Structural design of offshore ships
FOREWORD

DNV GL offshore standards contain technical requirements, principles and acceptance criteria related to classification of offshore units.

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Any comments may be sent by e-mail to rules@dnvgl.com
CHANGES – CURRENT

General

This document supersedes DNV-OS-C102, October 2014.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

On 12 September 2013, DNV and GL merged to form DNV GL Group. On 25 November 2013 Det Norske Veritas AS became the 100% shareholder of Germanischer Lloyd SE, the parent company of the GL Group, and on 27 November 2013 Det Norske Veritas AS, company registration number 945 748 931, changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to “Det Norske Veritas AS”, “Det Norske Veritas”, “DNV”, “GL”, “Germanischer Lloyd SE”, “GL Group” or any other legal entity name or trading name presently owned by the DNV GL Group shall therefore also be considered a reference to “DNV GL AS”.

Main changes July 2015

• General

The revision of this document is part of the DNV GL merger, updating the previous DNV standard into a DNV GL format including updated nomenclature and document reference numbering, e.g.:

— Main class identification 1A1 becomes 1A.
— DNV replaced by DNV GL.
— DNV-RP-A201 to DNVGL-CG-0168. A complete listing with updated reference numbers can be found on DNV GL’s internet.

To complete your understanding, observe that the entire DNV GL update process will be implemented sequentially. Hence, for some of the references, still the legacy DNV documents apply and are explicitly indicated as such, e.g.: Rules for Ships has become DNV Rules for Ships.

• Ch.2 Sec.1 Material selection and fabrication principles

— [3.2.6] Included specification of length for topside module.

• Ch.2 Sec.2 Design principles

— [1.1.3]: A reference to arrangement of water tight bulkheads given in DNV Rules for ships Pt.3 Ch.1 Sec.3 A is included

• Ch.2 Sec.3 Design loads

— [3.8] Including definitions of sagging and hogging in guidance note.

• Ch.2 Sec.4 Strength of hull structure

— [2.2.8] Rewritten clause in line with original intention.
— [5.5.5] Rewritten clause in line with original intention.
— Table 7: Permissible peak stress for the LRFD method limited to the material tensile stress.

• Ch.2 Sec.5 Strength of topside structures

— Table 3 Removed previous column c) as ALS is not a required design condition for topside structure.

Editorial corrections

In addition to the above stated main changes, editorial corrections may have been made.
CONTENTS

CHANGES – CURRENT .............................................................................................................. 3

CH. 1 INTRODUCTION ........................................................................................................ 9
Sec.1 General ......................................................................................................................... 9
  1 General ......................................................................................................................... 9
     1.1 Introduction ............................................................................................................. 9
     1.2 Objectives .............................................................................................................. 9
     1.3 Scope and applications .......................................................................................... 9
  2 Definitions .................................................................................................................... 10
     2.1 Verbal forms .......................................................................................................... 10
     2.2 Terms .................................................................................................................... 10
     2.3 Symbols ................................................................................................................. 11
     2.4 Abbreviations ....................................................................................................... 11
     2.5 References ........................................................................................................... 12

CH. 2 TECHNICAL PROVISIONS ............................................................................. 13
Sec.1 Material selection and fabrication principles ......................................................... 13
  1 Introduction .................................................................................................................. 13
  2 Selection of material .................................................................................................... 13
     2.1 General ................................................................................................................. 13
     2.2 Design and service temperatures ......................................................................... 13
     2.3 Hull structure ....................................................................................................... 14
     2.4 Topside structure and elements not covered by the DNV Rules for ships ........... 14
  3 Fabrication principles ................................................................................................. 16
     3.1 General ................................................................................................................. 16
     3.2 Topside structure and topside interface to hull structure ......................................... 16
  4 Corrosion addition ....................................................................................................... 17
     4.1 General ................................................................................................................. 17
     4.2 Offshore specific tanks .......................................................................................... 17

Sec.2 Design principles ...................................................................................................... 18
  1 Introduction .................................................................................................................. 18
     1.1 Overall design principles ..................................................................................... 18
  2 Design conditions ......................................................................................................... 18
     2.1 General ................................................................................................................. 18
     2.2 Transit condition ................................................................................................. 18
     2.3 Operating conditions ............................................................................................ 18
     2.4 Survival condition (ULS) ..................................................................................... 19
     2.5 Accidental condition (ALS) .................................................................................. 19
     2.6 Benign waters or harsh environmental areas ......................................................... 19
     2.7 Wave load analysis ............................................................................................... 20
  3 Design methods ............................................................................................................ 22
     3.1 General ................................................................................................................. 22
     3.2 Working stress design method .............................................................................. 22
     3.3 Load and resistance factor design method ............................................................. 23

Sec.3 Design loads .............................................................................................................. 24
  1 Introduction .................................................................................................................. 24
     1.1 General ................................................................................................................. 24
2 Static loads ........................................................................................................ 24
  2.1 General ........................................................................................................ 24
  2.2 Still water hull girder loads ........................................................................... 24
3 Environmental loads .......................................................................................... 25
  3.1 General .......................................................................................................... 25
  3.2 Wave induced loads ....................................................................................... 25
  3.3 Wind loads ..................................................................................................... 25
  3.4 Green sea ....................................................................................................... 26
  3.5 Sloshing loads in tanks .................................................................................. 26
  3.6 Bottom slamming ......................................................................................... 27
  3.7 Bow impact .................................................................................................... 27
  3.8 Combination of dynamic loads ...................................................................... 27
  3.9 Design density of tanks ................................................................................ 29

Sec.4 Strength of hull structure ............................................................................ 31
1 Introduction ......................................................................................................... 31
2 General technical requirements ........................................................................ 31
  2.1 Overview ........................................................................................................ 31
  2.2 Girder system ................................................................................................. 31
3 Hull girder longitudinal strength (ULS) ............................................................. 33
  3.1 General .......................................................................................................... 33
  3.2 Design loading conditions ............................................................................. 33
  3.3 Hull girder capacity ...................................................................................... 34
4 Local supports .................................................................................................... 35
5 Local stress analysis ........................................................................................... 35
  5.1 Application .................................................................................................... 35
  5.2 General .......................................................................................................... 37
  5.3 Analysis model ............................................................................................... 37
  5.4 Design loading condition ............................................................................. 37
  5.5 Fine mesh criteria .......................................................................................... 37

Sec.5 Strength of topside structures ..................................................................... 39
1 Application .......................................................................................................... 39
  1.1 General .......................................................................................................... 39
  1.2 Definition of load point .................................................................................. 40
2 Local static loads on topside structures ............................................................ 40
3 Local requirements to plates and stiffeners ..................................................... 41
  3.1 Plates (local design) ..................................................................................... 41
  3.2 Stiffeners (local design) ............................................................................... 41
4 Requirements to simple girders (primary design) .......................................... 42
  4.1 General .......................................................................................................... 42
  4.2 Strength assessment ...................................................................................... 42
5 Complex girder system ...................................................................................... 43
  5.1 General .......................................................................................................... 43
  5.2 Strength assessment ...................................................................................... 43
6 Global assessment of topside structure ............................................................. 44
  6.1 General .......................................................................................................... 44
  6.2 Strength assessment ...................................................................................... 45
7 Acceptance criteria ........................................................................................... 46
  7.1 Usage factors ................................................................................................ 46
  7.2 Local liquid tanks .......................................................................................... 46
  7.3 Buckling control ............................................................................................. 46
7.4 Fatigue control .................................................................47

Sec.6 Topside interface to hull structure ................................................................. 48
1 Application .............................................................................................48
2 Strength assessment ..............................................................................48
  2.1 Requirements to the FE model ...................................................... 48
  2.2 Design load ............................................................................... 48
  2.3 Load combination ...................................................................... 48
  2.4 Acceptance criteria ................................................................... 49
  2.5 Fatigue ..................................................................................... 49

Sec.7 Fatigue ........................................................................................................ 50
1 Principles and methodology ....................................................................50
  1.1 General ..................................................................................... 50
  1.2 Assessment principles .................................................................. 50
  1.3 Methods for fatigue capacity ..................................................... 50
  1.4 Fatigue details to be considered ............................................... 50
  1.5 Design loads and calculation of stress range.................................. 51
  1.6 Design fatigue factor ................................................................ 51
  1.7 Details to be checked ................................................................ 51
2 Advanced fatigue methodology ................................................................53
  2.1 Introduction ............................................................................... 53
  2.2 Principles ................................................................................. 53

Sec.8 Accidental conditions ............................................................................... 56
1 Introduction ........................................................................................... 56
  1.1 General ..................................................................................... 56
2 Accidental scenarios ............................................................................... 56
  2.1 Dropped objects ...................................................................... 56
  2.2 Fires ....................................................................................... 56
  2.3 Explosions ............................................................................... 56
  2.4 Unintended flooding .................................................................. 57
  2.5 Collision .................................................................................. 57
  2.6 Loss of heading control ............................................................. 57
  2.7 Heeled condition .................................................................... 57

Sec.9 Welding and weld connections ................................................................. 58
1 Introduction ........................................................................................... 58
  1.1 General requirements ............................................................... 58
2 Size of welds ....................................................................................... 58
  2.1 Double continuous fillet welds .................................................. 58
  2.2 Fillet welds and deep penetration welds subject to high tensile stresses ... 59
  2.3 Full penetration welds ............................................................... 59
  2.4 End connection of stiffeners ..................................................... 59
  2.5 Direct calculations ................................................................ 59

Sec.10 Special provisions for drilling units .......................................................... 61
1 Introduction ........................................................................................... 61
2 Design principles .................................................................................. 61
  2.1 General ..................................................................................... 61
3 Strength assessment ............................................................................... 61
  3.1 General ..................................................................................... 61
  3.2 Green sea loads ...................................................................... 61
  3.3 Design loading conditions ....................................................... 61
  3.4 Fatigue ..................................................................................... 61
4 Fabrication principles ............................................................................. 62
  4.1 Hull structure ................................................................................... 62
  4.2 Topside and topside support structure ................................................. 62
5 Corrosion control..................................................................................... 62
  5.1 Hull and topside structure .................................................................. 62

Sec.11 Special provisions for floating production, storage and offloading units ....................................................................... 63
1 Introduction ........................................................................................... 63
2 Design principles .................................................................................... 63
  2.1 General........................................................................................... 63
3 Strength assessment .............................................................................. 63
  3.1 General........................................................................................... 63
  3.2 Green sea loads ............................................................................... 64
  3.3 Design loading conditions .................................................................. 64
  3.4 Fatigue strength ............................................................................... 64
  3.5 Hull support structure for mooring system ........................................... 66
  3.6 Bilge keel ........................................................................................ 67
  3.7 Loading instrument ........................................................................... 67
4 Fabrication principles ............................................................................. 67
5 Corrosion control..................................................................................... 68
  5.1 Hull structure................................................................................... 68
  5.2 Topside structure.............................................................................. 68

CH. 3 CLASSIFICATION ........................................................................... 69
Sec.1 Classification services ........................................................................ 69
  1 General................................................................................................ 69
    1.1 Introduction..................................................................................... 69
    1.2 Application....................................................................................... 69
    1.3 Documentation................................................................................. 69

APP. A CONVERSION OF TANKER TO FLOATING OFFSHORE UNIT ........................................................................... 70
  1 Introduction .......................................................................................... 70
    1.1 General........................................................................................... 70
  2 Strength ................................................................................................. 70
    2.1 General........................................................................................... 70
    2.2 Benign waters operation .................................................................. 70
    2.3 Basis requirements .......................................................................... 71
    2.4 Hull girder longitudinal strength........................................................ 71
    2.5 Topside and topside interface to hull structure ...................................... 71
  3 Fatigue ................................................................................................... 72
    3.1 General........................................................................................... 72
    3.2 Previous trade............................................................................... 72
    3.3 Operation ....................................................................................... 72
    3.4 Areas to be checked ......................................................................... 72
    3.5 Mean stress effect ........................................................................... 73
    3.6 Documentation................................................................................. 73
    3.7 Environmental reduction factors ......................................................... 73
## APP. B LIFETIME EXTENSION OF FLOATING OFFSHORE UNITS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>76</td>
</tr>
<tr>
<td>1.1</td>
<td>General</td>
<td>76</td>
</tr>
<tr>
<td>1.2</td>
<td>Survey extent</td>
<td>76</td>
</tr>
<tr>
<td>2</td>
<td>Structural strength</td>
<td>76</td>
</tr>
<tr>
<td>2.1</td>
<td>General</td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>Fatigue</td>
<td>76</td>
</tr>
<tr>
<td>3.1</td>
<td>General</td>
<td>76</td>
</tr>
<tr>
<td>3.2</td>
<td>Previous trades</td>
<td>76</td>
</tr>
<tr>
<td>3.3</td>
<td>Operation</td>
<td>76</td>
</tr>
<tr>
<td>3.4</td>
<td>Areas to be checked</td>
<td>77</td>
</tr>
<tr>
<td>3.5</td>
<td>Mean stress effect</td>
<td>77</td>
</tr>
<tr>
<td>3.6</td>
<td>Documentation</td>
<td>77</td>
</tr>
</tbody>
</table>
CHAPTER 1 INTRODUCTION

SECTION 1 GENERAL

1 General

1.1 Introduction

1.1.1 This standard comprises sections with provisions applicable to Floating Production and/or Storage Units (FSO/FPSO) and Drillships.

1.1.2 This standard describes both the Working Stress Design (WSD) method and the Load and Resistance Factor Design (LRDF) method. The design principle method should be used consequently through the whole project. The design methods are described in [3.2] and [3.3] respectively.

1.2 Objectives

The objectives of this standard are to:

— provide an internationally acceptable standard for design of offshore ship-shaped units
— serve as a technical reference document in contractual matters between purchaser and manufacturer
— serve as a guideline for designers, purchaser, contractors and regulators
— provide, as far as possible, consistent loads for both topside and hull design.

1.3 Scope and applications

1.3.1 This standard is applicable to hull and topside of ship-shaped offshore units, such as drilling units and floating production/storage units, constructed in steel for both non-restricted and restricted operations.

1.3.2 This standard covers the following structural items:

— material selection and fabrication principles
— design principles
— design loads
— ultimate strength requirements
— fatigue requirements
— specify procedures and requirements for units subject to DNV GL classification services.

1.3.3 Serviceability (SLS) condition is not covered in this standard.

1.3.4 The hull girder longitudinal strength principles are based on site specific environmental loads.

1.3.5 For application of this standard as technical basis for classification see Ch.3.

1.3.6 Flag and shelf state requirements are not covered by this standard.

Guidance note:

Governmental regulations may include requirements in excess of the provisions of this standard depending on the type, location and intended service of the offshore unit or installation. The 100 year return period is used to ensure harmonisation with typical Shelf State requirements and the code for the construction and equipment of mobile offshore drilling units (MODU code).

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
2 Definitions

2.1 Verbal forms

Table 1 Verbal forms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>shall</td>
<td>verbal form used to indicate requirements strictly to be followed in order to conform to the document</td>
</tr>
<tr>
<td>should</td>
<td>verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required</td>
</tr>
<tr>
<td>may</td>
<td>verbal form used to indicate a course of action permissible within the limits of the document</td>
</tr>
</tbody>
</table>

2.2 Terms

2.2.1 Standard terms are given in DNVGL-OS-C101.

Table 2 Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>drilling unit</td>
<td>a unit used for drilling in connection with exploration and/or exploitation of oil and gas. The unit is generally operating on the same location for a limited period of time and is normally equipped with dynamic positioning system with several thrusters. The unit follows the normal class survey program.</td>
</tr>
<tr>
<td>floating production and offloading unit</td>
<td>a unit used for the production of oil with arrangement for offloading to a shuttle tanker. The units normally consist of a hull, with turret or spread mooring arrangement, and production facilities above the main deck. The unit can be relocated, but is generally located on the same location for a prolonged period of time.</td>
</tr>
<tr>
<td>floating storage and offloading unit</td>
<td>a unit used for storage of oil with arrangement for offloading to a shuttle tanker. The units normally consist of a hull, with turret or spread mooring system. The unit is equipped for crude oil storage. The unit can be relocated, but is generally located on the same location for a prolonged period of time.</td>
</tr>
<tr>
<td>floating production, storage and offloading unit</td>
<td>a unit used for the production and storage of oil with arrangement for offloading to a shuttle tanker. The unit is equipped for crude oil storage. The unit is normally moored to the seabed with production facilities on the main deck. The unit can be relocated, but is normally located on the same location for a prolonged period of time.</td>
</tr>
<tr>
<td>floating production, drilling, storage and offloading unit</td>
<td>a unit used for drilling, storage and production of oil with arrangement for offloading to a shuttle tanker. The unit is equipped for crude oil storage.</td>
</tr>
<tr>
<td>LNG/LPG floating production and storage units</td>
<td>a unit with facilities for oil and gas production and storage. The unit is typically permanently moored. Due to the complexity of the unit more comprehensive safety assessment are typically carried out. The unit is normally equipped with solutions for quick disconnection of mooring lines between the shuttle tanker and the oil and gas producing and storage unit.</td>
</tr>
<tr>
<td>turret</td>
<td>a device providing a connection point between the unit and the combined riser- and mooring- systems, allowing the unit to freely rotate (weather vane) without twisting the risers and mooring lines.</td>
</tr>
<tr>
<td>temporary mooring</td>
<td>anchoring in sheltered waters or harbours exposed to moderate environmental loads</td>
</tr>
<tr>
<td>structural design brief</td>
<td>a document providing criteria and procedures to be adopted in the initial stages of the design process. The structural design brief should include analytical methods, procedures and methodology used for the structural design taking all relevant limiting design criteria into account. Owner’s additional specification, if any, should be clearly described in the structural design brief.</td>
</tr>
<tr>
<td>service life</td>
<td>the expected life time of the unit</td>
</tr>
<tr>
<td>DFF</td>
<td>design fatigue factor applied to reduce the probability for fatigue failure</td>
</tr>
<tr>
<td>fatigue life</td>
<td>service life × design fatigue factor (DFF)</td>
</tr>
</tbody>
</table>
2.3 Symbols

2.3.1 The following Latin characters are used in this standard:

Table 3 Latin characters used

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V$</td>
<td>Speed in knots</td>
</tr>
<tr>
<td>$C_W$</td>
<td>Wave coefficient as given in DNV Rules for ships Pt.3 Ch.1 Sec.4</td>
</tr>
<tr>
<td>$a_v$</td>
<td>Vertical acceleration</td>
</tr>
<tr>
<td>$a_t$</td>
<td>Transverse acceleration</td>
</tr>
<tr>
<td>$a_l$</td>
<td>Longitudinal acceleration</td>
</tr>
<tr>
<td>$M_{vv}$</td>
<td>Vertical wave bending moment</td>
</tr>
<tr>
<td>$M_{wh}$</td>
<td>Horizontal wave bending moment</td>
</tr>
<tr>
<td>$Q_{vv}$</td>
<td>Vertical wave shear force</td>
</tr>
</tbody>
</table>

2.3.2 The following Greek characters are used in this standard:

Table 4 Greek characters used

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_0$</td>
<td>Basic usage factor</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Coefficient depending on type of structure</td>
</tr>
<tr>
<td>$\eta_p$</td>
<td>Permissible usage factor</td>
</tr>
</tbody>
</table>

2.4 Abbreviations

The abbreviations given in Table 5 are used in this standard. Definitions are otherwise given in DNVGL-OS-C101 ‘Design of Offshore Steel Structures, General’ (LRFD method).

Table 5 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>In full</th>
</tr>
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<tbody>
<tr>
<td>ALS</td>
<td>accidental limit state</td>
</tr>
<tr>
<td>BHD</td>
<td>bulkhead</td>
</tr>
<tr>
<td>DFF</td>
<td>design fatigue factor</td>
</tr>
<tr>
<td>FEA</td>
<td>finite element analysis</td>
</tr>
<tr>
<td>FLS</td>
<td>fatigue limit state</td>
</tr>
</tbody>
</table>
2.5 References

The following other DNV GL and DNV service documents given in Table 6 are referred to in this standard.

