OFFSHORE STANDARD
DNV-OS-C102

STRUCTURAL DESIGN OF OFFSHORE SHIPS

APRIL 2004

DET NORSKE VERITAS

FOREWORD

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

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

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

DNV Offshore Codes are offered within the following areas:

A) Qualification, Quality and Safety Methodology

B) Materials Technology

C) Structures

D) Systems

E) Special Facilities

F) Pipelines and Risers

G) Asset Operation

H) Marine Operations

Amendments and Corrections

This document is valid until superseded by a new revision. Minor amendments and corrections will be published in a separate document on the DNV web-site; normally updated twice per year (April and October). To access the web-site, select short-cut options "Technology Services" and "Offshore Rules and Standards" at http://www.dnv.com/

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

Comments may be sent by e-mail to *rules@dnv.com*
For subscription orders or information about subscription terms, please use *distribution@dnv.com*
Comprehensive information about DNV services, research and publications can be found at *http*://www.dnv.com, or can be obtained from DNV, Veritasveien 1, NO-1322 Høvik, Norway; Tel +47 67 57 99 00, Fax +47 67 57 99 11.

© Det Norske Veritas. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, including photocopying and recording, without the prior written consent of Det Norske Veritas.

Computer Typesetting (FM+SGML) by Det Norske Veritas.
Printed in Norway.

If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million.
In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.

Main changes

- **General**

The present edition supersedes the October 2000 edition.

- **Main changes**

The main changes are:

— A new Ch.0 has been introduced, providing an introduction including terms and definitions used in the two other chapters. In addition, terms and definitions have generally been harmonised with other offshore standards.
— The standard has been aligned with the other relevant structural standards (i.e. references, terminology, definitions, etc.). The relevant object standards are DNV-OS-C101, DNV-OS-C103 and DNV-OS-C104, as well as the fabrication standard DNV-OS-C401.
— Definition and application of *design temperature* and *service temperature* have been updated and aligned with DNV OS-C101, DNV-OS-C103 and DNV-OS-C104.
— Structural elements listed in the material categorisation tables have been revised.
— Wave loads based on 10 years return period for FPSO/FSO's in the transit condition has been allowed.

Corrections and clarifications

In addition to the above mentioned changes, a number of corrections and clarifications have been made to the existing text.

CONTENTS

OFFSHORE STANDARD
DNV-OS-C102

STRUCTURAL DESIGN OF OFFSHORE SHIPS

CHAPTER 0

INTRODUCTION TO THIS STANDARD

CONTENTS PAGE

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

SECTION 1 INTRODUCTION

A. General

A 100 Organisation of this standard

101 This standard provides requirements and guidance to the structural design of offshore ships constructed in steel.

— Ch.1. 'World Wide Operation' is applicable to any defined environmental condition, whereas
— Ch.2. 'Benign Waters' provides alternative requirements to units intended for operation under restricted environmental condition.

102 This standard refers to relevant parts of the general standard DNV-OS-C101 'Design of Offshore Steel Structures, General' (LRFD Method). In case of deviating requirements between this standard and DNV-OS-C101, this standard overrules the general standard.

103 Costal State requirements may include requirements in excess of the provisions of this standard depending on size, type, location and intended service of the offshore object.

A 200 Objectives

201 The objectives of this standard are to:

— provide an internationally acceptable standard for design of ship-shaped offshore structures
— serve as a technical reference document in contractual matters between purchaser and manufacturer
— serve as a guideline for designers, purchaser, contractors and regulators.
— specify procedures and requirements for units and installations subject to DNV verification and classification services.

A 300 Classification

301 Classification principles related to classification of offshore units are given the DNV Offshore Service Specifications given in Table A1.

Table A1 DNV Offshore Service Specifications	
Reference	*Title*
DNV-OSS-101	Rules for Classification of Offshore Drilling and Support Units
DNV-OSS-102	Rules for Classification of Floating Production and Storage Units
DNV-OSS-103	Rules for Classification of LNG/LPG Floating Production and Storage Units or Installations

302 Documentation requirements for classification are given by DNV-RP-A202.

303 Technical requirements given in DNV-OS-C101, section 8, related to Serviceability Limit States, are not required to be fulfilled as part of classification.

B. Assumptions and applications

B 100 General

101 It is assumed that the units will comply with the requirement for retention of the Class as defined in the DNV-OSS-, DNV-OSS-102 or DNV-OSS-103. Units intended to stay on location for prolonged periods shall also comply with the requirements given in Appendix A.

102 This standard is regarded as supplementary to the 'Main Class structural Requirements'.

103 This standard is in principle applicable to all types of offshore ships of conventional ship shape including, but not limited to, the following variants:

— Floating production units (FPU)
— Floating storage and offloading units (FSO)
— Floating production, storage and offloading units (FPSO)
— Floating production, drilling, storage and offloading units (FPDSO)
— LNG/LPG Floating Production and Storage units
— Drilling vessels
— Well stimulation or intervention vessels.

The above objects (vessels, installations or units) listed above are collectively referred to as "units".

104 This standard is intended to cover several variations with respect to conceptual solutions as listed below:

— units intended for production normally equipped with topside structures to support the production facilities
— units intended for storage in the hull tanks with facilities for offloading to shuttle tankers
— units intended for drilling or well preservations. The units are typically kept in position by thrusters
— units designed with a internal turret for mooring and riser connections. Internal turret may, dependent on location, be of significant size and will affect the distribution of hull girder bending and shear stresses.
— units designed with a submerged dis-connectable turret (buoy) normally located in the foreship or bow region
— units designed with external turret forward of the bow, spread mooring system or similar solutions. Such designs are typical for operation in benign environments.

105 Requirements concerning mooring and riser systems other than the interfaces with the structure of the units are not explicitly considered in this standard.

106 In addition to the hull structure, this standard is also applicable to turret structures and supporting structure for topside facilities.

B 200 World-wide operation

201 Ch.1 of this standard is based on the LRFD method employing a defined scatter diagram for determination of wave bending moments, shear forces, motions and accelerations.

202 For units, such as Drilling Vessels, operating on a given location for a limited period of time, the North Atlantic scatter diagram as defined in DNV Classification Note 30.5 is considered sufficient for non-restricted operations.

203 For units, such as FPSOs, operating on a location for long period of time a specific scatter diagram shall be defined as basis for the design.

