be uncoated, hence, they shall be free of scale, except for tight mill scale, and free of coating, including inadvertent overspray, in areas closer than one bolt diameter but not less than 1 inch (25mm) from the edge of any hole and in all areas within the bolt pattern.

B.4.13 Where faying surfaces are coated or galvanized, the requirements in Section 3.2.2.b and 3.2.2.c of RCSC, Ref. [35], shall apply.

B.4.14 The inspection of bolted connections should be according to RCSC (Ref. [35], Inspection, Section 9.2).

B.5 **Particular Points to Note**

B.5.1 Re-use of bolts which have been pre-tensioned is not permitted by most codes. Re-use will be considered on a case by case basis, taking due account of factors including, but not limited to:

- The number of uses proposed and how they are recorded
- The means of identifying batches of bolts
- Whether initial pretensioning has exceeded 60% of bolt yield strength, or loads have exceeded the maximum design values.
- The procedure for ensuring that the required pre-tension is achieved for each use in accordance with B.4.9 i.e. a tension calibration should be undertaken before each use and for each batch
- Fatigue and how the fatigue history can be measured.

In general it will be difficult to justify pretension bolts re-use if the fatigue and usage history of each bolt is not known or if pretensioning may have exceeded 60% of yield.

B.5.2 Gasket or other compressible materials should not be introduced within the grip of the bolted connection.

B.5.3 Nuts should never be welded to prevent movement or loosening.