### Table 6  DNV GL and DNV offshore standards rules, classification notes and recommended practices

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
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<tbody>
<tr>
<td>DNVGL-OS-B101</td>
<td>Metallic materials</td>
</tr>
<tr>
<td>DNVGL-OS-C101</td>
<td>Design of offshore steel structures, general (LRFD method)</td>
</tr>
<tr>
<td>DNVGL-OS-C201</td>
<td>Structural design of offshore units (WSD method)</td>
</tr>
<tr>
<td>DNVGL-OS-C301</td>
<td>Stability and watertight integrity</td>
</tr>
<tr>
<td>DNVGL-OS-C401</td>
<td>Fabrication and testing of offshore structures</td>
</tr>
<tr>
<td>DNVGL-OS-E301</td>
<td>Position mooring</td>
</tr>
<tr>
<td>DNVGL-RP-C201</td>
<td>Buckling strength of plated structures</td>
</tr>
<tr>
<td>DNV-RP-C202</td>
<td>Buckling Strength of Shells</td>
</tr>
<tr>
<td>DNV-RP-C205</td>
<td>Environmental Conditions and Environmental Loads</td>
</tr>
<tr>
<td>DNVGL-RP-C203</td>
<td>Fatigue strength analysis of offshore steel structures</td>
</tr>
<tr>
<td>DNVGL-RP-C206</td>
<td>Fatigue methodology of offshore ships</td>
</tr>
<tr>
<td>DNV Classification Note No. 30.7</td>
<td>Fatigue Assessment of Ship Structures</td>
</tr>
<tr>
<td>DNV Classification Note No. 34.1</td>
<td>CSA - Direct Analysis of Ship Structures</td>
</tr>
<tr>
<td>DNV Rules for ships Pt.3 Ch.1</td>
<td>Hull Structural Design, Ships with Length 100 metres and above</td>
</tr>
<tr>
<td>DNV Rules for ships Pt.3 Ch.3</td>
<td>Hull Equipment and Safety</td>
</tr>
<tr>
<td>DNV Rules for ships Pt.2 Ch.2</td>
<td>Metallic Materials</td>
</tr>
<tr>
<td>DNV Rules for ships Pt.5 Ch.1</td>
<td>Ships for Navigation in Ice</td>
</tr>
</tbody>
</table>
CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1  MATERIAL SELECTION AND FABRICATION PRINCIPLES

1  Introduction
This section describes the selection of steel materials and fabrication principles to be applied in design and construction of offshore ship-shaped units.

2  Selection of material

2.1  General

2.1.1  A material specification shall be established for all structural materials. The materials shall be suitable for their intended purpose and have adequate properties in all relevant design conditions.

2.1.2  The material grade shall be selected according to the DNV Rules for ships Pt.3 Ch.1 Sec.2 when the design temperature is equal to or above -10°C, related to the lowest mean daily average temperature (MDAT).

2.1.3  For design temperature lower than -10, the requirements to material class is given in the DNV Rules for ships Pt.5 Ch.1 Sec.7.

Guidance note:
The purpose of the structural categorization is to ensure adequate material and suitable inspection to avoid brittle fracture, and to ensure sufficient fracture resistance of a material (stress intensity factor) to avoid crack sizes which may develop into brittle fracture at certain stress situations.

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

2.1.4  In structural cross-joints where high tensile stresses are acting perpendicular to the plane of the plate, the plate material shall be tested according to DNV Rules for ships Pt.2 Ch.2 Sec.1 to prove the ability to resist lamellar tearing (Z-quality). Continuous deck plate under crane pedestal shall have Z-quality steel with minimum extension of 500 mm. If the pedestal is continuous through the deck plate within 0.6 L amidship, the pedestal plate shall have Z-quality steel with minimum extension of 500 mm above and below the deck, see also Figure 2.

2.1.5  For stiffeners, the grade of material may be determined based on the thickness of the web.

2.1.6  Structural elements used only in temporary conditions, e.g. lifting lugs and pad eyes, are not part of the class scope and thus not covered in this standard.

2.1.7  Elements welded to the hull girder longitudinal strength members (deck, bottom, long BHD, etc) such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, shall follow the material requirement for the structural member it is welded to.

2.1.8  Doubling plates shall generally be avoided when exposed to tensile force perpendicular to the connecting main plate.

2.1.9  In areas where the stress level is small or moderate, doublers supporting minor structure such as pipe supports, minor foundations, fittings, etc. may be defined in a structural member group lower than the structural member group it is connected to. See Table 1 for structural member groups.

2.1.10  When higher material steel grade than required is used, stricter requirements related to the fabrication is not required.

2.2  Design and service temperatures

2.2.1  The service temperature for external structures above the lowest ballast waterline shall be set equal to the design temperature for the area(s) in which the unit is specified to operate. External structure is defined, with respect to design temperature, as the plating with stiffening to an inwards distance of 0.6 metre from the shell plating.
2.2.2 The service temperature for external structures below the lowest ballast waterline needs normally not to be set lower than 0°C.

2.2.3 The service temperature for internal structures in way of permanently heated rooms needs normally not to be set lower than 0°C.

2.2.4 The service temperature for internal structures in oil storage tanks need normally not to be set lower than 0°C except where stated in [2.2.1] above.

2.2.5 The service temperature for internal structures in ballast tanks need normally not to be set lower than 0°C except where stated in [2.2.1] above.

2.3 Hull structure
The selection of the material for the hull structure are given in the DNV Rules for ships Pt.3 Ch.1.

2.4 Topside structure and elements not covered by the DNV Rules for ships
2.4.1 Structural members are classified into Material Classes according to the following criteria:
— significance of member in terms of consequence of failure
— stress condition at the considered detail that together with possible weld defects or fatigue cracks may provoke brittle fracture.

Guidance note:
The consequence of failure may be quantified in terms of residual strength of the structure when considering failure of the actual component.

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2.4.2 Material categorization for topside modules, topside supporting structures, foundations and main supporting structures of heavy equipment attached to deck and hull shall be determined according to Table 1.
### Table 1 Material classes

<table>
<thead>
<tr>
<th>Material class</th>
<th>Structural member groups</th>
<th>Equivalent structural category in the DNVGL-OS-C101</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>— Outfitting steel&lt;br&gt;— Mezzanine decks, platforms&lt;br&gt;— Pipe support structure&lt;br&gt;— Laydown platforms&lt;br&gt;— Doubler plates, closer plates and support infill steels in topside structures 1)&lt;br&gt;— Foundation attached to decks (excl. main deck) where weight of equipment &lt; 50 ton</td>
<td>Secondary</td>
</tr>
<tr>
<td>II</td>
<td>— Stair towers&lt;br&gt;— Topside modules (plate, web frame, girder) 2)&lt;br&gt;— Main structures in riser hold 4)&lt;br&gt;— Longitudinal and transverse bulkheads in way of moonpool and setback area&lt;br&gt;— Offshore Crane boom rest and main supporting structures&lt;br&gt;— Foundation attached to main deck where weight of equipment &lt; 50 ton&lt;br&gt;— Foundation attached to other deck where weight of equipment &gt; 50 ton</td>
<td>Secondary</td>
</tr>
<tr>
<td>III</td>
<td>— Main girders and columns in truss work type modules&lt;br&gt;— Topside support stools and main supporting structures&lt;br&gt;— Pipe/riser rack stanchions&lt;br&gt;— Main structures in drill-floor and substructure 4)&lt;br&gt;— Main supporting structures (substructure) for helideck 3) 4)&lt;br&gt;— Crane pedestal (shipboard and offshore)&lt;br&gt;— Shipboard crane pedestal supports&lt;br&gt;— Flare tower&lt;br&gt;— Riser balcony and pull in structure&lt;br&gt;— Mating ring for STL/STP structure&lt;br&gt;— Foundations and main supporting structures of heavy machinery and equipment typically; thruster, gantry and rail, winches, davits, hawser winch, etc. 6)&lt;br&gt;— Foundation attached to main deck where weight of equipment &gt; 50 ton</td>
<td>Primary</td>
</tr>
<tr>
<td>IV</td>
<td>— Deck and bottom corner plates in way of moonpool&lt;br&gt;— Foundations and main supporting structures for derrick and drillfloor, flare tower, offshore crane pedestals 5), anchor line fairleads, riser fairleads, chain stopper 7), towing brackets, mooring winch foundation 7)&lt;br&gt;— Main supporting structures for turret 4)</td>
<td>Special</td>
</tr>
</tbody>
</table>

1) Shall follow the same strength member group as the material it is welded to.<br>2) Stiffener and other local members (brackets, collar plates, web stiffeners) are classified as Class I.<br>3) For material selection of the helideck pancake, see DNVGL-OS-E401.<br>4) Main structures and main supporting structures are primary load bearing members such as plates, girders, web frames/bulkheads and pillar.<br>5) Minimum the area 0.5m from the deck plate is defined as special area, see also Figure 2.<br>6) Foundation of heavy equipment may be categorized in a higher or lower group depending on the strength capacity, criticality wrt structural failure and the possibility for stress retribution.<br>7) Related to permanent mooring systems. If the structural member not is related to permanent mooring it may, based on actual stress level, be categorized within material class III.

#### 2.4.3 The material for the topside structure specified in Table 1 may alternatively be selected according to the principles given in DNVGL-OS-C101.
3 Fabrication principles

3.1 General
For the fabrication principles for the unit specific provisions are given in Sec.10 and Sec.11.

3.2 Topside structure and topside interface to hull structure

3.2.1 Fabrication and testing of topside and topside interface to the hull structure shall follow the requirements given in DNVGL-OS-C401.

3.2.2 The inspection categories are related to the material class and structural categories as shown in Table 2.

Table 2 Inspection categories

<table>
<thead>
<tr>
<th>Material Class</th>
<th>Inspection Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>I</td>
</tr>
<tr>
<td>III</td>
<td>II</td>
</tr>
<tr>
<td>I, II</td>
<td>III</td>
</tr>
</tbody>
</table>

3.2.3 The weld connection between two components shall be assigned inspection category according to the highest of the joined components. For stiffened plates, the weld connection between the plate and stiffener, stringer, and girder web to the plate may be inspected according to inspection category III.

3.2.4 Critical details within material class II or III shall be inspected according to inspection category I.

Guidance note:
Critical details are localized attached structures such as supports of which failure is critical for the overall safety or personnel.

3.2.5 Welds in fatigue critical areas not accessible for inspection and repair during operation shall be inspected according to requirements in inspection category I.

3.2.6 Topside stools and the topside connections to the hull structure shall be inspected as shown in Figure 1.

Figure 1 Inspection categories for topside stool with soft nose brackets

The length “a” shall be 0.35 x l, minimum 120 mm, maximum 500 mm.

3.2.7 Inspection categories for offshore crane pedestals connection to deck are shown in Figure 2.
4 Corrosion addition

4.1 General
Corrosion addition for the for plate, stiffeners and girders shall follow the requirements given in the DNV Rules for ships Pt.3 Ch.1 Sec.2.

4.2 Offshore specific tanks
For tanks containing liquids used for offshore service and not defined in the DNV Rules for ships, Pt.3 Ch.1 Sec.2 the corrosion addition $t_k$ is given in Table 3 shall be used.

Table 3 Corrosion addition $t_k$ in mm

<table>
<thead>
<tr>
<th>Internal members and plate boundary between spaces of the given category.</th>
<th>Tank/hold region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Within 1.5 m below weather deck or hold top</td>
</tr>
<tr>
<td>Mud tanks /Brine tanks/ Produced water tanks</td>
<td>3.0</td>
</tr>
<tr>
<td>Methanol tanks /MEG tanks/ Condensate tanks</td>
<td>2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plate boundary between given space category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 1.5 m below weather deck or hold top</td>
</tr>
<tr>
<td>Ballast/Mud/Brine/Produced water tanks towards cargo oil/condensate/MEG/methanol tanks</td>
</tr>
<tr>
<td>Ballast/Mud/Brine/Produced water tanks towards other category space ¹)</td>
</tr>
<tr>
<td>Cargo oil/condensate/MEG/methanol tanks towards other category space ¹)</td>
</tr>
</tbody>
</table>

¹) Other category space denotes the hull exterior and all spaces other than water ballast, cargo oil tanks and tanks mentioned above.
²) The figure in brackets refers to non-horizontal surfaces.
SECTION 2 DESIGN PRINCIPLES

1 Introduction

1.1 Overall design principles

1.1.1 This section defines the principles for design of the hull, topside structures and topside support structures.

1.1.2 The overall principles are based on the following:

- safety of the structure can be demonstrated by addressing the potential structural failure mode(s) when the unit is subjected to loads scenarios encountered during transit, operation and in harbour.
- structural requirements are based on a consistent set of loads that represent typical worst possible loading scenarios
- unit has inherent redundancy. The unit’s structure works in a hierarchical manner and as such, failure of structural elements lower down in the hierarchy should not result in immediate consequential failure of elements higher up in the hierarchy
- structural continuity is ensured. The hull, topside structures and topside interface to the hull structure should have uniform ductility.

1.1.3 Subdivision and arrangement of water tight bulkheads shall in general follow the requirements given in DNV Rules for ships Pt.3 Ch.1 Sec.3 A.

2 Design conditions

2.1 General

2.1.1 All relevant design condition shall be considered e.g:

- transit and non-operational conditions
- operating conditions
- survival conditions.
- accidental conditions

2.1.2 Design conditions of offshore ship-shaped units are usually accompanied by draughts, mass distribution, loading conditions, mooring configuration, etc.

2.1.3 The suitability of offshore ship-shaped units is dependent on the environmental conditions in the areas of the intended operation. A drilling unit in normally designed for World Wide operation but may also be designed for operating at site specific region(s). A production unit is normally designed to operate at site specific area.

2.2 Transit condition

2.2.1 Unrestricted transit is defined as moving the unit from any geographical location to another, and is covered by the DNV Rules for ships Pt.3 Ch.1.

2.2.2 Units that are intended to stay at one specific location for most of the design life may be designed for restricted transit, see Sec.11 [2.1] for details.

2.2.3 The design accelerations for the topside structures and topside interface to hull may be based on the DNV Rules for ships Pt.3 Ch.1. Alternatively design accelerations may be based on direct calculations, see [2.7.7].

2.3 Operating conditions

2.3.1 Operating condition is related to a maximum operational criteria for the environmental loads at which the unit need to suspend the operation, typically suspend the drilling operation. Operation criteria is mainly relevant for drilling units.
2.3.2 The maximum allowable sea state (Hs) for the criteria of aborting the operation shall be defined when relevant. The operation condition may be a governing condition for the topside interface, as the mass distribution and centre of gravity for the topside equipments may be different than in the survival condition given in [2.4].

2.3.3 The operating condition shall account for the combination of wave and wind effects.

2.3.4 Limiting design data for each operation mode shall be described in the structural design brief and in the units operating manual.

2.4 Survival condition (ULS)

2.4.1 The survival is here related to the "ultimate limit state (uls)" condition and is the most severe environmental loads the unit may be exposed to. The unit has normally suspend all operational work due to the severity of the environmental loads. The unit may either be weather-vaned at the location with own propulsion or moored to the sea bed, as applicable.

2.4.2 The survival condition shall account for the combination of wave effects and wind effects.

2.4.3 For unit operating in areas exposed to forecast hurricanes and intend to leave the site and seek for sheltered waters, the survival condition may be considered as an accidental condition. The unit shall anyhow be checked for the most severe 100 year storm condition or sudden hurricane scenario.

2.5 Accidental condition (ALS)

2.5.1 An accidental event is related to undesired incident or condition which in combination with other conditions leads to an accidental effect, such as e.g. explosion, fire, technical failure, etc.

2.5.2 The principles and generic design loads are given in Sec.8.

2.6 Benign waters or harsh environmental areas

2.6.1 If the unit is restricted to operate in benign waters, the strength requirements given in [2.4] for the survival condition are not required as the transit condition given in [2.2] will be governing. Operation conditions given in [2.3] may still be relevant design conditions and shall be considered.

2.6.2 The Benign waters criteria are defined in Table 1.

a) If Hs\(_{100\ year}\) < 8.0 m (or 10.0 m depending on the ship length) is specified and documented for the actual site specific location, no wave load analysis is required to demonstrate that the actual area is benign waters.

b) If Hs\(_{100\ year}\) > 8.0 m (or 10.0 m depending on the ship length) or if no sufficient information of actual Hs\(_{100\ year}\) for the actual location is available, the Mw\(_{Site-100\ year}\) need to be determined by using a wave load analysis for the survival condition as described in Table 2 in order to demonstrate that Mw\(_{Rule-20\ year}\) > Mw\(_{Site-100\ year}\), i.e. Benign waters.

If neither the a) or the b) requirements given above are satisfied, the unit is defined to operate in harsh environmental area.

**Guidance note:**
The Mw Site-100year is the characteristic wave bending moment and includes non-linear correction factor as defined in [2.7.8].
Chapter 2  Section 2

Guidance note:
The significant wave height \((H_{\text{s100 year}})\) for the survival condition can be estimated using 2-parameter Weibull parameters \((\alpha_s, \beta_s)\) for different scatter diagram as present in DNV-RP-C205 Appendix C together with the formula:

\[ H_s = \alpha_s \cdot \left[ \ln(N) \right]^{1/\beta_s} \]

where "N" is the number of maxima for the sea state in a time period "t". \(N = t/r\) and "r" is the is the duration of each short-term variation (normally taken as 3 hours). E.g. for a time period of 100 year the value N is then \(N=100 \times 365 \times 24/3 = 292000\).

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2.7 Wave load analysis

2.7.1 When a wave load analysis is carried out to check the criteria given in [2.6.2] or to determine accelerations for topside and topside interface to the hull structure, the wave load analysis shall be carried out using the design basis criteria given in Table 2 and [2.7.7].

For offshore installations (FPSO/FSO) that stay at one location for most of the design life, the actual weather window route may be used as basis for the transit condition, see also Sec.11.

2.7.2 The design still water loading conditions shall be based on the loading manual for the unit and in order to determine the envelope curves. The most unfavourable loading conditions shall be used as basis for the wave load analysis.

2.7.3 If short term response analysis is carried out for ultimate strength, the combination of significant wave height \((H_s)\) and spectral peak period \((T_p)\) or zero-crossing period \((T_z)\) for all sea states along the contour line shall be considered. The most probable maximum (MPM) value may be used for calculating the wave responses.

Guidance note:
The MPM value corresponds to the 37\% percentile, i.e. 63\% probability of exceedance.

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2.7.4 The sectional loads shall be calculated at the neutral axis of the section considered.

2.7.5 The section loads shall be determined at a sufficient number of positions along the hull in order to calculate the maximum responses in all relevant sections.

2.7.6 Table 2 defines the basis for the wave load analysis that shall be used for the hull girder ultimate strength, see Sec.4 [3], the topside structure, see Sec.5 and the topside interface to hull structure, see Sec.6.

The operation condition shall be checked when found relevant for the project based on the units operation philosophy, but is mainly relevant for strength check of the topside and topside interface structure for drilling units.

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### Table 1  Benign waters criteria

| Rule ship length | \(H_{s100 \text{ year}} \leq 8.0\text{m} \text{ or when} \) | \(H_{s100 \text{ year}} \leq 10.0\text{m} \text{ or when} \)
|------------------|-----------------|-----------------|
| \(L > 200\text{ m}\) | \(M_{\text{Wrule-20 year}} > M_{\text{Wsite-100year}}\) | \(M_{\text{Wrule-20 year}} > M_{\text{Wsite-100year}}\)

#### Guidance note:
The significant wave height \((H_{s100\text{ year}})\) for the survival condition can be estimated using 2-parameter Weibull parameters \((\alpha_s, \beta_s)\) for different scatter diagram as present in DNV-RP-C205 Appendix C together with the formula:

\[ H_s = \alpha_s \cdot \left[ \ln(N) \right]^{1/\beta_s} \]

where "N" is the number of maxima for the sea state in a time period "t". \(N = t/r\) and "r" is the is the duration of each short-term variation (normally taken as 3 hours). E.g. for a time period of 100 year the value N is then \(N=100 \times 365 \times 24/3 = 292000\).