204 Ch.1 of this standard shall be used when the requirement to hull girder capacity according to the LRFD method at a given geographical area is higher than the minimum section modulus according to the 'Main Class Requirements'.

B 300 Benign waters

301 Ch.2 of this standard may be used when the requirement to hull girder capacity according to the LRFD method at a given geographical area is less than the minimum section modulus according to the 'Main Class Requirements'.

302 The hull of conventional ships intended for conversion to an offshore unit comply with the requirements to structural strength, welds and material qualities provided the hull comply with the 'Main Class Requirements' and satisfy the criteria for Benign Water according to 401.

B 400 Decision criteria for world-wide and benign waters

401 Benign Waters is defined by:

$$M_{WB}\,\gamma_{fi}\,\gamma_{nc} \leq 1.17\,M_{WR} + 0.17M_S$$

and worldwide operation is defined by:

$$M_{WB}\,\gamma_{fi}\,\gamma_{nc} > 1.17\,M_{WR} + 0.17M_S$$

where

M_{WB} = linear wave bending moment at an annual probability of exceedance 10^{-2} (100 years return period)
γ_{fi} = partial load coefficient = 1.15
γ_{nc} = non-linear correction factor 1.1 in sagging and 0.9 in hogging condition unless otherwise documented [1)]
M_{WR} = absolute value of wave bending moment as given in the Rules for Classification of Ships Pt.3 Ch.1
M_S = absolute value of maximum still water bending moment.

1) The default values given are for ships of conventional hull form. The non-linear correction factors for unconventional hull forms shall be documented by direct calculations.

Guidance note:
Applicable chapter of this standard for worldwide and benign waters is illustrated as guidelines in Fig.1.

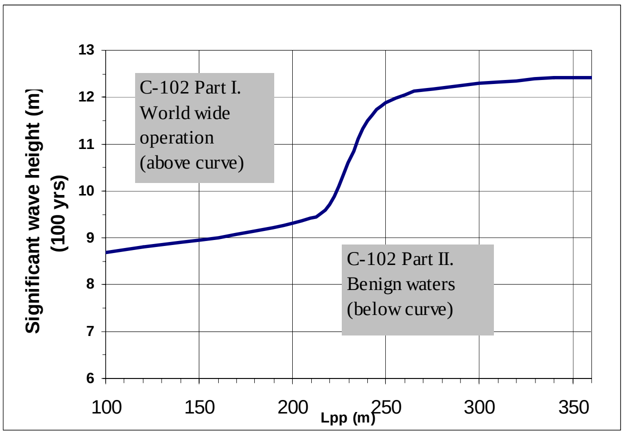

Figure 1
Applicable chapter of DNV-OS-C102

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

402 If the significant wave height is less than 8.5 m for a probability of exceedance of 10^{-2} (100 years return period), benign waters can be assumed without further calculation.

C. Definitions

C 100 Verbal forms

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

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

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

C 200 Terms

201 Standard terms are given in DNV-OS-C101.

202 *Transit conditions:* All unit movements from one geographical location to another.

203 *Floating production and offloading unit:* 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.

204 *Floating storage and offloading unit:* 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.

205 *Floating production, storage and offloading unit:* 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 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.

206 *Floating production, drilling, storage and offloading unit:* 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.

207 *Drilling vessel:* 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.

208 *Well stimulation vessel* or *well intervention vessel:* A unit equipped for performing wireline intervention (without riser) of subsea wells and or coiled tubing of subsea. 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.

209 *LNG/LPG Floating Production and Storage units:* A unit with facilities for oil and gas producing 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.

210 *Turret:* 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.

211 *Main Class Requirements:* Provisions and requirements given in DNV Rules for Classification of Steel Ships Pt.3. Ch.1 or Ch.2.

212 *Load and Resistance Factor Design (LRFD):* Method for design where uncertainties in loads are represented with a load factor and uncertainties in resistance are represented with a material factor.

213 *Benign Waters*: Environments at which the required to hull girder capacity calculated according to the LRFD method is less than the minimum section modulus according to the ‘Main Class Requirements’.

C 300 Symbols

301 The following Latin characters are used in this standard:

Table C1 Latin characters used	
V	speed in knots
C_W	wave coefficient as given in Rules for Classification of Ships Pt.3 Ch.1 Sec.4
P_{dp}	design load on weather deck
h_0	vertical distance from the waterline at draught T to the load point (m)
Z	vertical distance from the baseline to the load point (m)
Y	horizontal distance from the centre line to the load point (m)
F	vertical distance from the waterline to the top of the side of the unit at transverse section considered (m)
b_1	breadth of deckhouse at position considered
B_1	maximum breadth of the unit at the weather deck at position considered
H_s	significant wave height
M_g	characteristic bending moment resistance of the hull girder
M_S	characteristic design still water bending moment of the hull girder based on actual cargo and ballast conditions
M_W	characteristic wave bending moment of the hull girder based on an annual probability of exceedance of 10^{-2}
Q_g	characteristic shear resistance of a longitudinal shear element in the hull girder
Q_S	characteristic design still water shear force in the longitudinal shear element based on actual cargo and ballast conditions
Q_W	characteristic wave shear force in the longitudinal shear element based on an annual probability of exceedance of 10-2

302 The following Greek characters are used in this standard:

Table C2 Greek characters used	
γ_M	material factor
$\gamma_{f,G,Q}$	partial load factor for functional and variable loads
γ_w	environmental load factor
A_{ps}	area of panel (plate and stiffeners)
z	distance from panel to plastic neutral axis
σ_{cr}	characteristic longitudinal stress on the compression side corresponding to critical buckling capacity of the panel
σ_f	characteristic yield stress of panel on the tension side
A_p	area of panel (plate area only)
τ_{cr}	characteristic shear stress in panel

C 400 Abbreviations

401 The abbreviations given in Table C3 are used in this standard. Definitions are otherwise given in DNV-OS-C101 ‘Design of Offshore Steel Structures, General’ (LRFD method)

Table C3 Abbreviations	
Abbreviation	*In full*
ALS	Accidental limit states
DFF	Design fatigue factor
FLS	Fatigue limit states
LRFD	Load and resistance factor design
NDT	Non-destructive testing
SCF	Stress concentration factors
SLS	Service limit states
ULS	Ultimate limit states