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
The Transit condition may optionally be assessed using direct calculated accelerations for topside and topside interface structure as alternative to the accelerations given in DNV Rules for ships Pt.3 Ch.1.

### Table 2 Design basis of wave load analysis for ultimate strength calculations

<table>
<thead>
<tr>
<th>Wave parameters</th>
<th>Design condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transit</td>
</tr>
<tr>
<td>Wave environment</td>
<td>North Atlantic scatter diagram</td>
</tr>
<tr>
<td>Wave spectrum</td>
<td>PM spectrum</td>
</tr>
<tr>
<td>Wave heading profile</td>
<td>All headings included (0° to 360°)</td>
</tr>
<tr>
<td>Wave spreading</td>
<td>Cos²</td>
</tr>
</tbody>
</table>

1) JONSWAP spectrum is normally used, see DNV-RP-C205
2) Relevant for weather-vaning units. Other heading profile for operation and survival condition may be used, if documented. For units with spread mooring arrangement, all heading with same probability should be considered
3) Accelerations for topside interface analysis shall be based on Cos² wave spreading
4) Operation is mainly related to drilling operations like maximum sea state for the drilling operation, stand-by condition, etc.
5) For units intended for unrestricted service (World Wide operation), North Atlantic scatter diagram shall be used. The scatter diagram used shall represent a period of 100 years, when used for ultimate strength.
6) The direction (0°, 15° or 30°) giving the highest short term response shall be used.

### 2.7.7 [2.7.7] defines the basis for the wave load analysis that shall be used when the direct wave loads are used as basis for the fatigue calculation, see Sec.7.

### Table 3 Design basis of wave load analysis for fatigue strength

<table>
<thead>
<tr>
<th>Wave parameters</th>
<th>Design condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transit</td>
</tr>
<tr>
<td>Wave environment</td>
<td>World Wide scatter diagram</td>
</tr>
<tr>
<td>Probability of exceedance</td>
<td>10⁻⁴</td>
</tr>
<tr>
<td>Wave spectrum</td>
<td>PM spectrum</td>
</tr>
<tr>
<td>Wave heading profile</td>
<td>All headings included (0° to 360°)</td>
</tr>
<tr>
<td>Wave spreading</td>
<td>Cos²</td>
</tr>
</tbody>
</table>

1) Cos² shall be used, unless otherwise documented.
2) For weather-vaning units. Other heading profile for operation condition may be used, if documented. For units with spread mooring arrangement, all heading with same probability shall be considered
3) For units intended for unrestricted service (World Wide operation), the World Wide scatter diagram should be used. Units designed for site specific service locations shall base the fatigue assessment on the scatter diagram for the given service locations.

### 2.7.8 Non-linear correction factor shall be included for the survival condition when using the wave bending moments and shear forces from a linear wave load analysis. Typical non-linear correction factors for ships with traditional hull shape are given in Table 4 and shall be used, unless otherwise documented.

### Table 4 Non-linear correction factor for ultimate strength

<table>
<thead>
<tr>
<th>Item</th>
<th>Sagging</th>
<th>Hogging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave bending moment</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Wave shear force</td>
<td>1.1</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Guidance note:**
In operation condition the waves are smaller and the non-linear correction effect may be excluded.

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3 Design methods

3.1 General

3.1.1 The two acceptable design methods are described below:
- Working Stress Design (WSD)
- Load and Resistance Factor Design (LRFD).

The design method shall be defined for the project and consequently used. Mixing between different design methods during the design is generally not accepted. Both methods are applicable for hull and topside structure.

3.1.2 The level of safety of a structural element is considered to be satisfied if the design load effect \( (S_d) \) is less or equal the design resistance \( (R_d) \) where \( (S_d) \) and \( (R_d) \) represents the limit states defined in Sec.1 [2].

\[ S_d \leq R_d \]

3.1.3 The capacity assessment related to the allowable yield stress is related to Von Mises equivalent membrane stress.

3.1.4 For the topside structure, see Sec.6, a \( \beta \)-coefficient is introduced in addition for the permissible usage factors.

3.1.5 Independent of the design method, each structural member shall be designed for the most unfavourable loading conditions given in [3.1.4].

Table 5 Load conditions and relevant limit states

<table>
<thead>
<tr>
<th>Limit State</th>
<th>Description</th>
<th>Relevant for design condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit</td>
<td>Operating</td>
<td>Survival</td>
</tr>
<tr>
<td>ULS</td>
<td>Maximum static/ Maximum combined static and dynamic loads</td>
<td>X 1)</td>
</tr>
<tr>
<td>FLS</td>
<td>Dynamic cyclic loads</td>
<td>X</td>
</tr>
<tr>
<td>ALS</td>
<td>Accidental loads and associated static loads</td>
<td></td>
</tr>
</tbody>
</table>

1) Transit condition is covered by the DNV Rules for ships Pt.3 Ch.1

3.2 Working stress design method

3.2.1 The Working stress design (WSD) method is also known as the allowable stress method and is a method where the target safety level is achieved by comparing the calculated stress with the permissible stress by multiply the characteristic strength, or capacity, with the applicable usage factor.

The permissible usage factor, \( \eta_p \), depends on load combination, failure mode and importance of strength member, and is found by calculate the basic usage factor, \( \eta_0 \), found in Table 6.

The design load \( (S_d) \) contains both static and dynamic loads.

The design resistance \( (R_d) \) is found by multiply the basic usage factor given in Table 6 with the characteristic resistance \( (R) \) for the structural element of concern.

\[ \eta_0 \cdot R \leq R_d \]

Table 6 Basic usage factors for different load conditions

<table>
<thead>
<tr>
<th>Cond.</th>
<th>Limit state</th>
<th>Description</th>
<th>Basic usage factor, ( \eta_0 )</th>
<th>Relevant for design condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Operating</td>
<td>Survival</td>
</tr>
<tr>
<td>a)</td>
<td>ULS</td>
<td>Max static loads</td>
<td>0.60</td>
<td>X</td>
</tr>
<tr>
<td>b)</td>
<td>ULS</td>
<td>Maximum combined static and dynamic loads</td>
<td>0.80</td>
<td>X</td>
</tr>
<tr>
<td>c)</td>
<td>FLS</td>
<td>Dynamic cyclic loads</td>
<td>1.00</td>
<td>X</td>
</tr>
<tr>
<td>d)</td>
<td>ALS</td>
<td>Accidental loads and associated static loads</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>
3.2.2 The basic usage factor $\eta_0$ accounts for:
- possible unfavourable deviations of specified or expected loads
- uncertainties in the model and analysis used for determination of load effects
- possible unfavourable deviations in the resistance of materials
- possible reduced resistance of the materials in the structure, as a whole, as compared to the values deduced from test specimens
- deviation from calculated strength resistance due to fabrication.

3.3 Load and resistance factor design method

3.3.1 The load and resistance factor design (LRFD) method is a design method by which the target safety level is obtained by applying the load with a load factor, together with a material factor.

The design load ($S_d$) is found by multiply the characteristic loads, permanent static ($G$) and dynamic ($E$), with a given partial load factor ($\gamma_f$). The design resistance ($R_d$) is found by divide the characteristic resistance ($R$) to a material factor ($\gamma_m$).

$$\gamma_f G \cdot \eta G + \gamma_f E \cdot \eta E \leq R / \gamma_m$$

3.3.2 Similar as for the (WSD) format the conditions as given in [3.3.2] shall be checked.

### Table 7 Partial load coefficients for different load conditions

<table>
<thead>
<tr>
<th>Cond.</th>
<th>Limit state</th>
<th>Description</th>
<th>Load category</th>
<th>Relevant for design condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Static loads ($\eta G$)</td>
<td>Env. loads ($\eta E$)</td>
</tr>
<tr>
<td>a)</td>
<td>ULS</td>
<td>Static combined dynamic loads</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>b)</td>
<td>ULS</td>
<td>Static combined dynamic loads</td>
<td>1.0</td>
<td>1.15</td>
</tr>
<tr>
<td>c)</td>
<td>FLS</td>
<td>Dynamic cyclic loads</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>d)</td>
<td>ALS</td>
<td>Accidental loads and associated static loads</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Guidance note:**
- Environmental loads are loads caused by the environmental phenomena, i.e. hull girder loads, inertia loads, sea pressure, winds loads. Ice is to be considered as additional weight to the structure, i.e. included as part of the static load
- Variable functional loads are to be considered as static loads.

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3.3.3 The material factors that shall be used in combination with the partial load factors for the different limit state and design conditions are given in Table 8.

### Table 8 Material factor, $\gamma_m$

<table>
<thead>
<tr>
<th>Design condition</th>
<th>Cond.</th>
<th>Limit state</th>
<th>Operating</th>
<th>Survival</th>
<th>Accidental</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>ULS</td>
<td>1.15</td>
<td>1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>ULS</td>
<td>1.15</td>
<td>1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>FLS</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>ALS</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
SECTION 3 DESIGN LOADS

1 Introduction

1.1 General

1.1.1 The requirements in this section define and specify load components to be considered in the overall strength analysis as well as design pressures applicable for local scantling design.

1.1.2 Design load criteria given by operational requirements shall be fully considered. Examples of such requirements may be:

- drilling, production, work-over and combinations thereof
- consumable re-supply procedures and frequency
- maintenance procedures and frequency
- possible load changes in most severe environmental conditions.

2 Static loads

2.1 General

2.1.1 The still water loads consist of the permanent and variable functional loads.

2.1.2 Permanent functional loads relevant for offshore units are:

- mass of the steel of the unit including permanently installed modules and equipment, such as accommodation, helicopter deck, cranes, drilling equipment, flare and production equipment.
- mass of mooring lines and risers.

2.1.3 Variable functional loads are loads that may vary in magnitude, position and direction during the period under consideration.

2.1.4 Typical variable functional loads are:

- hydrostatic pressures resulting from buoyancy
- crude oil
- ballast water
- fuel oil
- consumables
- personnel
- general cargo
- riser tension.
- mooring forces
- mud, brine and drill water.

2.1.5 The variable functional loads utilised in structural design shall normally be taken as either the lower or upper design value, whichever gives the more unfavourable effect.

2.1.6 Variations in operational mass distributions (including variations in tank filling conditions) shall be adequately accounted for in the structural design.

2.2 Still water hull girder loads

2.2.1 All relevant still water load conditions shall be defined and permissible limit curves for hull girder bending moments and shear forces shall be established for transit and operating condition separately.

2.2.2 The permissible limits for hull girder still water bending moments and hull girder still water shear forces shall be given at least at each transverse bulkhead position and be included in the loading manual.
Separate limits shall be defined for stillwater sagging and hogging moments, together with positive and negative stillwater shear forces.

2.2.3 Actual still water shear forces shall be corrected for structural arrangement according to the procedures given in the DNV Rules for ships Pt.3 Ch.1 Sec.5.

2.2.4 The shape and values of the limit curves for still water bending moments and shear forces are defined in the DNV Rules for ships Pt.3 Ch.1 Sec.5. The stillwater limit curves from the loading manual for the actual design conditions defined in Sec.2 [2.1] may alternatively be used, and shall be used if the stillwater limits are above the rule values in Pt.3 Ch.1 Sec.5. Some contingency margin should be considered for the limit curves.

3 Environmental loads

3.1 General

Environmental loads are loads caused by environmental phenomena. Environmental loads which may contribute to structural damages shall be considered. Consideration should be given to responses resulting from the following listed environmental loads:

- wave induced loads
- wind loads
- current loads
- snow and ice loads, when relevant
- green sea on deck
- sloshing in tanks
- slamming (e.g. on bow and bottom in fore and aft ship)
- vortex induced vibrations (e.g. resulting from wind loads on structural elements in a flare tower).

3.2 Wave induced loads

3.2.1 If wave induced loads are not based on the DNV Rules for ships Pt.3 Ch.1, see Sec.2 [2.6], the wave induced loads shall be calculated by the hydrodynamic wave load analysis using three dimensional sink source (diffraction) formulation with the weather vaning characteristics given in Sec.2 [2.7].

3.2.2 The wave loads shall be determined for the site specific environment in which the unit is intended to operate, see DNV-RP-C205 for environmental data.

3.2.3 The following wave induced responses shall be calculated:

- motions in six degrees of freedom
- vertical wave induced bending moment at a sufficient number of positions along the hull. The positions shall include the areas where the maximum vertical bending moment and shear force occur and at the turret position. The vertical wave induced bending moment shall be calculated with respect to the section’s neutral axis
- horizontal bending moment
- accelerations
- axial forces
- external sea pressure distribution.

3.2.4 Torsional moments may normally be disregarded, unless found relevant.

3.3 Wind loads

3.3.1 Wind loads shall be accounted for in the design of topside structures subject to significant wind exposure, e.g. flare tower, derrick, modules, etc. The mean wind speed over 1 minute period at actual position above the sea level shall be used together with the inertia loads from the waves. The calculation procedure of wind loads may be found in DNV-RP-C205, but should normally not be less than 2.5 kN/m².
3.3.2 For slender member, e.g. members in a flare tower structure, additional assessments of Vortex-Shedding shall be carried out according to DNV-RP-C205.

3.3.3 The wind velocity for transit, operating and survival condition should normally be not less than the following, unless otherwise documented:

- Transit and operation conditions: \( v_{1\text{min}10\text{m}} = 36 \text{ m/s} \) (1 minute period at 10 m above sea level).
- Survival condition: Site specific.

**Guidance note:**

For units intended for World Wide operation (unrestricted service) winds speed of \( v_{1\text{min}10\text{m}} = 51.5 \text{ m/s} \) for the survival condition will cover most locations.

Typical wind speed values for other locations are given in DNVGL-OS-E301. Mean wind speed is normally specified for 1 hour mean but the following values may be used:

<table>
<thead>
<tr>
<th>Elevation above sea level (z)</th>
<th>Average time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 sec</td>
</tr>
<tr>
<td>1 m</td>
<td>0.934</td>
</tr>
<tr>
<td>5 m</td>
<td>1.154</td>
</tr>
<tr>
<td>10 m</td>
<td>1.249</td>
</tr>
<tr>
<td>20 m</td>
<td>1.344</td>
</tr>
<tr>
<td>30 m</td>
<td>1.400</td>
</tr>
<tr>
<td>40 m</td>
<td>1.439</td>
</tr>
<tr>
<td>50 m</td>
<td>1.470</td>
</tr>
<tr>
<td>60 m</td>
<td>1.494</td>
</tr>
<tr>
<td>100 m</td>
<td>1.564</td>
</tr>
</tbody>
</table>

The values in the table above are based on the following expression given in DNV-RP-C205:

\[
U(T, z) = U_{10} \cdot (1 + 0.137 \cdot \ln(z/H) - 0.047 \cdot \ln(T/T_{10})
\]

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.4 Green sea

3.4.1 The green sea is the overtopping by sea in severe wave conditions. The forward part of the deck and areas aft of midship will be particularly exposed to green sea. Short wave periods are normally the most critical.

3.4.2 Appropriate measures should be considered to avoid or minimise the green sea effects on the hull structure, accommodation, deckhouses, topside modules and equipment. These measures include bow shape design, bow flare, bulwarks and other protective structure. Adequate drainage arrangements shall be provided.

3.4.3 Structural members exposed to green sea shall be designed to withstand the induced loads. Green sea loads are considered as local loads.

3.4.4 When lacking more exact information, e.g. from model testing, green sea loads specified in unit specific provisions Sec.10 and Sec.11 shall be used.

3.4.5 Shadow effects from either green water protection panel or other structure may be accounted for.

3.5 Sloshing loads in tanks

3.5.1 In partly filled tanks sloshing occurs when the natural periods of the tank fluid is close to the periods of the motions of the unit. Factors governing the occurrence of sloshing are:

- tank dimensions
- tank filling level
- structural arrangements inside the tank (wash bulkheads, web frames etc.)
- transverse and longitudinal metacentric height (GM)
— draught
— natural periods of unit and cargo in roll (transverse) and pitch (longitudinal) modes.

3.5.2 The pressures generated by sloshing of the cargo or ballast liquid and the acceptance criteria shall comply with the requirements given in the DNV Rules for ships Pt.3 Ch.1 Sec.4 C300.

3.6 Bottom slamming

3.6.1 When lacking more exact information, e.g. from model testing, relevant requirements to strengthening against bottom slamming in the bow region are given in the DNV Rules for ships Pt.3 Ch.1 Sec.6 H.

3.6.2 The bottom aft of the unit shall be strengthened against stern slamming according to DNV Rules for ships Pt.3 Ch.1 Sec.7 E200.

3.7 Bow impact

3.7.1 The bow region is normally to be taken as the region forward of a position 0.1 L aft of F.P. and above the summer load waterline. The design of the bow structure exposed to impact loads shall be carried out according to DNV Rules for ships Pt.3 Ch.1 Sec.7 E.

3.7.2 The speed V in knots used in the formulas shall not be less than 8.0.

3.8 Combination of dynamic loads

3.8.1 The tables below gives combination responses based on the requirements given in Sec.2 Table 2 for Transit, Operation and Survival condition. The tables may be used when the responses are calculated using long term approach, or alternatively short term approach provided the maximum response for the most severe direction given in Sec.2 Table 2 is used as basis. The tables are development with basis for combination of dynamic responses related to the topside and topside interface given in Sec.5 and in Sec.6. For each load case (LC) the loads shall be multiplied with the factors as given in the tables.

Guidance note:

- Beam sea condition is not included as a main wave direction in the tables Table 1 to Table 3 as the oblique sea condition is found governing. However, for spread mooring system the response (a_t) from a beam sea condition should be considered when relevant.
- Sagging condition is when a wave trough is positioned at the midship for maximum draught (full load condition)
- Hogging condition is when a wave crest is positioned at the midship for minimum draught (ballast condition).
### Table 1  Combination of dynamic responses at 0.25 Lpp (aft quarter length) and aft

<table>
<thead>
<tr>
<th>Wave dir.</th>
<th>Max response</th>
<th>LC</th>
<th>Combination with fraction of responses</th>
<th>Global Hull girder loads</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$M_{WV}$</td>
<td>$Q_{WV}$</td>
</tr>
<tr>
<td>Head Sea</td>
<td>$M_{WV}$</td>
<td>1a</td>
<td>1.0</td>
<td>1.0</td>
<td>-0.5</td>
</tr>
<tr>
<td></td>
<td>$M_{WV}$</td>
<td>1b</td>
<td>-1.0</td>
<td>-1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>2a</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>2b</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>2c</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>2d</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>3a</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>3b</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>3c</td>
<td>-0.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>3d</td>
<td>-0.7</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

### Table 2  Combination of dynamic responses at 0.5 Lpp (midship)

<table>
<thead>
<tr>
<th>Wave dir.</th>
<th>Max response</th>
<th>LC</th>
<th>Combination with fraction of responses</th>
<th>Global Hull girder loads</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$M_{WV}$</td>
<td>$Q_{WV}$</td>
</tr>
<tr>
<td>Head Sea</td>
<td>$M_{WV}$</td>
<td>1a</td>
<td>1.0</td>
<td>-0.3</td>
<td>-0.4</td>
</tr>
<tr>
<td></td>
<td>$M_{WV}$</td>
<td>1b</td>
<td>-1.0</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>2a</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>2b</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>2c</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>2d</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>3a</td>
<td>0.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Hogging</td>
<td>3b</td>
<td>0.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>3c</td>
<td>-0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Oblique Sea</td>
<td>$a_L$</td>
<td>Sagging</td>
<td>3d</td>
<td>-0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>
3.8.2 Sign convention for the accelerations given in Table 1 to Table 3 is related to the hull motions and when used for topside interface analysis, the topside loads shall be applied in the opposite direction of the sign presented for the accelerations in the tables.

3.8.3 Other responses not presented in the tables below as e.g. sea pressure, horizontal bending moment and torsion when relevant shall be considered acting simultaneously, if not else documented.

3.8.4 Linear interpolation may be used between the positions.

3.8.5 If the structure and supporting structure is symmetric of one or more axis, the number of load combinations may be reduced.

3.9 Design density of tanks

3.9.1 The following minimum design density of tanks shall be used for the strength and fatigue analysis, unless otherwise agreed by the project:

- Ballast tanks: 1.025 t/m³ (seawater)
- Cargo tanks: 0.9 t/m³ 1)
- Fuel oil tanks: 0.9 t/m³ 1)
- Mud tanks: 2.5 t/m³
- Brine tanks: 2.2 t/m³
- Fresh water tanks: 1.0 t/m³ 1)

---

Table 3  Combination of dynamic responses at 0.75 Lpp (quarter length) and fwd

<table>
<thead>
<tr>
<th>Wave dir.</th>
<th>Max response</th>
<th>LC</th>
<th>Combination with fraction of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Global Hull girder loads</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Acceleration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MWv</td>
</tr>
<tr>
<td>Head Sea</td>
<td>M_Wv</td>
<td>1a</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>M_Wv</td>
<td>1b</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>2a</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>2b</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>2c</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>2d</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>3a</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>3b</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>3c</td>
<td>-0.7</td>
</tr>
<tr>
<td></td>
<td>a_L</td>
<td>3d</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

---

1) Positive vertical bending moment (Ms, M_Wv) is Hogging moment and negative is Sagging moment

---

- Positive longitudinal acceleration (a_L) is along positive x-axis (forward)
- Positive transverse acceleration (a_t) is along positive y-axis (towards portside of the unit)
- Positive vertical acceleration (a_v) is along positive z-axis (upwards)
- The sign of positive vertical shear force (Qs, Q_Wv) is shown in the figure at right
— Drill water tanks: 1.0 \text{t/m}^3 1)

1) For tank testing condition density of seawater 1.025 \text{t/m}^3 shall be used both for local strength check and in the cargo hold FE analysis for the harbour condition.

3.9.2 The actual tank densities shall be stated on the tank plan drawing.

3.9.3 Higher design densities than given in [3.9.1] shall be used if specified by the project.
SECTION 4 STRENGTH OF HULL STRUCTURE

1 Introduction

The hull girder and its structural members shall comply with the requirements as outlined in Sec.2. In general, all elements exposed to local loads in both transit and in-situ conditions shall comply with the technical requirements (DNV Rules for ships Pt.3 Ch.1). Exception may be given to units with restricted transit as outlined in Sec.2 [2.2.2].

The longitudinal strength requirements in transit conditions, and also in survival conditions in benign waters are assessed according to the technical requirements.

In harsh environments, the longitudinal strength shall be assessed for the actual site specific loads. Consistent environmental loads derived from direct calculations shall be used.

2 General technical requirements

2.1 Overview

Typical elements which shall comply with the technical requirements are given in Table 1. The computer programs given in the table are not mandatory.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Elements complying with the technical requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computer programs</td>
</tr>
<tr>
<td></td>
<td>Harsh environment</td>
</tr>
<tr>
<td>Tasks</td>
<td>Transit</td>
</tr>
<tr>
<td>Local strength to plates, stiffeners</td>
<td>Nauticus Section Scantlings 1)</td>
</tr>
<tr>
<td>Wave loads, Pressure, bending moments, shear forces</td>
<td>Nauticus Section Scantlings</td>
</tr>
<tr>
<td>Transverse frames, stringers, side girders, girders on transverse bhds</td>
<td>FEA – Part ship model</td>
</tr>
<tr>
<td>Longitudinal Strength</td>
<td>Nauticus Section Scantlings</td>
</tr>
<tr>
<td>Fore and Aft ship</td>
<td>Nauticus Section Scantlings and 3D-Beam 2)</td>
</tr>
</tbody>
</table>

1) DNV GL rule scantling program
2) 3D analysis based on beam theory

Guidance note:
In DNV Rules for ships Pt.3 Ch.1, local dynamic loads and corresponding acceptance criteria for transverse strength are given at a probability of exceedance of $10^{-4}$ (daily return period) in the North Atlantic.

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

2.2 Girder system

2.2.1 The girder system comprises typically transverse web frames, stringers and web frames on transverse bulkheads, side girders and horizontal stringers.

2.2.2 The transverse members shall be checked by use of FE analysis and shall meet the requirement with respect to material yield and buckling capacity given in the DNV Rules for ships Pt.3 Ch.1 Sec.12 and Sec.13 respectively.

2.2.3 Where the effect of openings is not considered in the FE model, the Von Mises equivalent membrane stress in way of the opening is to be properly modified with adjusting shear stresses in proportion to the ratio of web height and opening height, see DNV Classification Note No.31.3.
Guidance note:
The von Mises equivalent stress is defined as follows:

\[
\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}
\]

Where \(\sigma_x\) and \(\sigma_y\) are element membrane stresses in x- and y-direction respectively, \(\tau\) is element shear stress in the x-y plane, i.e. local bending stresses in plate thickness not included.

---end---of---guidance---note---

2.2.4 Where elements are smaller than the standard mesh size, the stresses may be obtained using the average stress over the elements within the standard mesh size.

Guidance note:
Standard mesh size is normally related to one element between the stiffeners spacing (700-800mm). For a transverse stringer typically 3 elements over the high is sufficient.

---end---of---guidance---note---

2.2.5 All relevant tank filling configuration shall be included.

2.2.6 The topside loads shall be represented in the FE model to account for the effect of topside interface with the hull structure.

2.2.7 Net scantlings according to the requirements given in DNV Rules for ships Pt.3 Ch.1 in shall be used in the FE-model

2.2.8 Buckling capacity of individual unstiffened plate panels shall comply with the requirements given in the DNV Rules for ships Pt.3 Ch.1 Sec.13. Using unstiffened plate panel defined in DNVGL-RP-C201 together with the acceptance criteria in the DNV Rules for ships Pt.3 Ch.1 Sec.13, is also accepted.

2.2.9 Local hot spots typically for stringer/girder toes as given in Table 5 shall follow the fine mesh criteria in Table 7.

2.2.10 The transverse girder system may alternatively be checked using site specific 100 years loads according to the principles in Sec.2 [2.7] and the acceptance criteria given in Sec.2 [3.2] or Sec.2 [3.3].
3 Hull girder longitudinal strength (ULS)

3.1 General

3.1.1 The longitudinal hull girder strength is an additional offshore strength control for the elements that contributes to the units longitudinal strength like; Main deck, bottom, longitudinal BHDs and side shell.

The hull girder longitudinal strength is related to the ULS condition defined in Sec.2 [2.4] where 100 years loads based on direct calculations as specified in Sec.2 [2.7] are used.

Table 2 Typical work flow for ULS strength assessment.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Applicable Rules</th>
<th>Harsh</th>
<th>Transit</th>
<th>Survival</th>
<th>Benign</th>
<th>Transit</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave loads 100yrs. Pressure, bending moments, shear forces</td>
<td>Sec.2 [2.7] Direct analysis</td>
<td>Not required</td>
<td>WADAM or WASIM 1)</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td>Hull girder strength (longitudinal strength) ULS – Yield and Buckling</td>
<td>Subsec [3.2] Transverse stresses- 100 yrs</td>
<td>Not required</td>
<td>FEA – Part ship model with 100 yrs loads</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td>Subsec [3.3] Yield and Buckling capacity</td>
<td>Not required</td>
<td>Nauticus Section Scantlings/ FEA and PULS 1)</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
</tr>
</tbody>
</table>

1) Linear/non-linear wave load program based on 3D radiation diffraction theory
2) DNV GL buckling capacity program.

3.1.2 Hull girder longitudinal strength may be evaluated by FE analysis or using the DNV GL NAUTICUS Hull program for ultimate strength calculation. The probability of exceedance shall be consistent when global and local loads are combined.

3.1.3 Horizontal wave bending moments may be disregarded in the assessment of the hull girder longitudinal strength.

3.1.4 The static and wave axial force acting at the fore and aft part of the unit shall be considered.

3.1.5 The shear correction factor for the longitudinal bulkheads shall be calculated. The factor is defined as the ratio between the corrected still water shear force and actual still water shear force at the relevant section. See DNV Classification Note No.31.3 Sec.4.

3.1.6 Phase angles between global and local loads are normally disregarded, i.e. it is assumed that maximum responses occur at the same time.

3.1.7 Gross scantlings (no corrosion margin deducted) may be used for the calculation of the hull girder longitudinal strength.

3.2 Design loading conditions

3.2.1 For still water hull girder loads, see Sec.3 [2.2].

3.2.2 Local static and dynamic loads from topside, tank pressure and sea pressure shall be considered.

3.2.3 Dynamic loads shall be determined from the wave load analysis according to the principles given in Sec.2 [2.7].

3.2.4 For the purpose of structural analysis, the loading conditions in the loading manual may need to be modified to satisfy the principles given in [3.2.1] and [3.2.2].

3.2.5 The design loading conditions for the hull girder longitudinal strength for the survival condition are given in Table 3. Additional load cases may be considered and agreed depending on the structural arrangements such as moonpool, setback area, etc.
3.3 Hull girder capacity

3.3.1 The hull girder ultimate yield and buckling capacity checks of the main longitudinal members are performed by assessment of local stiffened panels subject to:

- longitudinal nominal stress (in direction of primary stiffener for stiffened panel)
- transverse nominal stress (in direction perpendicular to primary stiffener for stiffened panel)
- nominal in-plane shear stress
- lateral pressure from sea or cargo.

![Buckling check of each individual stiffened plate field including all stress components and lateral pressure component](image)

3.3.2 The von Mises criteria shall be used for the yield stress control according to the criteria given in Sec.2 [3]. Local peak stresses by refined mesh density in local areas described in [5.1.2] and [5.1.3] shall comply with the requirement given in Table 7.

3.3.3 The permissible still water bending moment and still water shear force curves (limit curves) shall be

![Stress components acting on the hull](image)
used together with the characteristic wave bending moments and wave shear forces (limit curves) for the actual location. Simultaneously presence of the stillwater values and phase information between the wave load responses may be considered if available.

3.3.4 The ultimate buckling capacity control of local stiffened panels shall be performed according to DNVGL-RP-C201, and shall comply with the acceptance criteria given in Sec.2 [3]. The ultimate buckling capacity of stiffened panels accepts local elastic buckling of the plates.

3.3.5 When ultimate buckling capacity using site specific wave loads is used to check the hull girder capacity, the requirements given in the DNV Rules for ships Pt.3 Ch.1 Sec.5, Sec.12 and Sec.13 for longitudinal strength may be waived.

Guidance note:
The hull girder ultimate buckling capacity may be checked using DNV GL NAUTICUS Hull. The transverse stresses due to bending of the main primary members from external and internal pressure are determined from a FE analysis. The average membrane stress is to be calculated from a group of elements representing one plate field between stiffeners.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4 Local supports
Design principles for foundations and supporting structures of hull equipment and machinery are given in Table 4.

Table 4 Design principles for foundations and supporting structures of hull equipment and machinery

<table>
<thead>
<tr>
<th>Supporting structures of thruster</th>
<th>DNV Rules for ships Pt.3 Ch.3 Sec.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rudders, nozzle and steering gears</td>
<td>DNV Rules for ships Pt.3 Ch.3 Sec.2</td>
</tr>
<tr>
<td>Supporting structures of helicopter deck and substructure</td>
<td>DNVGL-OS-E401</td>
</tr>
<tr>
<td>Foundations and supporting structures of temporary mooring equipment (e.g. chain stoppers, windlasses or winches, bollards, chocks, etc)</td>
<td>DNV Rules for ships Pt.3 Ch.3 Sec.5</td>
</tr>
<tr>
<td>Supporting structures of position mooring equipment (e.g. turret, etc)</td>
<td>Sec.11</td>
</tr>
<tr>
<td>Davits and supporting structures of launching appliances (e.g. life boat, raft, etc)</td>
<td>DNV Rules for ships Pt.3 Ch.3 Sec.5</td>
</tr>
</tbody>
</table>

5 Local stress analysis

5.1 Application

5.1.1 Local stress analyses are applicable to local areas of the hull where part ship FE model(s) used for the strength of the main girder system does not represent the local response sufficiently, e.g. toe of girder bracket, etc.

5.1.2 Typical local hull structure details to be analysed are given in Table 5.

More details may be necessary to be checked depending on the structure complexity.
5.1.3 Typical local topside supporting structures details to be analysed are given in Table 5. More details may be necessary to be checked based on the topside arrangement and complexity. Table 6 present details normally most relevant for the different ship shape type but details shall be included for each ship type when relevant.

Table 5 Hull structure details

| Relevant for: | — Toe of girder bracket at typical transverse web frame | Rules for ships Pt.3 Ch.1 |
| — Toe and heel of horizontal stringer in way of transverse bulkhead | Rules for ships Pt.3 Ch.1 |
| — Local stiffener in way of transverse bulkhead subjected to relative deformation. | Rules for ships Pt.3 Ch.1 |
| — Large opening in main deck, bottom and inner bottom, e.g. moonpool corner. | Hull girder strength (ULS) |

Table 6 Hull-topside interface details

| Relevant for: | FPSO | Drillships | |
| — Drillfloor substructure and supporting structure | X | |
| — Topside stool and support structure | X | X |
| — Turret support and interface structure | X | |
| — Crane pedestal foundation and supporting structures | X | X |
| — Foundation and supporting structures for rail of gantry crane | X | |
| — Riser interface | X | X |
| — Fairlead support | X | |
| — Flare tower foundation | X | |
| — Foundation, skids and supporting structures for heavy equipment like BOP, Xmas, etc | X | X |

Transit ==> loads as defined in Rules for ships
Survival ==> Hull girder strength (ULS)
5.2 General

5.2.1 Local structural details shall be evaluated by fine mesh FE analysis or equivalent methods to determine local stress distribution in the local areas which is difficult to achieve with coarse mesh.

5.2.2 The stress distribution in areas with global stress concentrations and discontinuities, e.g. moonpool openings, turret openings, etc. shall be derived from fine mesh FE analysis.

5.2.3 Net scantlings are to be utilised in the local strength analysis according to DNV Rules for ships Pt.3 Ch.1 Sec.12. Alternatively, gross scantlings may be utilised in case WSD design method defined in Sec.2 [3] is used for the evaluation.

5.3 Analysis model

5.3.1 Local models may be included directly in FE model used for the part ship analysis or by separate sub-models with prescribed boundary conditions, displacements and forces.

5.3.2 If sub-model is used, the extent of the local FE model is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the FE model should be coincided with primary support members, such as girders, stringers and floors, in the part ship model.

5.3.3 Local details at the areas of interest should be generally modelled with element mesh size of either $50 \times 50$ mm or $100 \times 100$ mm or $200 \times 200$ mm depending on the actual thickness and geometrical complexity of local details to be checked. See Table 7. Proper attention should be paid to transition of mesh density. Abrupt changes of mesh density should be avoided and transition area should be well off the stress concentration.

5.4 Design loading condition

5.4.1 The most onerous loading condition among those relevant for the hull girder longitudinal strength analysis or transverse strength analysis shall be applied for the local areas to be assessed.

5.4.2 If the local fine mesh analysis is run as a sub-model, prescribed boundary deformations or forces taken from the hull girder longitudinal strength analysis or the transverse strength analysis shall be applied. Local loads acting on the structure shall be applied to the model.

5.5 Fine mesh criteria

5.5.1 Fine mesh FE-analysis is to be used when the coarse mesh FE-analysis is insufficient to give required results for the area of interest.

5.5.2 The purpose of a local fine mesh analysis is:

— to check local details as given in Sec.4 [5.1].
— to find local hot spots relevant for fatigue calculations for details given in Sec.7 Table 1 and Table 2.

when the actual geometry cannot be adequately represented in the FE-model by normal coarse mesh size. The fine mesh criteria for local yield acceptance is given in Table 7

5.5.3 The extent of the fine mesh should not be less than 10 elements in all directions from the area to be checked and shall have a smooth transition of the mesh density from the fine mesh zone to the surrounding coarse mesh.
5.5.4 Local peak stress may be accepted in small areas provided redistribution of stresses to the adjacent area is possible without developing a mechanism, and that the dynamic part of the loads is not governing for fatigue.

5.5.5 The fine mesh analysis shall be performed with the same thickness (net or gross) as required for the coarse mesh analysis.

5.5.6 The peak usage factor ($\eta_{peak}$) given in Table 7 is the ratio between the calculated peak stress from the fine mesh FE-analysis and the corresponding yield stress of the material used. 50 $\times$ 50 mm mesh size is recommended but coarser mesh size up to 200 $\times$ 200 mm is accepted for checking peak stress as given in Table 7.

The calculated usage factors are related to Von Mises equivalent membrane stress at centre of a plane element (shell or membrane).

$$\sigma_{peak} = \eta_{peak} \cdot \sigma_{Material yield stress}$$

Table 7 Permissible peak usage factor ($\eta_{peak}$) for fine mesh FE analysis

<table>
<thead>
<tr>
<th>Structural component 1)</th>
<th>Design method</th>
<th>Load combination</th>
<th>Mesh size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 $\times$ 50 mm</td>
</tr>
<tr>
<td>Hull in general</td>
<td>DNV Rules for ships</td>
<td>Static + Dyn. (10^{-4} level) 2)</td>
<td>1.53</td>
</tr>
<tr>
<td>Hull and topside</td>
<td>WSD method</td>
<td>Static</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>interface structures</td>
<td>Static + Dyn. (10^{-8} or 10^{-8.7} level) 2)</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>LRDF method</td>
<td>Static + Dyn. (10^{-8} or 10^{-8.7} level) 2)</td>
<td>1.7</td>
</tr>
</tbody>
</table>

1) For typical details to be checked, see Sec.4 [5.1].
2) See [2.2.1] for definition. The load level for the applied loads must be consistent with the relevant acceptance criteria. Maximum permissible peak stress is limited to the material tensile strength.

5.5.7 For fatigue critical connections local peaks are not accepted, see Sec.7

5.5.8 Non-linear analysis using recognized finite element program with a given plastic strain criteria may be accepted as an alternative method to demonstrate acceptable local peak stress.

Guidance note:
A local strain of maximum 5% may be accepted provided redistribution of loads is possible.
SECTION 5 STRENGTH OF TOPSIDE STRUCTURES

1 Application

1.1 General

1.1.1 The requirement in this section is applicable for:

— local strength of plate and stiffener
— simple girders
— calculation of complex girder systems.

1.1.2 This section gives provisions for checking the strength of topside structures if part of the DNV GL classification scope, see Ch.3 Sec.1 Table 1.

1.1.3 The topside structures shall be designed to withstand the relevant loading conditions according to the transit, operating and survival conditions.

1.1.4 Topside structures consisting of truss work as the primary load-bearing elements, any plated structures used in mezzanine decks, etc. which are not part of the primary strength shall only comply with the local strength requirements, see Table 2.

1.1.5 The deformations due to hull girder bending and stiffness variations of the supporting structure shall be accounted for in the structural analyses when relevant.

1.1.6 Deck houses, accommodation or superstructure, which is not part of the load-bearing structure for typical offshore element loads, shall comply with the requirements given in the DNV Rules for ships Pt.3 Ch.1.