D. References

D 100 DNV Offshore Standards, Rules and Classification Notes

101 The offshore standards and rules given in Table D1 are referred to in this standard.

Table D1 DNV Offshore Standards, Rules, Classification Notes and Recommended Practice	
Reference	*Title*
DNV-OS-C101	Design of Offshore Steel Structures, General (LRFD method)
DNV-OS-C401	Fabrication and Testing of Offshore Structures
DNV-OS-B101	Metallic Materials
DNV-RP-102	Structural Design of Offshore Ships
DNV-RP-C201	Buckling Strength of Plated Structures
Classification Note 30.5	Environmental Conditions and Environmental Loads
Classification Note 30.7	Fatigue Assessment of Ship Structures
DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
Rules	Classification of Ships - Pt.3 Ch.1 or Pt.3 Ch.2

OFFSHORE STANDARD
DNV-OS-C102

STRUCTURAL DESIGN OF OFFSHORE SHIPS

CHAPTER 1

WORLD-WIDE OPERATION

CONTENTS PAGE

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

SECTION 1 INTRODUCTION

A. General

A 100 Assumptions and applications

101 This chapter provides requirements and guidance to the structural design of offshore ships constructed in steel for any defined environmental condition. Reference is made to Ch.0 of this standard for detailed description of the area of application.

102 The hull girder capacity is based on the principles of the Load and Resistance Factor Design method, referred to as LRFD method, and is described in DNV-OS-C101.

103 The design wave bending moments and shear forces at an annual probability of 10^{-2} (100 year return period) are determined by means of direct calculations based on a site specific wave scatter diagram.

104 The requirements given in this chapter are supplementary to the “main class requirements” This implies that the unit shall comply with the “main class requirements” for the midship section modulus. These requirements are based on the wave bending moments for the North Atlantic at an annual probability of $10^{-1.3}$ (20 year return period).

105 The standard has been written for general world-wide application. Costal State requirements may include requirements in excess of the provisions of this standard depending on size, type, location and intended service of the offshore unit or installation.

SECTION 2
STRUCTURAL CATEGORISATION, MATERIAL SELECTION AND INSPECTION PRINCIPLES

A. Selection of Material

A 100 General

101 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.

102 Selection of steel grade is based on the principles and requirements given in DNV-OS-C101.

103 In structural cross-joints where high tensile stresses are acting perpendicular to the plane of the plate, the plate material shall be tested to prove the ability to resist lamellar tearing (Z-quality).

104 The steel grades selected for structural components are to be related to weldability and requirements to toughness properties and are to be in compliance with the requirements given in the DNV-OS-B101.

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

106 Structural elements used only in temporary conditions, like fabrication, are not considered in this standard.

A 200 Structural categorisation

201 According to DNV-OS-C101 material shall be categorised into a *special*, *primary* or *secondary* category. With reference to the application of material classes as given in the Rules for Classification of Ships Pt.3 Ch.1 or Pt.3 Ch.2 the relationship between the material classes and structural categories is as given in Table A1.

Table A1 Relationship between material classes and structural categories

Material class	*Structural category*
I, II	Secondary
III, IV	Primary
V	Special

For stiffened plates, the plates are considered as *primary* category whilst the stiffeners are considered as *secondary* category.

202 Typical elements for offshore ships, which are not given in the Rules for Classification of Ships Pt.3 Ch.1 or Pt.3 Ch.2, are given in 300 and 400.

A 300 Special category - typical locations

301 The following locations are considered special category:

— highly stressed [1)] elements in way of moonpool such as corner plates in rectangular moonpools
— highly stressed [1)] elements in way of support structure for turret
— highly stressed [1)] elements in way of main supporting structures of heavy substructures and equipment e.g. topside support structure, support of chain stoppers, support of offloading riser fairleads, anchor line fairleads, supporting structure for winches, crane pedestals, flare boom, davits, hawser brackets for shuttle tanker, towing brackets etc.

Guidance note:

If the stresses induced by environmental loads small, and the permanent and variable functional loads cause compression stresses, the materials can be considered as primary category.

1) Highly stressed elements are elements utilised more than 85 % of the allowable structural capacity (ULS yield and buckling).

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

A 400 Primary category - typical locations

401 The following locations are considered primary category:

— non-highly-stressed elements given in A301
— topside support stools
— gantry structure
— turret structure
— pipe rack stanchions
— drillfloor substructure
— helicopter deck substructure
— flare supporting structure.

A 500 Service temperatures

501 The *service temperature* for external structures above the lowest ballast waterline shall be set equal to the lowest mean daily temperature for the area(s) in which the unit is specified to operate.

502 The *service temperature* for external structures below the lowest ballast waterline needs normally not to be set lower than 0°C.

503 The *service temperature* for internal structures in way of permanently heated rooms needs normally not to be set lower than 0 °C. Crude oil tanks may be considered to be permanently heated.

504 The *service temperature* for internal structures in oil storage tanks in FPSOs/FSUs needs normally not to be set lower than 0°C except for the upper strake in longitudinal bulkheads and top wing tanks.

B. Inspection Principles

B 100 General

101 The extent of non-destructive testing during fabrication shall be in accordance with the requirements for the appropriate inspection category as defined in DNV-OS-C101, Sec.4.

102 Requirements for type and extent of inspection are given in DNV-OS-C401, dependent on assigned inspection category for the welds. The requirements are based on the consideration of fatigue damage and general fabrication quality.

More detailed description of a typical extent of inspection is given in the Recommended Practice DNV-RP-C102 “Structural Design of Offshore Ships”.

103 The inspection category for units covered by this standard shall relate to the structural category as shown in Table B1.

Table B1 Inspection categories

Inspection category	*Structural category*
I	Special
II	Primary
III	Secondary

104 When determining the locations of required non-destructive testing (NDT), consideration should be given to relevant fabrication parameters including; location of block (section) joints, manual versus automatic welding, start and stop of weld etc.

SECTION 3 DESIGN BASIS AND PRINCIPLES

A. Design Basis

A 100 Operational modes

101 A unit shall be designed for all relevant modes of operation. Typically, the assessment of the unit shall be based on the following operational modes:

- all operating conditions, intact and damaged, at the design location(s)
- all transit conditions
- docking condition afloat
- dry-docking condition.

A 200 Still water load conditions

201 All relevant still water loading conditions shall be considered to determine the limit curves for maximum permissible bending moments and shear forces.

A 300 Environmental loads

301 Environmental loads shall in principle be based on site specific data representative for the areas in which the unit is to operate. For units, such as FPSOs, operating on a location for long period of time, the specified scatter diagram will govern the areas of operation for the unit.

302 For units, such as drilling vessels, operating on a given location for a limited period of time, the North Atlantic scatter diagram as defined in DNV Classification Note 30.5 is considered sufficient for non-restricted operations, and shall be used as basis for assessment of the ULS and FLS.

A 400 Prolonged survey periods

401 Units intended to stay on location for a prolonged survey period, i.e. without dry-docking, shall also comply with the requirements in Appendix A.

B. Strength Assessment

B 100 Compliance with main class requirements

101 The requirements given in this standard are supplementary to the requirements for main class.

102 The main class requirements for plates and stiffeners exposed to local loads ensure sufficient safety level for local capacity, and need no further assessment unless otherwise noted.

103 Non-operating conditions like transit conditions, docking condition afloat and dry-docking condition, are considered to be covered by the main class requirements.

104 In the transit condition, the design values of global accelerations for assessment of topside facilities and supporting structure may be taken from the wave load analysis provided the assessment is in accordance with 302. The wave load analysis shall in such cases be based on an annual probability of exceedance of $10^{-1.3}$ (20 year return period).

For units which are intended to operate on a specific location for the main part of the design life, wave loads can be based on the actual transit route and season at an annual probability of exceedance of $10^{-1.0}$ (10 year return period), or on the Rules from a recognised Marine Warranty.

105 The main class requirements for plates and stiffeners on transverse bulkheads are considered to provide sufficient structural capacity.

106 Hull structural elements with less importance for overall structural integrity such as deckhouses, elements within the fore and aft unit structure, may be assessed according to the main class requirements unless otherwise noted. See also Sec.6 B303.

Guidance note:

Fore and aft unit is normally areas outside 0.4 L amidships or the cargo area whichever is the larger.

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

B 200 Global strength

201 For the intact and damage operating conditions, the hull girder capacity shall be based on the LRFD method as defined in DNV-OS-C101. The hull girder will typically comprise the following stiffened panels in:

- deck and bottom
- longitudinal bulkheads
- sides and inner sides
- inner bottom
- longitudinal stringers and girders.

202 The structural capacity of the hull girder shall comply with the ULS and ALS requirements given in the respective sections in this standard.

203 The strength of the hull girder shall be assessed based on the load conditions that result in maximum longitudinal tension and compression stresses in deck and bottom plating. This will normally be the extreme full load and ballast condition. The effect of topside facilities shall be included in the hull girder assessment for these load conditions.

204 The effect of large openings in the hull (e.g. moonpool) which affect the distribution of global stresses shall be considered accounting for three dimensional effects.

B 300 Local strength assessment

301 Local strength assessment shall be carried out for typical elements like:

- supporting structure for topside structure
- supporting structure for thrusters
- turret
- crane pedestals
- bow recess area for submerged type of turrets.

302 The supporting structure for topside structure (e.g. topside modules, derrick, flare etc.) shall be assessed according to the LRFD format. The extent of the supporting structure is limited to the structural members affected by the local loads from the topside structure. Structural capacity of the supporting structure shall be assessed according to DNV-OS-C101.

303 Supporting structure for thrusters are normally considered for a specified thrust using the acceptance criteria given in the Rules for Classification of Ships Pt.3 Ch.1.

304 The turret shall be analysed according to the LRFD format based on the specific loads from the mooring system in the operational mode. Both global and local response of the turret shall be considered. In addition the local structure shall be considered for the special load cases as defined in Sec.8 C101.

305 The supporting structure for the turret shall be assessed based on the LRFD format. Hull deformations shall be considered.

C. Fatigue Assessment

C 100 General principles

101 Fatigue capacity shall be carried out according to Classification Note 30.7 or DNV-RP-C203.

102 The fatigue capacity is calculated assuming that the linear accumulated damage (Palmgren – Miner rule). The different methods given in Classification Note 30.7 are used at different stages in the design loop. Applicable method can also be selected depending on the results from a screening process to identify fatigue critical details.

SECTION 4 DESIGN LOADS

A. Introduction

A 100 General

101 The loads shall in general be determined according to the principles in DNV-OS-C101 for all structural elements assessed in compliance with the LRFD format.

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

- drilling, production, workover and combination thereof
- consumable re-supply procedures and frequency
- maintenance procedures and frequency
- possible load changes in extreme conditions.

B. Design Loads for Minimum Structural Capacity

B 100 General principles

101 To define the minimum design basis, the design sea pressures and pressures from liquid in tanks according to the Rules for Classification of Ships Pt.3 Ch.1 shall be used for assessment of elements like plates and stiffeners, girders, frames, web frames and stringers. The acceptance criteria for these elements shall be as given in the Rules for Classification of Ships Pt.3 Ch.1.

C. Design Loads for Global Hull Girder Capacity Assessment

C 100 Application

101 The design loads given in D and E are used to assess the hull girder capacity (global). Loads used in the global check shall be consistent. This implies that the longitudinal stresses based on global load conditions in D and E shall be combined with transverse stresses based on sea pressures and tank pressures as defined in DNV-OS-C101.

D. Still Water Loads

D 100 General

101 With reference to DNV-OS-C101, the still water loads consist of the permanent and variable functional loads.

102 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.

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

104 Typical variable functional loads are:

- hydrostatic pressures resulting from buoyancy
- crude oil
- ballast water
- fuel oil
- consumables
- personnel
- general cargo
- riser tension.

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

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

107 All relevant still water load conditions shall be defined and limit curves for hull girder bending moment and shear forces shall be established. The shear force limit curves shall be corrected for actual load condition and structural arrangement as given in the Rules for Classification of Ships Pt.3 Ch.1 Sec.5 D.

108 The shape of the limit curves for the still water bending moments and shear forces are defined in the Rules for Classification of Ships Pt.3 Ch.1. If the extreme still water bending moment and/or shear exceed the main class minimum values, the limit curve should be based on all relevant load combinations.

109 Limit curves for the still water loading conditions shall be presented for operational and transit mode separately.

E. Environmental Loads

E 100 General

101 Environmental loads are loads caused by environmental phenomena. The characteristic value of an environmental load is the maximum or minimum value (whichever is the most unfavourable) corresponding to a load effect with a prescribed probability of exceedance.

102 The long-term variation of environmental phenomena such as wind, waves and current shall be described by recognised statistical distributions relevant to the environmental parameter considered, see DNV-OS-C101. Information on the joint probability of the various environmental loads may be taken into account if such information is available and can be adequately documented.