1.1.7 Green sea loads specified for each unit specific provisions in Sec.10 and Sec.11 and wind loads according to Sec.3 [3.3] shall be considered.

1.1.8 The local requirements to end connections of stiffeners and design of brackets are given in DNV Rules for ships Pt.3 Ch.1 Sec.3.

1.1.9 For slender members, e.g. flare tower, the response due to vortex shedding shall be considered. See DNV-RP-C205.

1.1.10 Overview of the design principles are given in Table 1.

Table 1 Design principles for topside structures

<table>
<thead>
<tr>
<th>Items</th>
<th>Transit</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rules for ships</td>
<td>Direct calculation</td>
</tr>
<tr>
<td>Local requirements to topside structure (plates / stiffeners / girders / beams)</td>
<td>Given in [2], [3] and [4] below. Alternatively direct calculation with permissible usage factors as specified in Sec.2 [3]</td>
<td></td>
</tr>
<tr>
<td>Design accelerations</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4</td>
<td>See Sec.2 [2.7]</td>
</tr>
<tr>
<td>Wind loads</td>
<td>Sec.3 [3.3]</td>
<td>Sec.3 [3.3]</td>
</tr>
<tr>
<td>Green sea</td>
<td>Sec.10 [3] and Sec.11 [3.2]</td>
<td></td>
</tr>
</tbody>
</table>

1.1.11 No additional corrosion margin is required for the topside structures as the topside structure shall follow the principles given in DNVGL-OS-C101/201 for corrosion protection.
1.2 Definition of load point

The load point for which the design pressure shall be calculated is defined for various strength members as follows:

a) For plates:
   midpoint of horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field.

b) For stiffeners:
   midpoint of span.
   When the pressure is not varied linearly over the span the design pressure shall be taken as the greater of:
   \[ P_m \text{ and } \frac{P_a + P_b}{2} \]
   \( p_m \), \( p_a \) and \( p_b \) are calculated pressure at the midpoint and at each end respectively.

c) For girders:
   midpoint of load area.

2 Local static loads on topside structures

The local static loads for decks and bulkheads in topside facilities, which are not part of a tank, are given in Table 2. For areas not listed in Table 2, relevant values in the DNV Rules for ships Pt.3 Ch.1 Sec.9 may be applied.

Table 2 Static loads on areas for topside structures

<table>
<thead>
<tr>
<th>Decks</th>
<th>Local design (Plates, stiffeners)</th>
<th>Primary design (Girders and columns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distributed load (KN/m²)</td>
<td>Point load (KN)</td>
</tr>
<tr>
<td>Storage areas in modules</td>
<td>q</td>
<td>1.5 q</td>
</tr>
<tr>
<td>Lay down areas</td>
<td>q</td>
<td>1.5 q</td>
</tr>
<tr>
<td>Lifeboat platforms</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Area between equipment</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Walkways, staircases and</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>platforms, crew spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkways and staircases for</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>inspection only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum values for areas not</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>given above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

— Wheel loads to be added to distributed loads where relevant. (Wheel loads can normally be considered acting on an area of 300 × 300 mm.)
— Point load may be applied on an area 100 × 100 mm, and at the most severe position, but not added to wheel loads or distributed loads
— q = distributed load. Should be evaluated for each case. Lay down areas should not be designed less than 15 kN/m²
— The f factor may be taken as
  \[ f = \min \left\{ 1.0; \left( 0.5 + \frac{3}{\sqrt{A}} \right) \right\} \]
  Where, A is the loaded area in m².
— Global design presents variable functional loads to be included in the load model for the global analysis. In the capacity checks, stresses from the global analysis shall be combined with the effect of local loads, i.e. tank pressures, weight of equipments, etc.
— Functional variable load shall be considered as static load.
3 Local requirements to plates and stiffeners

3.1 Plates (local design)

3.1.1 The plate thickness shall not be less than:

\[ t = \frac{5}{\sqrt{f_1}} + t_k \ (mm) \]

\( f_1 = \) see DNV Rules for ships Pt.3 Ch.1 Sec.2
\( t_k = \) corrosion addition according to the DNV Rules for ships Pt.3 Ch.1 Sec.2 Table D1
\( = 0 \) for elements which are not part of a tank

3.1.2 The thickness of plating subjected to lateral pressure shall not be less than:

\[ t = 15.8 \frac{k_a s \sqrt{p}}{\eta_p f_y} + t_k \ (mm) \]

\( k_a = \) correction factor for aspect ratio of plate field, \((1.1 - 0.25 s/l)^2\)
maximum 1.0 for \(s/l < 0.4\); minimum 0.72 for \(s/l > 1.0\)
\( s = \) stiffener spacing in m
\( l = \) stiffener span in m
\( p = \) local design load based on Sec.2 [3] together with the functional static loads given in Table 2.
\( \eta_p = \) permissible usage factors as given in [7.1]
\( f_y = \) specified minimum yield stress of the material in N/mm²

3.2 Stiffeners (local design)

3.2.1 The section modulus for longitudinals, beams, frames and other stiffeners subjected to lateral load shall not be less than:

\[ Z_s = \frac{l^3 s p}{k_m \eta_p f_y} \times 10^3 \ (cm^3) \]

\( l = \) stiffener span in m
\( s = \) stiffener spacing in m
\( p = \) design load based on Sec.2 [3] together with the functional static loads given in Table 2.
\( k_m = \) bending moment factor, see DNV Rules for ships Pt.3 Ch.1 Sec.3 Table B1
\( \eta_p = \) permissible usage factors as given in [7.1]
\( f_y = \) specified minimum yield stress of the material in N/mm²

3.2.2 The requirement in [3.2.1] applies to an axis parallel to the plating. For stiffeners at an oblique angle with the plating, the required section modulus shall be multiplied by:

\[ \frac{1}{\cos \phi} \]

\( \phi = \) angle in degrees between the stiffener web plane and the plane perpendicular to the plating, \( \phi \) is to be taken as 90° if the angle is greater or equal to 75°.

3.2.3 Stiffeners with snipped ends may be accepted where dynamic stresses are small and vibrations are considered to be of minor importance, provided that the thickness of the plate supporting the stiffener is not less than:

\[ t = 1.25 \frac{[(l - 0.5s)s p]}{f_1} \ (mm) \]

In such cases the required section modulus in [3.2.1] shall be based on \( k_m = 8 \).
Guidance note:
Stress range lower than 30 MPa may be considered as small dynamic stress.
---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.2.4 Plates and stiffeners exposed to green sea loads shall be checked according to the DNV Rules for ships Pt.3 Ch.1 Sec.9 with the design loads given in Sec.10 [3.2] and Sec.11 [3.2] if relevant.

4 Requirements to simple girders (primary design)

4.1 General

4.1.1 The requirements in this subsection apply to simple girders. Simple girders are not part of a grillage system, and the end fixations can be determined according to DNV Rules for ships Pt.3 Ch.1 Sec.3, or recognized text books. The girder is assumed to be exposed to a linearly distributed lateral load. Other loads should be specially considered. The minimum functional static loads that shall be applied are given in Table 2

4.1.2 When boundary conditions for individual girders are not predictable due to dependence of adjacent structures, a 2D or 3D analysis shall be carried out.

4.1.3 The local requirements to end connections of girders and design of brackets are given in DNV Rules for ships Pt.3 Ch.1 Sec.3.

4.1.4 The net thickness of web and flange of girders should not be less than 5.0 mm

4.1.5 The effective flange of girders may be determined according to DNV Rules for ships Pt.3 Ch.1 Sec.3.

4.1.6 The effective web of girders may be determined according to DNV Rules for ships Pt.3 Ch.1 Sec.3.

4.2 Strength assessment

4.2.1 Minimum section modulus \( Z_g \):

\[
Z_g = \frac{S_s b p}{k_m n_p f_y} \times 10^3 \text{ (cm}^3\text{)}
\]

4.2.2 Minimum web area after deduction of cut-outs:

\[
A_w = \frac{k_s b p - N_s P_p}{\tau_p} \times 10 \text{ (cm}^2\text{)}
\]

The web area at the middle of the span is not to be less than 0.5 \( A_w \)

\( S_g \) = girder span in m. see DNV Rules for ships Pt.3 Ch.1 Sec.3.

\( b \) = breadth of load area in m (plate flange), \( b \) may be determined as:

\( = 0.5 (l_1 + l_2) \) where \( l_1 \) and \( l_2 \) are the spans of the supported stiffeners on both sides of the girder, respectively, or distance between girders

\( p \) = local design load in sub-section [2]

\( k_m \) = bending moment factor, see DNV Rules for ships Pt.3 Ch.1 Sec.3 Table B1

\( k_s \) = shear force factor, see DNV Rules for ships Pt.3 Ch.1 Sec.3 Table B1

\( n_p \) = permissible usage factors as given in sub-section [7]

\( \tau_p \) = permissible shear stress in N/mm\(^2\) as given in sub-section [7]

\( N_s \) = number of stiffeners between considered section and nearest support. The \( N_s \) values shall in no case be taken greater than \((N_p + 1)/4\)

\( N_p \) = number of supported stiffener on the girder span

\( P_p \) = average design point load (KN) from stiffener between considered section and nearest support

\( f_y \) = specified minimum yield stress of the material in N/mm\(^2\)

4.2.3 Girder exposed to green sea loads shall be checked according to the DNV Rules for ships Pt.3 Ch.1 Sec.9 with the design loads given in Sec.10 [3.2] and Sec.11 [3.2] if relevant.
5 Complex girder system

5.1 General

5.1.1 Girders which are parts of a complex 2- or 3-dimensional structural system shall be assessed by means of a 2D or 3D element analysis to demonstrate acceptable yield and buckling capacity. The method used in the analysis shall be capable of describing the physical behavior of the structural response when exposed to the required loads.

5.1.2 The method used in the analysis shall be capable of describing the physical behaviour of the structure when exposed to the local and global loads.

5.1.3 The influence of surrounding structures shall be considered when relevant.

5.1.4 When the deck structure is supporting or being supported by pillars, the deck shall be part of the 3D model for module global assessment surrounding structures shall be considered when relevant.

Guidance note:
The deck girders and supporting pillars are normally assessed by means of the 3D model used for analysis of the module global capacity, see [6.1]. The girder system in deck structures may be analyzed by 2D models provided the boundary conditions correspond to the physical behavior of the supporting structure. Typical examples are a deck grillage which is only supported by vertical panel.

---end of guidance note---

5.2 Strength assessment

5.2.1 Design loads for deck girders shall include static and dynamic loads. The static loads consist of permanent functional loads, e.g. weight of equipment and variable functional loads. The latter may be determined according to Table 2 Primary design (Girders and columns).

5.2.2 When the girder system is assessed by a means of the 3D model, the most severe combination of loads shall be considered. Simultaneous acting loads may conservatively be considered.

Guidance note:
Example of typical load combinations for the girder system. A combination table needs to performed for each module based on the arrangement and complexity.

<table>
<thead>
<tr>
<th>Reduction factor for element</th>
<th>LC 1 V1, V5, V9</th>
<th>LC 2 V2, V6, V7, V10</th>
<th>LC 3 V3, V4, V8, V11</th>
<th>LC 4 H1</th>
<th>LC 5 H1, H2, H3</th>
<th>LC 6 H2, H3</th>
<th>LC 7 H4, H5, H7</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>H2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>H3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>H4</td>
<td>0.6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>H5</td>
<td>0.6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>H6</td>
<td>0.6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

* Vertical (V) and horizontal (H) Element number
5.2.3 The deflection of hull girder bending shall be accounted for, if relevant.

5.2.4 The inertial effect due to hull vertical accelerations shall be accounted for in the analysis.

5.2.5 Girders exposed to green sea loads shall be checked according to the DNV Rules for ships Pt.3 Ch.1 Sec.9 with the design loads given in Sec.10 [3.2] and Sec.11 [3.2], if relevant.

6 Global assessment of topside structure

6.1 General

6.1.1 The assessment of global strength of a module shall be done by means of a 3D structural analysis. The model includes primary supporting elements such as shell structures of deckhouse type of design, internal bulkheads, pillars between decks, drillfloor and substructure, main element in trusswork type of structures.

6.1.2 When the hull structure has different vertical stiffness at the support points, the hull structure under deck and topside stools, shall be part of the 3D analysis.

6.1.3 Topside modules which are little affected by hull girder bending, may be analysed as a stand-alone model.

6.1.4 If the longitudinal deformations of the hull at the module/hull connections due to hull girder bending affect the stresses in the primary elements of the module, the hull deformation shall be accounted for. Hull girder deformation may be estimated by the simplified formula below.

Guidance note:
\[ \delta = \frac{0.5(M_1 + M_2)}{Z E} l_1 \]

1) The design bending moment \((M_1, M_2)\) consists of static \((M_s)\) and dynamic part \((M_w)\) and shall be considered for the transit condition, and load combination a), b) and d) given in Sec.2 Table 6 or Sec.2 Table 7 as applicable.
6.1.5 The global assessment may be based on the most probable simultaneous acting static loads (mass of module), inertial loads from hull motions and wind loads.

6.2 Strength assessment

6.2.1 The most probable simultaneous acting static loads may be determined according to, unless otherwise documented.

\[
M = Fs + \sum_{i=1}^{n} Fe_i + \sum_{i=1}^{m} K_i P_v i A
\]

- \(M\) = static global weight of module
- \(Fs\) = total steel weight of decks
- \(Fe\) = weight of equipment including tank loads when relevant
- \(n\) = total number of heavy equipments with weight above 5 ton
- \(K\) = reduction factor for the deck considered to account for simultaneous acting module loads
- \(P_v\) = evenly distributed design weight (ton/m\(^2\)) for the deck considered
- \(m\) = total number of decks
- \(A\) = loaded area of deck considered (area covered by equipment may be excluded)

6.2.2 The global dynamic loads shall be based on the accelerations as given in Sec.2 [2].

6.2.3 Wind loads shall be included for large modules, flare tower, derrick structure, etc.

6.2.4 The following combinations of hull girder loads, topside loads and wind loads shall be evaluated in the calculation for the topside structure.

<table>
<thead>
<tr>
<th>Hull girder deflection</th>
<th>Topside loads</th>
<th>Wind loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\delta) + (M (g +/- a_v +/- a_t +/- a_L))</td>
<td>+ (P_v)</td>
<td>+ (F_w)</td>
</tr>
</tbody>
</table>

- \(\delta\) = Hull girder longitudinal deflection due to stillwater (\(M_s\)) and wave bending moment (\(M_{wv}\)) for the sagging and hogging condition
- \(M\) = Mass of the topside unit
- \(g\) = Gravity acceleration
- \(a_v\) = Vertical accelerations
- \(a_t\) = Transverse accelerations
- \(a_L\) = Longitudinal acceleration
- \(F_w\) = Wind loads (acting in the same direction as the waves)

6.2.5 All load conditions given in Sec.2 Table 5 shall be considered.

6.2.6 The combinations shall be performed both for the Transit, Operation and Survival condition and for full load (sagging) and ballast (hogging) draft. The combination given in Sec.3 [3.8] may be used. If the structure and supporting structure is symmetric of one or more axis, the number of load combinations given in Sec.3 [3.8] may be reduced.

6.2.7 If the topside structure is not is affected by the hull girder loads (hull deformation) by e.g. introducing sliding supports the hull girder interaction may be ignored.

6.2.8 Green sea loads need not to be considered for the global assessment control.
7 Acceptance criteria

7.1 Usage factors

The maximum permissible usage factor, $\eta_p$, is calculated by:

$$\eta_p = \beta \eta_0$$
$$\tau_p = 0.57 \gamma_m$$

when using the WSD design method as defined in Sec.2 [3.2]

$$\eta_p = 1/(\beta \gamma_m)$$
$$\tau_p = 1/(0.57 \gamma_m)$$

when using the LRDF design method as defined in Sec.2 [3.3]

$\eta_0 = $ basic usage factor given in Sec.2 Table 6

$\gamma_m = $ material factor given in Sec.2 Table 8

$\beta = $ coefficient depending on type of structure

<table>
<thead>
<tr>
<th>Table 3 Usage factor coefficients ($\beta$)</th>
<th>Load combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient depending on type of structure, $\beta$</td>
<td>a)</td>
</tr>
<tr>
<td>Local requirements to plates and stiffeners</td>
<td>1.14</td>
</tr>
<tr>
<td>Local requirements to section modulus of girders and stringers</td>
<td>1.0</td>
</tr>
<tr>
<td>Global strength of topside load-bearing elements in general</td>
<td>1.0</td>
</tr>
<tr>
<td>Buckling stability check in general</td>
<td>1.0</td>
</tr>
</tbody>
</table>

7.2 Local liquid tanks

The local strength requirements to plates, stiffeners and simple girders in tanks shall comply with the requirements in DNV Rules for ships Pt.3 Ch.1 using an allowable stress of 160$f_1$ (MPa).

Guidance note:

For material factor $f_1$, see DNV Rules for ships Pt.3 Ch.1 Sec.2.

7.3 Buckling control

7.3.1 Buckling of beams, columns and frames may be checked using DNV Classification Notes 30.1 or other recognized standards as e.g. AISC.

Guidance note:

If buckling resistance is calculated in accordance with DNV Classification Note 30.1 for bars and frames, the tolerance requirements given in DNVGL-OS-C401 should not be exceeded.

7.3.2 The buckling check of plated structures may be checked according to DNVGL-RP-C201.

7.3.3 Tubular members may be checked according to DNV Classification Note 30.1 or API RP 2A.

7.3.4 Cross sections of tubular member are divided into different types dependent of their ability to develop plastic hinges and resist local buckling. Effect of local buckling of slender cross sections shall be considered.

Guidance note:

a) Effect of local buckling of tubular members without external pressure, i.e. subject to axial force and/or bending moment) given in section 3.8 of DNV-RP-C202 may be used.

b) Effect of local buckling of tubular members with external pressure need not be considered for the following diameter $D_m$ to thickness $t$ ratio:

$$\frac{D_m}{t} \leq 0.5 \sqrt{\frac{E}{f_y}}$$

where

$E =$ modulus of elasticity and

$f_y =$ minimum yield strength.
7.4 Fatigue control

7.4.1 Fatigue of topside structures shall be documented according to the principles and requirements given in Sec.7.

7.4.2 The most severe dynamic stress amplitude using the combinations in Sec.3 [3.8] shall be applied for a simplified fatigue calculation in transit and operation.
SECTION 6 TOPSIDE INTERFACE TO HULL STRUCTURE

1 Application
The overall principles for assessment of topside structure are given in Sec.5. This section gives provisions for the hull strength supporting structure of topside interface foundations and support of heavy equipment. Typical topside supporting structures to be analysed are given in Sec.4 Table 6.

2 Strength assessment

2.1 Requirements to the FE model
2.1.1 The structural strength of the topside supporting structures and foundations shall be documented by means of FE analyses.
2.1.2 The extent of the model shall be based on requirements to determine the stress distribution from:
   - hull girder bending moments and shear forces
   - local loads from equipment
   - lateral pressures in tanks and sea pressure, where relevant
2.1.3 When separate local analysis of hull and topside structures are performed, part of the topside structure should be implemented in the hull model in order to ensure that the reaction forces from the topside model will be applied correctly to the FE hull model.
2.1.4 The element mesh size in FE models should be sufficient to determine the stress distribution. See Sec.4 [2.2.4].
2.1.5 When local peak stress criterion is applied in the assessment, the element mesh size as defined in Sec.4 [5.5] shall be applied.
2.1.6 Topside structures, e.g. drillfloor substructure and main support stools for topside process, which will have significant impact of the hull girder stiffness, shall be part of the hull girder FE-model.

2.2 Design load
2.2.1 Hull girder loads for both sagging and hogging conditions shall be considered when relevant. The permissible still water bending moment and shear force values specified in the units loading manual shall be used. The design wave bending moments are specified in Sec.4 [3].
2.2.2 Tank pressure and sea pressure shall be included when relevant.