103 Consideration shall be given to responses resulting from the following listed environmental loads:

- wave induced loads
- wind loads
- current loads
- snow and ice loads
- sloshing in tanks
- green water on deck
- 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).

E 200 Wave induced loads

201 The wave loads shall be determined by methods giving adequate description of the kinematics of the liquid, reflecting the site specific environment in which the unit is intended to operate, see DNV-OS-C101 and Classification Note 30.5.

202 Global linear wave induced loads such as bending moments and shear forces shall be calculated by using either strip theory or three dimensional sink source (diffraction) formulation.

203 Linear wave induced loads are normally calculated by 3D sink-source theory. Strip theory may be used provided:

$$\frac{L_{pp}}{B} \geq 3.0$$

Guidance note:

Three-dimensional effects in fore and aft ship will reduce the drag force compared to a strip theory approach.

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

204 When a 3-D diffraction program is used, due consideration shall be given to the analytical model to determine the hull response with sufficient accuracy.

205 The following wave induced linear responses shall be calculated:

— motions in six degrees of freedom
— vertical 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
— torsional moment if relevant
— accelerations
— axial forces
— external sea pressure distribution.

206 The mass model shall be made sufficiently detailed to give centre of gravity, roll radius of inertia and mass distribution as correct as practically possible.

207 Non-linear effects such as slamming, water on deck and bow flare forces shall be considered with respect to local and global consequences.

208 The midship bending moments and shear forces shall be calculated considering the weather vaning characteristics of the unit. E.g. for turret moored units, the calculations are normally carried out for head seas.

209 Torsional moments may be of interest depending on the structural design.

210 The wave shear forces shall be determined at a sufficient number of sections along the hull to fully describe the limit curve for the maximum value.

211 If roll resonance occurs within the range of wave periods likely to be encountered, the effect of non-linear viscous roll damping shall be taken into account.

212 Viscous effects, such as eddies around the hull, act mainly as a damping mechanism, especially at large roll angles, and these effects shall be included.

213 The effects from roll damping devices, like bilge keels, shall be evaluated. The roll damping shall be evaluated for the return period in question.

E 300 Mooring loads

301 A unit may be kept on location by various methods. These methods may include several different types of station-keeping systems such as internal and submerged turret systems, external turret, buoy, fixed spread mooring and dynamic positioning. Each mooring system configuration will impose loads on the hull structure. These loads shall be considered in the structural design of the unit, and combined with other relevant load components.

E 400 Sloshing loads in tanks

401 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.

402 The pressures generated by sloshing of the cargo or ballast liquid shall be considered according to the requirements given in the Rules for Classification of Ships Pt.3 Ch.1 Sec.4 C300.

Guidance note:

The Rules for Classification of Ships differentiate between ordinary sloshing loads (non-impact) and sloshing impact loads.

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

E 500 Green water

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

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

503 Structural members exposed to green water shall be designed to withstand the induced loads. Green sea loads is considered as local loads, but shall be combined with the effect from global response.

504 In lack of more exact information, for example from model testing, the design pressure acting on weather deck shall be:

$$p = ab(p_{dp} - (4 + 0.2k_s)h_0) \quad (kN/m^2)$$

Minimum pressure is 5.0 kN/m^2.

The design pressure on topside support structure, unprotected bulkheads of deck houses and superstructures located forward of 0.15 L from F.P. shall be calculated according to the pressures given in Table E1, whichever is the greatest for the position in question.

Table E1 Design pressure for topside supports, deckhouses and superstructure

Structure	*Pressure kN/m²*
Unprotected front bulkheads	$p_1 = 5.7\ k_{hs}\ (2 + L/120)(k_w\ C_w - h_0)\ c$
	$p_2 = 3.4\ (2 + L/120)[(h_s/8.5)^{0.25}\ 1.07\ k_w\ C_w - h_0]\ c$
	$p_3 = 12.5 + 0.05\ L$ for first 4 m above the forecastle deck $p_3 = 6.25 + 0.025\ L$ elsewhere
Unprotected sides and topside supports	$p_4 = P_{dp} - (4 + 0.2k_s)\ h_0$ minimum p_3
Unprotected aft end bulkheads	$p_5 = 0.85\ p_4$ minimum p_3

a = 1.0 for weather decks forward of 0.15 L from F.P., or forward of deckhouse front, whichever is the foremost position
= 0.8 for weather decks elsewhere

b = 1.5 at unit's side and 1.75 at the centre line. Linear interpolation shall be used for intermediate locations

$$P_{dp} = P_l + 135\frac{y}{B + 75} - 1.2\ (T - z) \qquad (\text{kN/m}^2)$$

$$P_l = k_s\ C_w + k_f$$

$$= (k_s C_w + k_f)\left[0.8 + 0.15\frac{V}{\sqrt{L_1}}\right] \text{ if } \frac{V}{\sqrt{L_1}} > 1.5$$

V = speed in knots, minimum 8

C_B = block coefficient

$$k_s = 3\ C_B + \frac{2.5}{\sqrt{C_B}} \text{ at A.P. and aft}$$

= 2.0 between 0.2 L and 0.7 L from aft

$$= 3\ C_B + \frac{4.0}{C_B} \text{ at F.P. and forward}$$

Between specified areas, k_s shall be varied linearly.

Z = vertical distance from the baseline to the load point, maximum T (m)

Y = horizontal distance from the centre line to the load point, minimum B/4 (m)

k_f = the smallest of T and f

F = vertical distance from the waterline to the top of the unit's side at transverse section considered, maximum 0.8 C_W (m)

L_1 = unit length, need not be taken greater than 300 m

C = 0.3 + 0.7(b_1/B_1) For unprotected parts of machinery casings, C is not to be taken less than 1.0

b_1 = breadth of deckhouse at position considered

B_1 = maximum breadth of unit on the weather deck at position considered(b_1/B_1) not to be taken less than 0.25

$$k_{hs} = -0.016\ h_s^2 + 0.62\ h_s - 3.15 \qquad \text{maximum } 1.8$$

h_s = significant wave height minimum 8.5 m

$$k_w = 1.3 - 0.6\frac{x}{L} \text{ for } \frac{x}{L} \le 0.5$$

$$= 0.3 + 1.4\frac{x}{L} \text{ for } \frac{x}{L} > 0.5$$

x = longitudinal distance in m from A.P. to the load point.

Guidance note:

Note that the speed V = 8 knots should also be used as minimum for moored or dynamically positioned units to ensure sufficient minimum pressure.

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

505 The required local scantlings shall be according to the Rules for Classification of Ships Pt.3 Ch.1 using the design pressure as given in 504.

506 Glass thickness of windows in unprotected front bulkheads as well as the design of the fastening arrangement to the bulkheads shall be considered using the design pressures given in Table E1.

507 Topside members located in the midship or aft area of the unit shall be based on p_4 in Table E1.

Guidance note:

It is advised that provisions are made during model testing for suitable measurements to determine design pressures for local structural design. This implies that model tests should be performed at design draught, for sea states with a spectrum peak period approximately 70 to 100% of the pitch resonance period of the unit. The unit model should be equipped with load cells on the weather deck at positions of critical structural members or critical topside equipment.

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

E 600 Strengthening against bottom slamming

601 When lacking more exact information, for example from model testing, relevant requirements to strengthening against bottom slamming in the bow region are given in the Rules for Classification of Ships Pt.3 Ch.1 Sec.6 H200. 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.

602 The bottom aft of the unit may be strengthened against bottom slamming according to the Rules for Classification of Ships Pt.3 Ch.1 Sec.6 H200 dependent on draught, hull shape, environment, heading and relative velocity of the unit.

E 700 Strengthening against bow impact

701 The design of the bow structure exposed to impact loads shall be carried out according to Rules for Classification of Ships Pt.3 Ch.1 Sec.7 E300. The speed V in knots shall not be less than 8.0.

F. Deformation Loads

F 100 General

101 Relevant deformation loads for units covered by this standard shall be considered according to the principles given in DNV-OS-C101.

G. Accidental Loads

G 100 General

101 Accidental loads are loads related to abnormal operation or technical failure.

102 Attention shall be given to layout and arrangements of facilities and equipment in order to minimise the adverse effects of accidental events.

G 200 Safety assessment

201 Accidental events that will be a basis for the design shall be stated in the design brief. Such events are normally identified in a risk analysis. Typical events are:

— dropped objects (e.g. from crane handling)
— fire
— explosion.

H. Fatigue Loads

H 100 General

101 Repetitive loads, which may lead to possible significant fatigue damage, shall be considered. Such loads may comprise the following:

— wave induced loads
— wind loads (especially when vortex induced vibration may occur)
— loads on crane pedestals
— variation of filling level in cargo tanks (low cycle).

102 The effects of both local and global dynamic response shall be properly accounted for when determining response distributions of repetitive load effects.

103 Hull vibration is not covered by this standard.

SECTION 5
STRUCTURAL ANALYSES FOR CAPACITY CHECKS

A. Introduction

A 100 General requirements

101 The structural response shall be determined by recognised analytical methods. Computer programs used shall have documented test results.

102 The required types of analyses will depend on the structural design, but in general the following is required:

— finite element analysis for global hull girder strength assessment
— finite element analyses for strength assessment of local areas where the structural response cannot be adequately determined by the global analysis
— finite element analyses to determine stress concentration factors.

B. Longitudinal Stresses

B 100 General

101 Global longitudinal stresses should normally be calculated by a finite element analysis. Typical extent of the model may be three cargo tanks.

102 For units with moonpool or turret, a finite element analysis shall be carried out to describe the stress distribution in way of the openings, in particular in deck and bottom, and at termination of longitudinal strength elements.

C. Transverse Stresses

C 100 General

101 Transverse stresses shall normally be determined based on a 3-dimensional finite element analysis. The transverse stresses are normally derived from the same 3-cargo tank model as described in B101.

C 200 Global shear stresses

201 Global shear stresses shall be calculated considering the vertical shear force at the transverse section in question as well as the actual shear flow distribution in the section. The shear force shall be corrected according to the Rules for Classification of Ships Pt.3 Ch.1 Sec.5 D.

SECTION 6
ULTIMATE LIMIT STATES (ULS)

A. Introduction

A 100 General

101 According to the LRFD format, see DNV-OS-C101, two sets of partial coefficient combinations shall be analysed. These combinations are referred to as the a) and b) combinations.

102 The material factor to be used in the ULS assessment of the hull girder is 1.15.

103 The capacity assessment in the ULS condition shall include buckling and yield checks.

104 Buckling capacity checks shall be performed in accordance with DNV-OS-C101 Sec.5.

105 Gross scantlings may be utilised in the calculation of the buckling capacity of the hull structural elements, provided a corrosion protection system in accordance with DNV-OS-C101 is maintained.

B. Hull Girder Longitudinal Strength

B 100 Hull girder bending and shear checks

101 The hull girder bending and shear capacity in the operating conditions shall be checked according to B200 and B300. The capacity checks are based on the two equations below:

$$\gamma_{f, G, Q} M_s + \gamma_{f, E} M_w \le M_g / \gamma_m$$

$$\gamma_{f, G, Q} Q_s + \gamma_{f, E} Q_w \le Q_g / \gamma_m$$

M_g = characteristic bending moment resistance of the hull girder

M_S = characteristic design still water bending moment based on actual cargo and ballast conditions

M_w = characteristic wave bending moment based on an annual probability of exceedance of 10^{-2}

Q_g = characteristic shear resistance of a longitudinal shear element in the hull girder

Q_S = characteristic design still water shear force in the longitudinal shear element based on actual cargo and ballast conditions

Q_W = characteristic wave shear force in the longitudinal shear element based on an annual probability of exceedance of 10^{-2}

γ_m = material factor

$\gamma_{f,G,Q}$ = partial load factor for still water loads (permanent + variable functional loads)

$\gamma_{f,E}$ = partial load factor for environmental loads.

Guidance note:

Typical longitudinal shear elements are unit's side, inner side and longitudinal bulkheads that contribute to the global shear capacity of the hull girder. Each of such elements should be considered separately subjected to the shear force in the element.

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

102 The ULS partial load coefficients for assessment of global capacity, are given in Table B1.

Table B1 Partial coefficients for the Ultimate Limit States		
Combination	*Load category*	
	Still water loads	*Environmental loads*
a)	1.2	0.7
b)	1.0	1.15

103 The environmental loads for hull girder global response are mainly wave induced loads. Other environmental loads can normally be neglected.

104 The dimensioning condition for different M_w/M_s ratios is shown in Figure 1. Offshore units also complying with the main class requirements will typically have M_w/M_s ratios of 1.4 to 1.6. In such cases the b) combination is dimensioning.