2.3 Load combination
2.3.1 The following combinations of hull girder loads, topside inertia loads, wind loads and tank pressure shall be evaluated in the calculation of the topside interface to the hull structure.

<table>
<thead>
<tr>
<th>Hull girder</th>
<th>Inertia loads from topside</th>
<th>Wind loads</th>
<th>Local loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M_s + M_{WV}) + (Q_s + Q_{WV})</td>
<td>+ M (g +/- a_v +/- a_L +/- a_L) + F_w</td>
<td>+ F_w</td>
<td>Tank pressure</td>
</tr>
</tbody>
</table>

Where:
- \( M_s \) = Stillwater bending moment
  - Sagging: Normally loaded, max draft
  - Hogging: Normally ballast, min draft
- \( M_{WV} \) = Wave bending moment
- \( Q_s \) = Stillwater vertical shear force
- \( Q_{WV} \) = Wave vertical shear force
- \( M \) = Mass of the topside unit
- \( g \) = Gravity acceleration
2.3.2 Unless all loads are combined and applied maximum simultaneously the load combinations given in Sec.3 [3.8] may be used. Alternatively direct analysis may be carried out to determine the phases between the dynamic responses, or a spectral analysis may be performed.

2.3.3 The responses in Transit condition shall be calculated according to the DNV Rules for ships or the accelerations for the topside may alternatively be based on direct analysis using the principles given in Sec.2 Table 2.

### Table 1 Responses in transit condition

<table>
<thead>
<tr>
<th>Response</th>
<th>Transit condition - DNV Rules for ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_{S}, Q_{S} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4 or limit curve in loading for actual condition.</td>
</tr>
<tr>
<td>( M_{Wv}, Q_{Wv} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4</td>
</tr>
<tr>
<td>( a_{v}, a_{t}, a_{L} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4 or alt. Sec.2 Table 2 for Transit</td>
</tr>
<tr>
<td>( F_{w} )</td>
<td>Sec.3 [3.3] for Transit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank pressure (P) ( P = \rho \cdot g \cdot h + 25 \text{ (KN/m}^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho = \text{see Sec.3 [3.9]} )</td>
</tr>
<tr>
<td>( h = \text{distance from the load point to the top of tank} )</td>
</tr>
</tbody>
</table>

2.3.4 The responses in Operation and Survival condition shall be calculated from a direct analysis using the basis given in Sec.2 Table 2. Alternatively the responses may be based on the DNV Rules for ships if the unit is operating in benign waters, see Sec.2 [2.6].

### Table 2 Responses in operation and survival condition

<table>
<thead>
<tr>
<th>Response</th>
<th>DNV Rules for ships if benign waters</th>
<th>Direct analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_{S}, Q_{S} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4 or limit curve in loading for actual condition.</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4 or limit curve in loading for actual condition.</td>
</tr>
<tr>
<td>( M_{Wv}, Q_{Wv} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4</td>
<td>Sec.2 Table 2 for Operation and Survival</td>
</tr>
<tr>
<td>( a_{v}, a_{t}, a_{L} )</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.4</td>
<td>Sec.2 Table 2 for Operation and Survival</td>
</tr>
<tr>
<td>( F_{w} )</td>
<td>Sec.3 [3.3] for Transit</td>
<td>Sec.3 [3.3] for Operation or Survival</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank pressure (P) ( P = \rho \cdot g \cdot h + 25 \text{ (KN/m}^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho = \text{see Sec.3 [3.9]} )</td>
</tr>
<tr>
<td>( h = \text{distance from the load point to the top of tank} )</td>
</tr>
</tbody>
</table>

2.4 Acceptance criteria

The material yield and buckling strength shall comply with the requirements given in Sec.2 [3] taking into account design method, load combination and the element mesh size.

2.5 Fatigue

2.5.1 The fatigue life of the topside supporting structure shall be documented according to the principles and requirements given in Sec.7.

2.5.2 The most conservative dynamic stress amplitude using the combinations in Sec.3 [3.8] shall be applied when using simplified fatigue calculation.
SECTION 7 FATIGUE

1 Principles and methodology

1.1 General

1.1.1 This section gives provisions for assessment of fatigue capacity of structural details in the unit. The assessment shall account for all significant loads contributing to fatigue damage.

1.1.2 The DNV Classification Notes No. 30.7 is in general used as reference for principles and methodology but DNVGL-RP-C203 may also be used.

1.2 Assessment principles

1.2.1 In the assessment of fatigue life, consideration shall be given to the stress concentration factors from fabrication imperfections which exceed the values included in the S-N curves.

1.2.2 Hull vibration is not covered in this standard.

1.2.3 The correlation between different responses such as global wave bending, external and internal dynamic pressure and acceleration may be considered in the fatigue assessment.

1.2.4 Low cycle fatigue due to the repetitive loads from loading and unloading tanks shall be checked according to principles given in DNV Classification Notes No.30.7.

1.2.5 The accumulated fatigue damage from both transit and operating conditions shall be calculated according to the operational characteristics of the unit. Appropriate fraction of time in each condition and wave headings shall be considered.

1.2.6 The fatigue life shall be calculated considering the combined effects of global and local structural response.

1.2.7 The resistance against fatigue is normally given as S-N curves, i.e. stress range (S) versus number of cycles to failure (N) based on fatigue tests. Fatigue failure is defined as when the crack has grown through the thickness.

1.2.8 Gross scantling may be utilized in the fatigue calculation.

1.3 Methods for fatigue capacity

1.3.1 The fatigue analysis should be based on S-N data, determined by fatigue testing of the considered welded detail, and the linear damage hypothesis. When appropriate, the fatigue analysis may alternatively be based on fracture mechanics.

1.3.2 Acceptable analysis methods for calculation of the accumulated damage are given in DNV Classification Note 30.7.

1.3.3 When a wave load analysis is used for a spectral fatigue analysis, the design basis for transit and operating condition as specified in Sec.2 Table 3 shall be applied.

1.3.4 For detailed consideration on design loading conditions and mean stress effect, see unit specific provisions Sec.10 and Sec.11.

1.4 Fatigue details to be considered

1.4.1 Fatigue sensitive details in the hull and topside supporting structures shall be documented to have sufficient fatigue strength. Areas to be checked are given in Table 1 and Table 2.

1.4.2 Stress concentration factors of local details may be determined according to CN 30.7. For details not covered by CN 30.7, or documented in other recognised publications, detailed FE analysis shall be carried out for determination of SCFs, according to the procedure given in CN 30.7.
1.5 Design loads and calculation of stress range

1.5.1 The wave loads in transit and operating conditions shall be determined according to Sec.2 Table 3.

1.5.2 The effect of wind may be omitted except for large structures subject to significant wind exposure, e.g. flare tower, derrick, etc.

1.5.3 Typical global loads to be considered are:

- wave bending moments and shear forces
- horizontal and vertical hull deformations/deflections
- wave induced accelerations (inertia loads).

1.5.4 Typical local load effects to be considered are:

- vortex shedding
- external sea pressure
- tank pressure
- variation of filling level in cargo tanks (low cycle).

1.5.5 The global and local load effects shall be combined according to the procedures given in CN 30.7.

1.6 Design fatigue factor

1.6.1 DFF is required for different structural elements based on the consequences of failure and accessibility for in service inspection and repair.

1.6.2 The required service life of new units shall be minimum 20 years assuming that the unit complies with the Class requirements for inspection.

1.6.3 For additional consideration on DFF, see unit specific provisions Sec.10 and Sec.11.

1.6.4 Substantial consequences other than pure strength considerations may require higher design fatigue factors. Such factors should be specified in the structural design brief document.

**Guidance note:**
When defining the appropriate design fatigue factor for a specific fatigue sensitive detail, consideration shall be given to the following:
Evaluation of likely crack propagation paths (including direction and growth rate related to the inspection interval), may indicate the use of a higher design fatigue factor, such that:

a) Where the likely crack propagation indicates that a fatigue failure affects another detail with a higher design fatigue factor.
b) Where the likely crack propagation is from a location satisfying the requirement for a given "Access for inspection and repair" category to a structural element having another access categorisation.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.7 Details to be checked

1.7.1 Fatigue sensitive details in the hull and topside supporting structures shall be documented to have sufficient fatigue strength. The details given in Table 1 and Table 2 shall be checked. Additional details then those listed in the tables may be required documented based on the complexity of the hull structure/topside interface and design/fabrication details.
### 1.7.2 Typical hull structure details to be checked

**Table 1 Hull structure details**

<table>
<thead>
<tr>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>— Openings on main deck, bottom and inner bottom structure including deck penetrations</td>
<td><img src="image1.png" alt="Diagram 1" /></td>
</tr>
<tr>
<td>— Longitudinal stiffener end connections to transverse web frame and bulkhead.</td>
<td><img src="image2.png" alt="Diagram 2" /></td>
</tr>
<tr>
<td>— Shell plate connection to longitudinal stiffener and transverse frames with special consideration in the splash zone.</td>
<td><img src="image3.png" alt="Diagram 3" /></td>
</tr>
<tr>
<td>— Hopper knuckles and other relevant discontinuities</td>
<td><img src="image4.png" alt="Diagram 4" /></td>
</tr>
<tr>
<td>— Openings and penetrations in longitudinal members</td>
<td><img src="image5.png" alt="Diagram 5" /></td>
</tr>
<tr>
<td>— Bilge keel</td>
<td><img src="image6.png" alt="Diagram 6" /></td>
</tr>
<tr>
<td>— Toe and heel of horizontal stringer in way of transverse bulkhead</td>
<td><img src="image7.png" alt="Diagram 7" /></td>
</tr>
</tbody>
</table>
1.7.3 Typical topside interface details to hull structure to be checked.

Table 2  Tопside interface details

| — Attachments, foundations, supports etc. to main deck |
| — Hull connections including substructure for drill floor |
| — Topside stool and supporting structures |
| — Crane pedestal foundation and supporting structures. |
| — Turret Interface |
| — Moonpool corners |

2  Advanced fatigue methodology

2.1  Introduction

2.1.1 The technical requirements given in this sub-section represent an extended fatigue specification which may be applied in addition to the fatigue requirements given in [1].

Guidance note:
For the application of this section for classification purposes, see Ch.3.

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2.1.2 The requirements are primarily related to the hull structure and topside interface structures connected to the hull structure, but the principles may also be used for turret and topside modules, if specified by the project.

2.1.3 The technical guidance and principles to the fatigue analyses are generally given in DNVGL-RP-C206.

2.2  Principles

2.2.1 Design fatigue factors will typically be dependent of the criticality with respect to safety and economic consequences. Stricter DFF than defined for unit specific provisions in Sec.10 and Sec.11 is thus specified in this section. The DFF for each area is based on the accessibility of the connection for inspection and repair and the consequences of damage at the connection. Other DFF may be applied if dictated by project-specific requirements.
2.2.2 **Table 3** should be used for units not intended to be dry-docked. Normally most relevant for FPSO’s.

**Table 3** DFF for units not intended for dry docking

<table>
<thead>
<tr>
<th>DFF</th>
<th>Structural element</th>
<th>Typical areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Internal structure, accessible and not welded directly to the submerged part.</td>
<td>Transverse frames, transverse BHD, longitudinal BHD, stringers, cross ties.</td>
</tr>
<tr>
<td>2</td>
<td>External structure, accessible for regular inspection and repair in dry and clean conditions.</td>
<td>Main deck plate and connection to main deck plate, Topside support, side shell plate above lowest inspection or maintenance draft.</td>
</tr>
<tr>
<td>3</td>
<td>Internal structure, accessible and welded directly to the submerged part.</td>
<td>Longitudinals, transverse frames, transverse BHD’s welded to the bottom plate or side shell plate below highest loaded draft.</td>
</tr>
<tr>
<td>3</td>
<td>External structure not accessible for inspection and repair in dry and clean conditions.</td>
<td>Side shell plate below lowest inspection or maintenance draft, Bilge keel, Fairlead structure, Riser tubes.</td>
</tr>
<tr>
<td>5</td>
<td>Non-accessible areas, areas not planned to be accessible for inspection and repair during operation. Not critical for the unit’s hull integrity.</td>
<td>Void spaces, sea chests, small cofferdams.</td>
</tr>
<tr>
<td>10</td>
<td>Non-accessible areas, areas not planned to be accessible for inspection and repair during operation. May be critical for the unit’s hull integrity.</td>
<td>Topside support protected with passive fire protection.</td>
</tr>
</tbody>
</table>

2.2.3 **Table 4** should be used for units intended to be dry-docked. Normally most relevant for Drillships.

**Table 4** DFF for units intended for dry docking

<table>
<thead>
<tr>
<th>DFF</th>
<th>Structural element</th>
<th>Typical areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Internal structure, accessible.</td>
<td>Transverse frames, transverse BHD, longitudinal BHD, stringers, Longitudinals, cross ties.</td>
</tr>
<tr>
<td>2</td>
<td>External structure, accessible.</td>
<td>Main deck plate and connection to main deck plate, Drillfloor and topside support, side shell plate.</td>
</tr>
<tr>
<td>5</td>
<td>Non-accessible areas, areas not planned to be accessible for inspection. Not critical for the unit’s hull integrity.</td>
<td>Void spaces, small cofferdams.</td>
</tr>
<tr>
<td>10</td>
<td>Non-accessible areas, areas not planned to be accessible for inspection and repair during operation. May be critical for the unit’s hull integrity.</td>
<td>Topside (Drillfloor) support protected with passive fire protection.</td>
</tr>
</tbody>
</table>

2.2.4 The technical guidance and principles to the fatigue analyses are generally given in DNVGL-RP-C206.

2.2.5 A spectral fatigue analysis methodology shall be used, either a full stochastic method using a part-ship or global FE-model, or a component stochastic method. Both methods are based on a spectral procedure described in DNVGL-RP-C206 or in DNV Classification note 30.7 and include the following assumptions for the fatigue calculation:

— wave climate is represented by scatter diagrams (summation of short term conditions)
— Rayleigh distribution applies for stresses within each short term condition
— cycle count is according to zero crossing period of short term stress response
— Miner summation is according to linear cumulative damage.

The spectral method assumes linear load effects and responses. The hydrodynamic loads and structural responses shall be calculated using 3D potential theory and finite element analysis. Details are provided in DNVGL-RP-C206.

Stresses used for fatigue calculation shall either be calculated using a local FE-model or by using the nominal stresses combined with tabulated stress concentration factors. Other load effects, such as slowly varying response, impact loads, should be included if they influence the fatigue life.

**Guidance note:**

The DNV Rules for ships fatigue analysis methodology and procedure, as included in the DNV GL Nauticus HULL program, uses the long term distribution defined by Weibull shape parameters. This method shall only be used in the initial design prior to ordering steel.
This method will not be accepted as documentation of fatigue life in accordance with the extended fatigue specification as described in this sub-section.

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2.2.6 Details given in Table 1 and Table 2 shall be checked together with the following detail.

Table 5 Additional detail to be checked as part of the extended fatigue specification

**Guidance note:**
As a minimum the following number of stiffener-frame connections shall be checked for the midship area:

- 1 detail connection at the main deck
- 2 detail connection at the bottom
- 2-3 details connections at the side shell where connections close to the splash zone(s)
- 2 detail connection at each longitudinal bulkhead.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 8 ACCIDENTAL CONDITIONS

1 Introduction

1.1 General

1.1.1 Safety assessment shall be based on the principles given in DNVGL-OS-A101 for relevant accidental scenarios. The most relevant accidental scenarios for ship shape units are listed in Section 2 below, but a risk analysis for the project may require other scenarios.

1.1.2 Layout and arrangements of facilities and equipment shall be designed in order to minimise the adverse effects of accidental events.

1.1.3 The overall objective for design with respect to accidental conditions is that unit’s main safety functions shall not be impaired by accidental events. Satisfactory protection against accidental damage may be achieved by reducing the probability of any damage, or by reducing the damage consequence.

1.1.4 The design against accidental loads may be done by direct calculation of the effects imposed by the loads on the structure, or indirectly, by design of the structure as tolerable to accidents.

1.1.5 Non-linear static and dynamic FE analysis may be applied for the strength calculation. All relevant failure modes (e.g. strain rate, local buckling, joint overloading) shall be checked. Local overloading of the structural capacity is acceptable provided redistribution of forces is possible.

1.1.6 The accidental scenarios shall be checked according to loading condition d) given in Sec.2 [3].

2 Accidental scenarios

2.1 Dropped objects

2.1.1 Dropped objects shall be investigated in areas of crane lifts or other lifting related to operation. Dropped object shall not lead to critical failure like fire or explosions, or causing damage to the units process equipments or safety system.

All safety critical equipments shall be protected from dropped objects and the protecting structure shall resist the defined impact energy.

2.1.2 Critical areas for dropped objects should be determined assuming a minimum drop direction within an angle of 10° with the vertical direction.

2.1.3 Setback area shall be designed to satisfy the dropped object scenario in accordance with DNVGL-OS-E101.

2.1.4 Dropped object may be calculated according to DNV-RP-C204.

2.2 Fires

The structure that is subjected to a fire shall maintain sufficient structural strength before evacuation has occurred. The following fire scenarios shall be considered:

— jet fires
— fire inside or on the hull
— fire on the sea surface.

Assessment of fire may be omitted provided fire protection requirements made in DNVGL-OS-D301 are met.

2.3 Explosions

2.3.1 One or more of the following main design philosophies will be relevant:

— Ensure that hazardous locations are located in unconfined (open) locations and that sufficient shielding mechanisms (e.g. blast walls) are installed.
— Locate hazardous areas in partially confined locations and design utilising the resulting, relatively small overpressure.
— Locate hazardous areas in enclosed locations and install pressure relief mechanisms (e.g. blast panels) and design for the resulting overpressure.

2.3.2 As far as practicable, structural design accounting for large plate field rupture resulting from explosion actions should be avoided due to the uncertainties of the actions and the consequences of the rupture itself.

2.3.3 Structural support of blast walls and the transmission of the blast action into main structural members shall be evaluated when relevant. Effectiveness of connections and the possible outcome from blast, such as flying debris, shall be considered.

2.4 Unintended flooding

2.4.1 The structural design of the hull against unintended flooding shall be based on the deepest equilibrium waterline in damaged condition obtained from damage stability calculations.

2.4.2 The permissible stresses for local scantling, e.g. plating, stiffener and girder, in a flooded condition may be taken as $220f_1$ for normal stresses and $120f_1$ for shear stresses in accordance with DNV Rules for ships Pt.3 Ch.1.

2.5 Collision

Collision with a typical supply boat is normally not affecting the structural integrity as long as the unit complies with stability requirements from national or international bodies. Collision with supply boat and accidental flooding are thus not considered in this standard.

2.6 Loss of heading control

2.6.1 For units normally operated with heading control, either by weather vaning or by thruster assistance, the effects of loss of the heading control shall be evaluated.

2.6.2 The loss of heading control condition shall be considered in the hull, topside and turret structural design.

2.7 Heeled condition

2.7.1 Heeling of the unit after a damage flooding shall be considered for the strength of topside and topside support. The heeling angle shall be taken from the damage stability calculation.

2.7.2 The environmental condition corresponding to 1 year return period for the site specific location shall be used in the heeled condition.

Guidance note:
Heeled condition is normally not a governing condition for the structural strength, but may be governing when large static heeling angles and for large topside modules.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 9 WELDING AND WELD CONNECTIONS

1 Introduction

1.1 General requirements

1.1.1 The technical requirements for the welding and weld connections shall, as a minimum, comply with the DNV Rules for ships Pt.3 Ch.1 Sec.11.

1.1.2 Full penetration welds shall be used if weld improvements (e.g. grinding) is needed to achieve required design fatigue life, unless the fatigue life at the weld root is documented.

1.1.3 In structural parts where dynamic stress or high tensile stress act through an intermediate plate, see Figure 1 full penetration weld, partly penetration weld or alternatively increased fillet weld shall be used.

![Figure 1 Weld root face](image)

2 Size of welds

2.1 Double continuous fillet welds

Double continuous fillet welds shall be dimensioned according to principles given in DNV Rules for ships Pt.3 Ch.1 Sec.11. The Table 1 has been extended to include C factors for typical offshore members.

Table 1 Weld factor C

<table>
<thead>
<tr>
<th>Item</th>
<th>60% of span</th>
<th>At ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local buckling stiffeners</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Stiffeners, frames, beams or longitudinals to shell, deck, oil tight or water tight girders or bulkhead plating, except in after peaks. Secondary stiffeners in topside structures. Secondary stiffeners in turret</td>
<td>0.16</td>
<td>0.26</td>
</tr>
<tr>
<td>Web plates of non-watertight girders except in after peak.</td>
<td>0.20</td>
<td>0.32</td>
</tr>
<tr>
<td>Girder webs and floors in double bottom. Stiffeners and girders in after peaks. Main girder system in topside structures of stiffened plate design type. Main girder system and decks in turret Horizontal stringers on transverse bulkheads.</td>
<td>0.26</td>
<td>0.43</td>
</tr>
<tr>
<td>Watertight centre line girder to bottom and inner bottom plating. Boundary connection of ballast and liquid cargo bulkhead:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— longitudinal bulkheads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— transverse bulkheads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatch coamings at corners and transverse hatch end brackets to deck. Top horizontal profile to coaming. Strength deck plating to shell scuppers and discharges to deck. Main girder system in topside structures of framework design type. Fillet welds subject to compressive stresses only.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other welds not specified above.</td>
<td>0.25</td>
<td>0.43</td>
</tr>
</tbody>
</table>
2.2 Fillet welds and deep penetration welds subject to high tensile stresses

Fillet welds and deep penetration welds subject to high tensile stresses shall be dimensioned according to the principles given in DNV Rules for ships Pt.3 Ch.1 Sec.11.

2.3 Full penetration welds

In addition to the full penetration welds required for joints specified by the DNV Rules for ships Pt.3 Ch.1 Sec.11, full penetration welds shall be used for the following connections:

- crane pedestal to deck plating
- topside support stools to main deck ¹)
- flare to hull structure
- drill floor support structure to main deck ¹).

¹) See Sec.1 for details.

2.4 End connection of stiffeners

The connection area at supports of stiffeners shall comply with the DNV Rules for ships Pt.3 Ch.1 Sec.11 C400.

2.5 Direct calculations

2.5.1 The distribution of forces in a welded connection may be calculated on the assumption of either elastic or plastic behaviour.

2.5.2 Residual stresses and stresses not participating in the transfer of load need not be included when checking the resistance of a weld. This applies specifically to the normal stress parallel to the axis of a weld.

2.5.3 Welded connections shall be designed to have adequate deformation capacity.

2.5.4 In joints where plastic hinges may form, the welds shall be designed to provide at least the same design resistance as the weakest of the connected parts.

2.5.5 In other joints where deformation capacity for joint rotation is required due to the possibility of excessive straining, the welds require sufficient strength not to rupture before general yielding in the adjacent parent material.

Guidance note:
In general this will be satisfied if the design resistance of the weld is not less than 80% of the design resistance of the weakest of the connected parts.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.5.6 The design resistance of fillet welds is adequate if, at every point in its length, the resultant of all the forces per unit length transmitted by the weld does not exceed its design resistance.

2.5.7 The design resistance of the fillet weld will be sufficient if both the following conditions are satisfied:

WSD design method, see Sec.2 [3.2];

\[ \sqrt{\left(\sigma_\perp^2 + 3(\tau_{\parallel}^2 + \tau_\perp^2)\right)} \leq \frac{f_u}{\beta_w}\eta_0 \quad \text{and} \quad \sigma_\perp \leq \frac{f_u}{\beta_w}\eta_0 \]

LRFD design method, see Sec.2 [3.3]

\[ \sqrt{\left(\sigma_\perp^2 + 3(\tau_{\parallel}^2 + \tau_\perp^2)\right)} \leq \frac{f_u}{\beta_w\gamma_m} \quad \text{and} \quad \sigma_\perp \leq \frac{f_u}{\gamma_m} \]

\( \sigma_\perp \) = normal stress perpendicular to the throat based on the design methods given in Sec.2 [3].
\( \tau_\perp \) = shear stress (in plane of the throat) perpendicular to the axis of the weld based on the design methods given in Sec. 2 [3]

\( \tau_\parallel \) = shear stress (in plane of the throat) parallel to the axis of the weld based on the design methods given in Sec. 2 [3].

\( f_u \) = nominal lowest ultimate tensile strength of the weaker part joined

\( \beta_w \) = appropriate correlation factor, see Table 2

\( \eta_0 \) = basic usage factor, see Sec. 2 [3.2]

\( \gamma_m \) = material factor, see Sec. 2 [3.3]

---

**Figure 2 Stress component in a fillet weld**

**Table 2 The correlation factor \( \beta_w \)**

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Lowest ultimate tensile strength</th>
<th>Correlation factor ( \beta_w )</th>
</tr>
</thead>
<tbody>
<tr>
<td>NV NS</td>
<td>400</td>
<td>0.83</td>
</tr>
<tr>
<td>NV 27</td>
<td>400</td>
<td>0.83</td>
</tr>
<tr>
<td>NV 32</td>
<td>440</td>
<td>0.86</td>
</tr>
<tr>
<td>NV 36</td>
<td>490</td>
<td>0.89</td>
</tr>
<tr>
<td>NV 40</td>
<td>510</td>
<td>0.9</td>
</tr>
<tr>
<td>NV 420</td>
<td>530</td>
<td>1.0</td>
</tr>
<tr>
<td>NV 460</td>
<td>570</td>
<td>1.0</td>
</tr>
</tbody>
</table>
SECTION 10  SPECIAL PROVISIONS FOR DRILLING UNITS

1 Introduction
This section contains specific requirements and guidance applicable for drilling units which are intended to operate world wide or at specific locations.

2 Design principles

2.1 General

2.1.1 The limiting operating condition which the unit is intended to operate shall be specified and used as a basis for the design operating conditions. The condition shall be specified with:

— significant wave height and zero crossing period
— wind speed.

2.1.2 The design principles for transit, operating and survival conditions are given in Table 1.

Table 1  Design principles for drilling units

<table>
<thead>
<tr>
<th>Design condition</th>
<th>Design basis and environmental load level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit condition (World Wide)</td>
<td>DNV Rules for ships Pt.3 Ch.1 Sec.5. Acceleration for topside may alternatively be calculated using a wave load analysis see Sec.2[2.7].</td>
</tr>
<tr>
<td>Operating condition</td>
<td>Direct calculations using the maximum allowable sea state (max Hs) criteria for aborting the operation, ref Sec.2[2.7].</td>
</tr>
<tr>
<td>Survival condition</td>
<td>Direct calculations based on the specified sea state or site specific scatter diagram(s) with a 100 year return period, see Sec.2[2.7]. For benign water, see Sec.2[2.6], the DNV Rules for ships Pt.3 Ch.1 is governing.</td>
</tr>
</tbody>
</table>

Guidance note:
Operation condition may be governing if heavy loads are located on the drilifloor structure (e.g. set back, etc) compared to Transit or Survival condition.

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

3 Strength assessment

3.1 General
Requirements to the hull strength is given in Sec.4.

3.2 Green sea loads
In lack of more exact information, e.g. model tests, relevant requirements to strengthening against green sea pressure are given in the DNV Rules for ships Pt.3 Ch.1 Sec.8 and Sec.10 respectively.

3.3 Design loading conditions

3.3.1 The tank/hold arrangement for well service and drilling units may be significantly deviated compared to those for conventional tankers, but the design loading principles for FE analysis given in DNV Classification Notes No.31.3 may be used as reference.

3.3.2 The selection of the design loading conditions should be explained in the structural design brief document taking the structural arrangements of the unit into account.

3.4 Fatigue

3.4.1 Fatigue shall be documented in accordance with the principles given in Sec.7.

3.4.2 The fraction of the total design life spent for the transit and operating conditions shall be considered in the fatigue calculation.
Guidance note:
The fraction of the total design life using 80% in operation and 20% in Transit may be used if no other information is available.

3.4.3 Mean stress effect may be used in the reduction of the stress range for base material and welded structures as given in DNV Classification Notes No. 30.7

3.4.4 A design fatigue factor (DFF) of 1.0 is acceptable for all structural elements which are accessible for inspection and repair. For structural elements which are not accessible for inspection and repair, a DFF of 2.0 shall be used.

3.4.5 Fatigue sensitive details in the hull and topside supporting structure shall be documented as specified in Sec.7 [1.7].

4 Fabrication principles

4.1 Hull structure
Fabrication principles for the hull shall follow DNV Rules for ships Pt.2 Ch.3.

4.2 Topside and topside support structure
Fabrication principles for the topside and topside support structure shall be in accordance with DNVGL OS-C401.

5 Corrosion control

5.1 Hull and topside structure
5.1.1 The corrosion protection of the hull and topside structures shall comply with the requirements in DNV Rules for ships Pt.3 Ch.3 Sec.7.

5.1.2 Steel surfaces in topside structure except tanks shall be protected by a suitable coating system proven for marine atmospheres.

5.1.3 Tanks for fresh water shall have a suitable coating system. Special requirements will apply for coating systems used for potable water tanks.
SECTION 11 SPECIAL PROVISIONS FOR FLOATING PRODUCTION, STORAGE AND OFFLOADING UNITS

1 Introduction
This section contains specific requirements and guidance applicable for floating production, storage and offloading unit which are intended to operate at site specific location.

2 Design principles

2.1 General

2.1.1 If the unit is defined for "benign waters operation", see Sec.2 [2.6], the requirements to the midship section modulus are by definition more stringent than the design principles based on the direct calculations applied to "benign waters". In this case, hull structures complying with the minimum midship section modulus and moment of inertia given in the DNV Rules for ships Pt.3 Ch.1 Sec.5 do not require additional calculations of the hull girder strength.

2.1.2 The design principles for transit and operating conditions are given in Table 1.

Table 1 Design principles for floating production and storage units

<table>
<thead>
<tr>
<th>Design condition</th>
<th>Design basis and environmental loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit</td>
<td></td>
</tr>
<tr>
<td>Restricted transit route</td>
<td>Restricted transit route with a 10 years return period and equal probability of headings (0-360) or on the Rules from a recognised Marine Warranty</td>
</tr>
<tr>
<td>Worldwide transit</td>
<td>DNV Rules for ships Pt.3 Ch.1 Acceleration for topside may alternatively be calculated using a wave load analysis see Sec.2 [2.7]</td>
</tr>
<tr>
<td>Survival condition</td>
<td></td>
</tr>
<tr>
<td>Harsh environmental areas</td>
<td>Direct calculations based on the specified sea state or site specific scatter diagram(s) with a 100 year return period, see Sec.2 [2.7]</td>
</tr>
<tr>
<td>Benign waters</td>
<td>DNV Rules for ships Pt.3 Ch.1 Alternately direct calculations based on the specified sea state or site specific scatter diagram(s) with a 100 year return period, see Sec.4 [3.3.5] The 100 year vertical wave bending moment $M_{WV}$ shall not be taken lower than 50% of the rule wave bending moment given in the DNV Rules for ships Pt.3 Ch.1 Sec.5. The corresponding responses (wave shear, sea pressure, inertia loads) may be reduced similar the $M_{WV}$ reduction.</td>
</tr>
</tbody>
</table>

Guidance note:
Operation condition needs normally not to be considered for FPSO's as the weight distribution of the topside structure in the operation and in the survival condition is assumed to be similar.

3 Strength assessment

3.1 General

3.1.1 Requirements to the hull strength are given in Sec.4.

3.1.2 The quay requirement given in the DNV Rules for ships Pt.3 Ch.1 Sec.7 C103 may be omitted provided:

— The unit will not be in harbour condition (permanent on location).
— The off-loading will be arranged from the stern or bow.

3.1.3 If the off-loading will be arranged in a side-by-side configuration the quay requirement shall be included.
3.2 Green sea loads

3.2.1 In lack of more exact information, for example model testing, the following design pressure given in Table 2 shall be used for weather deck, topside supports and deckhouses.

**Table 2  Green sea design loads for weather deck, topside supports and deckhouses**

<table>
<thead>
<tr>
<th>Area</th>
<th>Benign waters</th>
<th>Harsh Environment Hs &gt; 10.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather deck</td>
<td>Pt.3 Ch.1 Sec.8</td>
<td></td>
</tr>
<tr>
<td>Area forward of 0.15 L from F.P., or forward of deckhouse front, whichever is the foremost position, the design pressure, ( P_1 = (P_{dp} - (4+ 0.2k_s) h_0) ) given in Pt.3 Ch.1 Sec.8 B100 shall be increased with a factor as following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( 10.0 m \leq H_s \leq 12.5 m )</td>
<td>At unit's side: 0.2 \times H_s -1.0</td>
<td>Hs \geq 12.5 m</td>
</tr>
<tr>
<td>At the centre line: 0.3 \times H_s -2.0</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Linear interpolation shall be used for intermediate locations between the unit’s side and the centre line.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unprotected front bulkheads</td>
<td>Pt.3 Ch.1 Sec.10 C100</td>
<td></td>
</tr>
<tr>
<td>The pressure, ( p_1 = 5.7 \ a \ (k \ C_{w} - h_0) \ c_1 ) defined in the DNV Rules for ships Pt.3 Ch.1 Sec.10 shall be increased with a factor as following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( 10.0 m \leq H_s \leq 12.5 m )</td>
<td>0.2 \times H_s-1.0</td>
<td>Hs \geq 12.5 m</td>
</tr>
<tr>
<td>8 knots speed shall be used as minimum to ensure sufficient minimum pressure.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.2 The local scantlings shall be checked according to the DNV Rules for ships Pt.3 Ch.1 Sec.10 using the design pressure as given in Table 2.

3.2.3 Requirements to glass thickness of windows and the fastening arrangement in unprotected front bulkheads shall meet the DNV Rules for Classification Pt.3 Ch.3 Sec.6 L, using the design pressures given in Table 2.

3.3 Design loading conditions

The design loading conditions for FE analysis are generally given in DNV Classification Notes No.31.3. The selection of the design loading conditions should be specified in the structural design brief taking structural arrangements of unit into account.

**Guidance note:**

DNV Classification Note No.31.3 is normally used for a cargo hold FE analysis for 3 standard types of tanker. Harbour conditions need normally not to be considered.

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3.4 Fatigue strength

3.4.1 Fatigue shall be documented in accordance with the principles given in Sec.7.

3.4.2 The fraction of the total design life spent in loaded and in ballast for the operating condition shall be considered in the fatigue calculation

**Guidance note:**

Normally 50% in full load and 50% in ballast may be used for the operation, unless otherwise documented. Partial filling should be considered if the difference in draft between full load and ballast exceed 8 m. 33% in each draft may then be used, unless otherwise documented.

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

3.4.3 The transit condition may be omitted, if the time in transit is below 5% of the total design life.

3.4.4 Mean stress effect for reduction of the stress range may only be used for fatigue calculation of base material details as shown in Table 3.
Guidance note:
Mean stress effect for welded structures is normally allowed for ships that are dry docked every 5th year. For units that are not required to be dry docked a higher safety margin with respect to fatigue is required, and the use of mean stress effect for welded structures is not allowed.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.4.5 The required fatigue life for a new permanently installed unit, not intended to be dry-docked, shall be minimum 20 years. The design fatigue factors are given in Table 4. See Figure 1 for the application for a typical shell structure.

Table 3 Mean stress effect for permanently installed units

<table>
<thead>
<tr>
<th>Base material</th>
<th>Welded structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNV Classification Notes No.30.7</td>
<td>Not allowed</td>
</tr>
</tbody>
</table>

Table 4 Design fatigue factors

<table>
<thead>
<tr>
<th>DFF</th>
<th>Structural element</th>
<th>Typical areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Internal structure, accessible and not welded directly to the submerged part.</td>
<td>Transverse frames, transverse BHD, longitudinal BHD, stringers, cross ties.</td>
</tr>
<tr>
<td>1</td>
<td>External structure, accessible for regular inspection and repair in dry and clean conditions.</td>
<td>Main deck plate and connection to main deck plate, Topside support, side shell plate above lowest inspection or maintenance draft.</td>
</tr>
<tr>
<td>2</td>
<td>Internal structure, accessible and welded directly to the submerged part.</td>
<td>Longitudinals, transverse frames, transverse BHD’s welded to the bottom plate or side shell plate below highest loaded draft.</td>
</tr>
<tr>
<td>2</td>
<td>External structure that can be inspected using in-water survey but not accessible for repair in dry and clean conditions.</td>
<td>Side shell plate below lowest inspection or maintenance draft, Bilge keel, Fairlead structure, Riser tubes</td>
</tr>
<tr>
<td>3</td>
<td>External structure not intended to be inspected using in-water survey, or non-accessible areas, areas not planned to be accessible for inspection and repair during operation.</td>
<td>Topside support protected with passive fire protection, void spaces, sea chests, small cofferdams</td>
</tr>
</tbody>
</table>

Figure 1 Example of design fatigue factor
3.4.6 Sufficient margin with respect to the lowest inspection waterline should be considered. The DFF applied will therefore be dependent on the accessibility for inspection and repair, and the position of the lowest inspection waterline.

Guidance note:
Normal 1 to 2 m below the lowest inspection waterline is normally considered as sufficient margin.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.4.7 Fatigue sensitive details in the hull and topside supporting structure shall be documented as required in Sec.7 [1.7].

3.5 Hull support structure for mooring system

3.5.1 Positioning mooring is related to the fixed mooring system at a site specific location. The design loads for the mooring system shall be based on the principles given in DNVGL-OS-E301

3.5.2 The units mooring system will impose loads on the hull structure and shall be considered in the structural design for the following:

— structural support of the turret
— structural support of the mooring equipment such as windlass/winch, chain stopper, fairlead, etc.

3.5.3 Gross scantlings may be used in the FE-analysis for the hull structural support provided a sufficient corrosion protection system is installed and maintained.

3.5.4 Strength assessment of hull structural support for the mooring system shall be checked in accordance with the main criteria given in Sec.2 [3]. Local stress analysis described in Sec.4 [5] shall be considered.

3.5.5 Fatigue of hull structural support shall be checked in accordance with the principles given in Sec.7.

3.5.6 The mooring/turret interface to the hull structure shall be calculated by use of a FE analysis considering all relevant loads. The combination of loads from mooring lines, external sea pressure, internal tank filling and hull girder loads shall be considered, see Figure 11-2.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Figure 2 Turret interface with hull structure

3.5.7 For units with a turret structure, the 100 years restoring loads from the mooring lines acting via the turret shall be used in the combination with the global 100 years hull girder loads and local pressure based on the principles given in Sec.2. The restoring loads from mooring shall be calculated according to the principles given in DNVGL-OS-E301.
Guidance note:
When the turret structure is placed in the bow part of the unit, the effect of global hull girder loads are relatively small. If the effect from hull girder contribution can be documented, e.g. a wave load analysis, to have insignificant effect for the turret support structure, the hull girder loads may be excluded.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.5.8 Local support structure in way of chain stopper, fairleads, winches or other component related to the mooring shall be documented according to the principles given in Section 2. The breaking strength of each individual mooring line shall be used together with the acceptance criteria given in Sec.2. Alternatively a load factor of 1.25 times the breaking strength with a material factor of 1.0 may be used.

The strength evaluation shall be undertaken utilising the most unfavourable operational direction of the anchor line and take into account the relative angular between the unit and the anchor lines.