105 Combination a) need not be assessed for the hull girder capacity if:

$$M_W \ge 0.44\, M_s$$

Guidance note:

Note that the M_s in the equations given above include the global effect of top side loads.

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

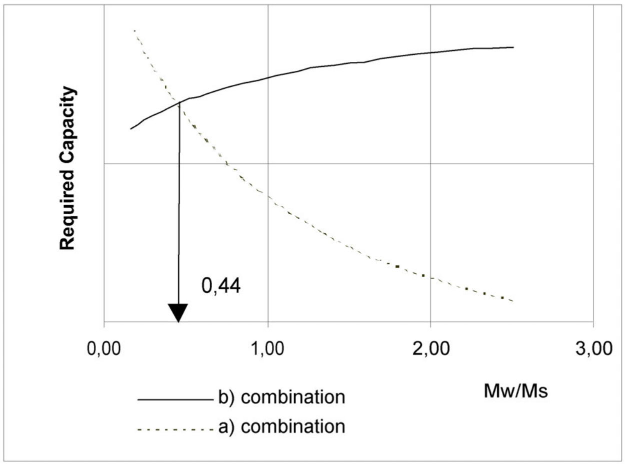

Figure 1
Dimensioning combination

B 200 Hull girder yield check

201 The global hull and main girder system nominal stresses derived from direct strength calculations shall comply with the yield criteria given below:

$$\sigma_e \le \frac{1}{\gamma_m} f_y$$ for operating conditions (100 years return period for environmental loads)

σ_e = nominal equivalent stress

γ_m = material factor = 1.15

f_y = yield stress of the material

202 Local peak stresses in areas with pronounced geometrical changes, such as in moonpool corners, frame corners etc., may exceed the yield stress criterion in 201 provided plastic mechanisms are not developed in the adjacent structural parts.

Guidance note:
Linear peak stress (von Mises) of $400 \frac{f_y}{f_{yNS}}$ N/mm^2

is generally acceptable. f_{yNS} and f_y are the yield stresses for mild steel and the actual material, respectively.

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

B 300 Hull girder buckling capacity

301 Hull girder buckling capacity shall be determined for all main longitudinal members such as:

— continuous decks, bottom and inner bottom
— side, inner side and longitudinal bulkheads
— longitudinal stringers and longitudinal girders.[1)]

1) Longitudinal stringers and longitudinal girders may be omitted from the ULS buckling assessment provided they are excluded from the longitudinal stress calculations.

302 ULS capacity assessment is not limited to 0.4 L amidships for the longitudinal elements given in 301.

303 The hull girder buckling capacity of the main longitudinal members are determined by assessment of each stiffened panel of the main member when exposed to longitudinal, transverse and shear design stresses as well as design lateral pressure.

304 The characteristic still water bending moments used in the buckling calculations shall not be less than the permissible bending moment curves (limit curves) at the transverse section considered.

305 The value of the still water shear forces used in the buckling calculations shall not be less than the shear force for the load condition with the governing bending moment at the section considered.

306 The transverse stresses shall be based on consistent loads using actual internal and external pressures corresponding to the worst combination of still water loads and wave position.

307 All stresses and pressure shall be based on an annual probability of exceedance of 10^{-2}.

308 The buckling capacity of each panel shall be determined according to DNV-RP-C201 Buckling Strength Analysis.

B 400 Hull girder shear capacity

401 The characteristic ultimate shear capacity of each longitudinal shear element shall be determined according to 402. The characteristic ultimate shear stress for each panel in 402 corresponds to the buckling capacity of the panel when exposed to design longitudinal and transverse stresses and lateral pressure. The longitudinal and transverse stresses shall be based on consistent loads using actual internal and external pressures corresponding to the worst combination of still water loads and wave position. All stresses and pressure shall be based on an annual probability of exceedance of 10^{-2}. The buckling capacity of each panel shall be determined according to DNV-RP-C201 Buckling Strength Analysis.

402 The global shear is calculated as follows:

$$Q_g = \sum_j \tau_{cr_j} A_{p_j}$$

A_p = area of panel in the shear element (plate area only)

τ_{cr} = characteristic ultimate shear stress in panel corresponding to buckling capacity according to Classification Note 30.1

j = includes all panels in the longitudinal shear element.

The number of panels in each longitudinal shear element should be sufficient to describe the shear distribution in the element and to account for plate thickness variation.

403 The characteristic still water shear forces used in the shear capacity checks shall not be less than the permissible shear force curves (limit curves) at the transverse section considered.

404 The value of the still water bending moment used in the buckling calculations shall not be less than the bending moment for the load condition with the governing shear force at the section considered.

C. Transverse Structural Strength

C 100 General

101 Transverse strength refers the strength of main transverse members such as transverse bulkheads and web frames. The transverse strength should be evaluated using a finite element model, and the effects of process equipment deck loads should be included. The transverse strength shall meet the requirements given in the Rules for Classification of Ships Pt.3 Ch.1 Sec.13.

D. Turret and Moonpool Areas

D 100 General

101 The following areas shall be considered as relevant, with respect to structural response from the mooring loads, combined with other relevant loads:

— structure in way of moonpool opening
— turret structure including support
— structure in way of loading buoy support
— gantry structure including support.

D 200 Structure in way of moonpool opening

201 The structural strength shall be evaluated considering all relevant, realistic load conditions and combinations, see Sec.4. In particular load combinations due to the following shall be accounted for in the design:

— loads from the turret bearings
— overall hull bending moments and shear forces
— internal and external pressure, covering the intended range of draughts and load conditions, including non-symmetric cases as applicable
— ovalisation of moonpool.

202 Particular attention shall be given to critical interfaces between the hull and the turret structure.

203 Continuity of primary longitudinal structural elements should be maintained as far as practicable in way of the turret opening. Reductions in hull section modulus shall be kept at a minimum and compensation shall be made where necessary.

D 300 Turret structure

301 The ULS is checked according to the requirements in DNV-OS-C101.

302 A finite element analysis of the turret structure shall be performed, see Sec.3, demonstrating that the structural strength of the turret is acceptable. The structural strength shall be evaluated considering all relevant, realistic load conditions and combinations, see Sec.4. Boundary conditions for the model shall reflect the actual configuration of the interface with the hull girder.