Guidance note:
As the breaking strength of the mooring lines normally is the main governing load part, the contribution of the hull girder load may be excluded.
As the breaking load is significantly larger than the dynamic loads in the mooring line, and when the mooring support structure is available for inspection and repair (DFF = 1.0), fatigue documentation of the local support may be excluded.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Figure 3  Fairlead with vertical inlet angle (γ) and horizontal working angle (ϕ)

3.6  Bilge keel

3.6.1 As FPSOs/FSOs stay on the location without possibility of access for repair, the bilge keel should be welded directly onto the shell plate without doubling plates as such detail increase the fatigue properties. Adequate transverse supporting brackets, or an equivalent arrangement, should also be provided.

3.6.2 Strength and fatigue strength shall be documented. The stress responses from the global and local dynamic shall be combined with wave motion induced drag forces.

3.7  Loading instrument

3.7.1 The loading instrument used to monitor the still water bending moments and shear forces as well as the stability of the unit shall be in compliance with the requirements of the DNV Rules for ships Pt.3 Ch.3 Sec.9.

3.7.2 The limitations for the still water bending moments and shear forces shall be in accordance with maximum permissible still water bending moments and shear forces specified in the loading manual.

4  Fabrication principles

The fabrication principles for hull and topside structure shall comply with the requirements given in DNVGL-OS-C401.
5 Corrosion control

5.1 Hull structure

5.1.1 For the requirements of Sec.4 [2], net scantlings using the corrosion margin given in the DNV Rules for ships Pt.3 Ch.1 shall be used.

5.1.2 For the hull girder strength and fatigue, see Sec.4 [3] and Sec.7, gross scantlings may be used provided the unit complies with the requirements for corrosion protection given in DNVGL-OS-C101/201.

5.2 Topside structure

For the topside structure the requirements for corrosion protection given in DNVGL-OS-C101/201 shall be followed.
CHAPTER 3 CLASSIFICATION

SECTION 1 CLASSIFICATION SERVICES

1 General

1.1 Introduction

1.1.1 As well as representing DNV GL’s recommendations on safe engineering practice for general use by the offshore industry, the offshore standards also provide the technical basis for DNV GL classification, certification and verification services.

1.1.2 This section identifies the specific documentation and surveying requirements to be applied when using this standard for classification purposes.

1.1.3 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification of is given by the applicable DNV GL Rules for classification of offshore units as listed in Table 1.

1.2 Application

1.2.1 It is expected that the unit will comply with the requirement for retention of the Class as defined in the above listed rule books.

1.2.2 Where codes and standards call for the extent of critical inspections and tests to be agreed between contractor or manufacturer and client, the resulting extent is to be agreed with DNV GL.

1.2.3 DNV GL may accept alternative solutions found to represent an overall safety level equivalent to the requirements given in this standard.

1.2.4 Any deviations, exceptions and modifications to the design codes and standards given as recognised reference codes shall be approved by DNV GL.

1.2.5 The technical requirements given in Ch.2 Sec.7 [2] are only applicable for units with class notation FMS.

1.2.6 Conversions of tankers to floating offshore units shall follow the requirements as described in App.A. For life time extensions, the requirements of App.B apply.

1.3 Documentation

Documentation for classification shall be in accordance with the NPS DocReq (DNV GL Nauticus Production System for documentation requirements) and DNVGL-CG-0168.

Table 1 DNV GL rules for classification - Offshore units

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNVGL-RU-OU-0101</td>
<td>Offshore drilling and support units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0102</td>
<td>Floating production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0103</td>
<td>Floating LNG/LPG production, storage and loading units</td>
</tr>
</tbody>
</table>
APPENDIX A  CONVERSION OF TANKER TO FLOATING OFFSHORE UNIT

1 Introduction

1.1 General

1.1.1 This section provides specific requirements and guidance applicable for the conversion from tanker for oil to floating offshore production and/or offshore storage unit, see Rules for FPSO, DNVGL-RU-OU-0102.

1.1.2 The basis of the conversion is a vessel that complies with the structural requirements to 1A Tanker for Oil or equivalent from the date the unit was built.

1.1.3 Prior to conversion it is to be evaluated for the following:

— Identification of steel wastages by thickness measurements.
— Identification of fatigue cracks or damage.

1.1.4 Any major change such as lengthening of the unit, increased draft, increased static loads, etc, shall be evaluated.

1.1.5 For the new structures added to the converted unit, material selection and inspection principles shall comply with the requirement given in Ch.2 Sec.1. The structural renewal including material shall be replaced by steel of the same or higher grade according to the approved design scantling or greater.

1.1.6 Loading manual containing all operational modes shall be submitted for approval. The permissible limit curves for the hull girder still water bending moments and shear forces shall be included.

2 Strength

2.1 General

2.1.1 Existing hull structure may be accepted “as is” provided that it complies with class requirements in force for 1A Tanker for Oil at the date of construction of the vessel. However, additional requirements with respect to longitudinal strength and fatigue capacity shall be complied with based on site specific environmental conditions.

2.1.2 New structures added to the converted vessel or existing structures affected by the new structures shall comply with the requirements of this standard. This will typically include but will not be limited to:

— installation of turret or mooring arrangement
— modification of super-structure
— installation of topside and modification to topside interface
— installation of helideck, lifeboat davits, cranes, etc.
— installation of heavy equipments and modules.

2.2 Benign waters operation

2.2.1 For conversions intended to operate in benign waters area(s) the following reduction of the rule wave coefficient ($C_w$) may be used provided the unit vessel has defined a restricted specified Transit route where:

\[ M_{w,\text{Transit route}} < M_{w,\text{Site-100 year}} \]

The wave coefficient $C_w$ as given in the DNV Rules for ships Pt.3 Ch.1 Sec.4 B200 may be used in the rule scantling requirements as following:

\[ C_w^{\text{reduction}} = \frac{M_{w,\text{Site-100 year}}}{M_{w,\text{Rule20 year}}} \]
Appendix A

The \( C_w \) factor shall not be reduced below 50\%. Both full load (sagging) and ballast (hogging) conditions shall be checked.

\( M_{\text{Site-100 year}} \) shall be calculated according to the principles given in Sec.2 [2.7].

2.2.2 The reduced \( C_w \) factor may be used in [2.3] and [2.4] below.

2.2.3 Any restriction related to operation on the site specific location and restricted transit route shall be reported as a "Memo to the owner".

2.3 Basis requirements

2.3.1 No additional strength calculation is required as long as the unit complies with class requirements in force for 1A Tanker for Oil at the date of construction of the vessel provided:

- Loading conditions in production and storage mode are not more severe than what the unit has been basis for the trade as a tanker.
- Minimum scantlings are within the minimum thickness list provided as a tanker.

Meaning the strength requirements to local scantlings of plate and stiffeners, see Sec.4 [2.1] and transverse girder strength, see Sec.4 [2.2] complies for the future operation as an offshore installation.

2.3.2 If the existing tanks are used differently or if any filling restriction is given as a tanker for oil, new strength requirements (e.g. sloshing loads or change of tank densities) of the tank boundary members are required.

2.4 Hull girder longitudinal strength

2.4.1 If the unit is defined for "benign waters operation", see Ch.2 Sec.2 [2.6], the hull girder strength complies with the requirements given in Ch.2 Sec.4 [3] via the DNV Rules for ships Pt.3 Ch.1 Sec.5.

2.4.2 For operation in "harsh environment", see Ch.2 Sec.2 [2.6], or if direct calculations are used as an alternative to check the longitudinal strength requirements given in the DNV Rules for ships Pt.3 Ch.1 Sec.5, the hull girder longitudinal strength shall comply with the requirements given in Ch.2 Sec.4 [3].

Guidance note:
If the longitudinal strength is checked by use of direct calculations, the scantlings shall not go below the minimum requirement to plate and stiffeners given in the DNV Rules for ships Pt.3 Ch.1, accounting for the \( C_w \) reduction factor when applicable.

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

2.4.3 For conversions the hull girder ultimate strength may alternatively be checked for the sagging condition LC1, see Ch.2 Sec.4 [3.2], using the principles given in DNV Classification Notes No. 34.1 App.C. The design criteria given in Ch.2 Sec.2 [3] for the hull girder ultimate strength, condition a) and b) shall be assessed, and the individual panel buckling shall meet the acceptance criteria for condition d).

Guidance note:
The hull girder ultimate capacity method, also known as HULS, requires extensive use of non-linear software tools and the methods and tools shall be approved by the Society. As the HULS method summarize the moment capacity and not include any bi-axial stress components, the method can not be assessed for the hogging condition LC2, see Ch.2 Sec.4 [3.2].

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

2.5 Topside and topside interface to hull structure

2.5.1 Topside structure shall be calculated according to Ch.2 Sec.5.

2.5.2 Topside interface to hull structure shall be calculated according to Ch.2 Sec.6.

2.5.3 The following approach should be taken to evaluate the suitability of the hull structure for the expected topside loads:

- Determine the condition of the tanker with respect to corrosion and cracks.
- Identify the weight of the topside loads.
- Identify positions of topside modules and strength of hull support structure.
— Uplift of the topside structure may introduce high tensile stresses perpendicular to the plate of the deck plate and replacing existing plate with z-quality steel may be required.
— Due to fatigue, existing fillet welds between transverse frame/bulkhead and deck plate may be increased or replaced with full penetration welds when topside support structure is mounted.

3 Fatigue

3.1 General

3.1.1 The fatigue capacity for conversions shall be considered, and is a function of the following parameters:
— results from survey and previous repair history
— service history of the unit as tanker for oil
— duration and environmental conditions at the site specific location.

3.1.2 The fatigue capacity shall be evaluated in accordance with the principles given in Ch.2 Sec.7.

3.2 Previous trade

3.2.1 Fatigue damage during the previous unrestricted trade shall be calculated. Service history with actual trading route may be used in the fatigue calculation. Alternatively World Wide scatter diagram may be used if the vessels trading history not is available.

3.2.2 For previous trading the design fatigue factor (DFF) of 1 may be used.

3.2.3 SN curves for air or with cathodic protection may be used in all areas and for the whole trading period as tanker provided the corrosion protection system (e.g. painting, anodes) was intact at the conversion time.

3.2.4 Previous repair and damage history should be evaluated with the focus on critical areas and how to remove these potential failures in the operation phase as a floating offshore installation.

3.2.5 Gross scantlings (as built) may be used for the previous tanker phase.

3.3 Operation

3.3.1 The fatigue capacity shall be evaluated in accordance with Ch.2 Sec.7. Minimum 10 years fatigue life in the intended operational site shall be basis for the fatigue calculations.

3.3.2 Design fatigue factors (DFF) as specified in Ch.2 Sec.11 [3.4] shall be followed unless the unit is going to be dry-dock every 5th year, see Table 2.

3.3.3 S-N curves in air in the DNV Classification Notes No.30.7 (CN30.7) may be used for the specified design life.

3.3.4 “As is” scantlings shall be used in the fatigue calculations, if available. Conservatively net scantling approach may be used assuming the corrosion margin from the new-building phase is wasted.

Guidance note:
It the unit has traded as a tanker for oil less than 5 years from the new-building to the conversion point and the corrosion protection system is maintained, the “as built” gross scantlings may in general be used for the fatigue calculations.

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

3.4 Areas to be checked

Fatigue sensitive details in the existing hull structure and newly installed structures shall be documented to validate sufficient fatigue strength. Particular attention shall be given to the following details:
— longitudinal stiffener end connections to transverse frames and bulkheads, see Ch.2 Sec.7 [1.7]
— bottom and side shell plate, see Ch.2 Sec.7 [1.7]
— foundations and supports to main deck, side and bottom structure (e.g. topside, flare tower, riser balcony, turret, etc), see Ch.2 Sec.7 [1.7].
Guidance note:
For side shell where the plate thickness is less than 1/46 of the stiffener spacing, the plate fatigue may be critical for the fillet weld between the longitudinal stiffener and side shell plate.

3.5 Mean stress effect
Mean stress effect according to Table 1 shall be used.

Table 1  Mean stress effect for conversion of tankers to floating offshore installation

<table>
<thead>
<tr>
<th>Operating profile</th>
<th>Base material</th>
<th>Welded structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trading as tanker</td>
<td>See DNV CN 30.7</td>
<td>See DNV CN 30.7</td>
</tr>
<tr>
<td>Operation at site</td>
<td>See DNV CN 30.7</td>
<td>Not to be used</td>
</tr>
</tbody>
</table>

3.6 Documentation
3.6.1 The calculated fatigue damage (CFD) shall satisfy the following requirements:

Table 2  Design fatigue requirements - Trading and operation

<table>
<thead>
<tr>
<th>Fatigue damage</th>
<th>Previous trade as tanker before conversion</th>
<th>Operation phase after conversion</th>
<th>CFD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D1</td>
<td>D2 x DFF</td>
<td>D1 + D2 x DFF &lt; 1.0</td>
</tr>
</tbody>
</table>

3.6.2 If the calculated fatigue damage (CFD) is above 1.0 this may in some cases be accepted upon special consideration. Any consideration shall be well supported and accepted both by the Society and the owner of the unit.

Guidance note:
Possible criteria for accepting CDF above 1.0 may be:

<table>
<thead>
<tr>
<th>Reason for accept details with CFD &gt; 1.0</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No or few fatigue cracks has been reported during the trading history or past operation</td>
<td>Conservative assumptions used in the fatigue calculation</td>
</tr>
<tr>
<td>Fatigue damage for future operation is low</td>
<td>Dynamic loads are small for the actual future operation compared with the dynamic loads used as basis for tanker trading. Low possibility for future cracks.</td>
</tr>
<tr>
<td>Inspection program is created or extended</td>
<td>Details or areas with fatigue damage &gt; 1 will be highlighted and inspected more frequently.</td>
</tr>
<tr>
<td>Criticality of possible cracks is low</td>
<td>Possible cracks will not be critical for the overall hull integrity or lead to possible oil leakage</td>
</tr>
</tbody>
</table>

3.7 Environmental reduction factors
3.7.1 The environmental reduction factor, $f_e$, is defined as the difference in response, calculated by using a wave load analysis, between North Atlantic scatter diagram and actual site specific scatter diagram. The calculated $f_e$ factor may be used in the simplified fatigue calculations given in DNV classification note no. 30.7 and thus as input in DNVGL Nauticus fatigue calculation, both for the past trading history and for the future operating.

The $f_e$ factor may alternatively be estimated using defined values, see Figure 1 and Table 3.

3.7.2 The procedure for how to calculate the $f_e$-factor is as following:

— Determine the operational history profile for vessel including area of operation and fraction of operation in each area.
— Determine the reduction factor for each area of operation, e.g. by interpolation of values in Table 3. Interpolation may be used to determine the $f_e$-factor between the given ship lengths.
— Final reduction factor is determined by weighing area $f_e$-factors by fraction of operation.
Guidance note:
In order to estimate the $f_e$-factor for the past when the unit was trading as a tanker for oil, the average wave climate may be used. E.g for a 200m tanker that has trading in area 25 of 40% of the time past, in area 16 of 20% of the time past and in area 55 of 40% of the time past, the total $f_e$-factor for the past trading will be:

$$0.90 \times 0.4 + 1.0 \times 0.2 + 0.46 \times 0.4 = 0.744$$

For World wide operation the $f_e$-factor of 0.8 shall be used. For units that has been operated in the North Atlantic or in other harsh environments, $f_e = 1.0$ should be used.

---e-n-d---o-f---g-u-i-d-a-n-c-e-n-o-t-e---

Table 3  Environmental reduction factor $f_e$ per vessel length and nautical zone, see Figure 1

<table>
<thead>
<tr>
<th>Zone no.</th>
<th>LBP 300m</th>
<th>200m</th>
<th>100m</th>
<th>Zone no.</th>
<th>LBP 300m</th>
<th>200m</th>
<th>100m</th>
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<td>0.62</td>
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<tr>
<td>5</td>
<td>0.38</td>
<td>0.47</td>
<td>0.52</td>
<td>57</td>
<td>0.43</td>
<td>0.52</td>
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<td>6</td>
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<td>0.95</td>
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<td>0.44</td>
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<td>0.57</td>
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</table>
Table 3  Environmental reduction factor \( f_e \) per vessel length and nautical zone, see Figure 1 (Continued)

<table>
<thead>
<tr>
<th>Zone no.</th>
<th>( f_e )- factor</th>
<th>Zone no.</th>
<th>( f_e )- factor</th>
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<td></td>
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</tr>
</tbody>
</table>
APPENDIX B  LIFETIME EXTENSION OF FLOATING OFFSHORE UNITS

1  Introduction

1.1  General

1.1.1  This section provides specific requirements and guidance for the hull structure applicable for life time extension of existing floating offshore productions (FPSO’s).

1.1.2  Any new structure shall follow the principles for conversion given in App.A.

1.1.3  Prior to the life time extension, the hull structure shall be evaluated for the following:

— Steel wastages shall be identified by thickness measurements, see also DNVGL-RP-C101 for thickness diminution
— Fatigue cracks shall be evaluated.

1.2  Survey extent

The unit shall follow the requirement to survey extent as given in DNVGL-RU-OU-0102 Ch.3.

2  Structural strength

2.1  General

2.1.1  If the unit shall operate at the same location no new strength documentation is required.

2.1.2  If the unit shall operate at a new location with stricter environmental conditions, i.e. when \( H_{\text{new location}} > H_{\text{existing location}} \) hull girder strength, topside and topside support interface, turret interface, etc. need to be checked according to the principles given in App.A [2.4] and App.A [2.5].

2.1.3  For benign waters, reduction of the rule wave coefficient \( C_w \) may be used according App.A [2.2].

3  Fatigue

3.1  General


3.2  Previous trades

See App.A [3.2].

3.3  Operation

3.3.1  Past time in operation and future extensional operation time at the specific location shall be used as basis for the fatigue calculations.

3.3.2  For operation until today, the design fatigue factor (DFF) of 1.0 may be used. For the extended operation DFF as specified in Sec.11 [3.4] shall be used unless the unit will be dry-dock every 5th year. See Table 2.
3.3.3 S-N curves in air as given in the DNV Classification Notes No.30.7 may be used for the specified design life provided a corrosion protection system is installed and maintained.

3.3.4 "As is" scantlings shall be used in the fatigue calculations, if available. Alternatively net scantling approach shall be used as the corrosion margin from the new-building phase is assumed wasted.

3.4 Areas to be checked
See App.3.4.

3.5 Mean stress effect
See App.3.5.

3.6 Documentation

3.6.1 The following design fatigue factors (DFF) shall be used for the fatigue calculations:

<table>
<thead>
<tr>
<th>Table 2  Design fatigue requirements - trading and operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue damage</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>D1</td>
</tr>
</tbody>
</table>

3.6.2 If the calculated fatigue damage is above 1.0, the actual detail may still be accepted without any modifications provided special consideration. Any consideration shall be well supported and accepted both by the Society and the owner of the unit.

Guidance note:
Possible criteria for accepting CFD above 1.0 may be:

<table>
<thead>
<tr>
<th>Reason for accept details with CFD &gt; 1.0</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No or few fatigue cracks has been reported during the trading history or past operation</td>
<td>Conservative assumptions used in the fatigue calculation.</td>
</tr>
<tr>
<td>Fatigue damage for future operation is low</td>
<td>Dynamic loads are small for the actual future operation compared with the dynamic loads used as basis for tanker trading. Low possibility for future cracks.</td>
</tr>
<tr>
<td>Inspection program is created or extended</td>
<td>Details or areas with fatigue damage &gt; 1 will be highlighted and inspected more frequently.</td>
</tr>
<tr>
<td>Criticality of possible cracks is low</td>
<td>Possible cracks will not be critical for the overall hull integrity or lead to possible oil leakage.</td>
</tr>
</tbody>
</table>

---end---of---guidance---note---
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