303 Local analyses shall be performed for structural areas, which are critical for the structural integrity of the turret. The following list contains typical areas which should be considered:

— structure in vicinity of riser connection(s)
— riser hang-off structure
— structure in way of fairleads
— hang-off structure for mooring line
— local structure transferring bearing reactions
— chain lockers
— pipe supports (single supports and complex structures)
— equipment supports
— foundation for transfer system (especially for swivel solutions)
— lifting appliances and pad-eyes including structure in way of these.

E. Topside Facilities Structural Support

E 100 General

101 The supporting structure is defined as the area where the stress pattern in the structural elements is significantly affected by the topside loads.

102 The strength of the supporting structure for the topside facilities shall be evaluated considering all relevant operational load conditions and combinations. For loads in transit conditions, see Sec.3 B103.

103 The following loads shall be considered:

— permanent loads (weight of structures, process and drilling equipment, piping etc.)
— variable loads (equipment functional loads related to liquid, machinery, piping reaction forces, helicopter, cranes etc.)
— wave loads
— wave accelerations (inertia loads)
— hull girder vertical deflections
— wind on topside facilities
— snow and ice
— green water
— longitudinal strain of upper deck due to global bending.

E 200 Partial load coefficients

201 The partial load coefficients to be used are given in Table E1.

Table E1 Partial coefficients for the Ultimate Limit States

Combination	*Load category*		
	G	Q	E
a)	1.2 [1)]	1.2 [1)]	0.7
b)	1.0	1.0	1.3 [2)]

Load categories are:

G = permanent load

Q = variable functional load

E = environmental loads

1) To be 1.3 if the loads can not be determined with a high accuracy. Tank loads and topside modules with documented weight better than 10% accuracy can use a load factor of 1.2.

2) A factor of 1.15 can be used for inertia loads caused by hull accelerations.

202 The ULS assessment shall be carried out according to the requirements in DNV-OS-C101. Both a) and b) combinations shall be considered.

F. Fore and Aft Ship

F 100 General

101 The local requirements for the structural members in the fore and aft ship including deck houses and accommodation shall comply with the technical requirements given in the Rules for Classification of Ships Pt.3 Ch.1, see also Sec.3 B100.

102 The main longitudinal structural members needed for the global continuity and hull integrity shall be assessed according to B200. For evaluation of slamming, sloshing and green water effects, see Sec.4.

SECTION 7
FATIGUE LIMIT STATES (FLS)

A. Introduction

A 100 General

101 The general requirements and guidance concerning fatigue criteria are given in DNV-OS-C101 Sec.7. The fatigue capacity shall be determined according to Classification Note 30.7 or DNV-RP–C203. Evaluation of the fatigue limit state shall include consideration of all significant loads contributing to fatigue damage.

102 The required fatigue life of new units shall be minimum 20 years. The effect of mean stresses should normally be ignored.

103 The fatigue capacity of converted units will be considered on a case-by-case basis, and is a function of the following parameters:

— results and findings form surveys and assessment of critical details
— service history of the unit and estimated remaining fatigue life.

Guidance note:

New structural steel in converted units older than 10 years, may normally be accepted with minimum 15 years documented fatigue life from the time of conversion.

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

104 The fatigue life shall be calculated considering the combined effects of global and local structural response. The expected dynamic load history shall be the basis for the calculations.

105 Local effects, due to:

— slamming
— sloshing
— vortex shedding
— dynamic pressures
— mooring and riser systems

shall be considered in the fatigue damage assessment, if relevant.

106 Calculations carried out in connection with the fatigue limit state may be based on gross thicknesses (i.e. without deducting the corrosion additions), provided a corrosion protection system in accordance with DNV-OS-C101 is maintained.

107 In the assessment of fatigue life, consideration shall be given to the stress concentration factors including those due to:

— large openings affecting the global stress distribution
— fabrication tolerances, including due regard to tolerances
— openings and penetrations
— local effects at connections or attachment of structural elements, e.g. scallops, brackets etc.

B. Design Fatigue Factors

B 100 General

101 Units covered by this standard have considerable redundancy. All elements can therefore be classified as, “without substantial consequences for total structural failure”. Offshore units covered by this standard have regular dry-docking for inspection and repair, and the term “splash” zone has no significance. It implies that all elements are accessible for inspection and repair. A design fatigue factor of 1.0 may therefore, be applied to all structural elements.

C. Structural Details and Stress Concentration Factors

C 100 General

101 Fatigue sensitive details in the hull shall be documented to have sufficient fatigue strength. Particular attention should be given to the following details:

— main deck, including deck penetrations, bottom structure and side shell
— hull longitudinal stiffener connections to transverse frames and bulkheads
— hopper tank knuckles and other relevant discontinuities
— attachments, foundations, supports etc. to main deck and bottom structure
— topside and hull connections
— hull and turret connections
— fairleads and supporting structure
— openings and penetrations in longitudinal members
— transverse frames
— submerged turret and supporting structure
— flare tower
— riser interfaces
— major process equipment foundations.

102 Calculations of stress concentration factors of local details may be undertaken in accordance with Classification Note 30.7. For details not covered by Classification Note 30.7, or documented in other recognised publications, detailed finite element analysis should be carried out for determination of SCFs, according to the procedure given in Classification Note 30.7.

103 Intersection between unit's side longitudinals and transverse bulkheads shall be fitted with double sided brackets.

Guidance note:

In order to cover typical unit structural details, the design should allow for the following stress concentration factors:

- the deck should at least be designed for $K_g K_w \geq 2.5$. Openings may require higher values of SCF
- brackets on side longitudinals have typical $K_g K_w$ of 1.8 to 2.4.

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

D. Design Loads and Calculation of Stress Ranges

D 100 Load factors

101 In the fatigue calculations, a load factor of 1.0 shall be used on all dynamic loads.

D 200 Fatigue loads

201 An overview of fatigue loads is given in Sec.4. Site specific environmental data shall be used for calculation of long term stress range distribution. Units intended for multi field developments shall base the fatigue life on the expected duration on each location employing the scatter diagram for each field. The most severe environmental loads may be applied for the complete lifetime of the unit, as a conservative approach.

202 A representative range of load conditions shall be considered. It is generally acceptable to consider the ballast and the fully loaded condition with appropriate amount of time in each condition.

Guidance note:

60% in full load and 40% in ballast for the two conditions may be used unless otherwise documented, ref. DNV-RP-C102 Structural Design of Offshore Ships.

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

203 An appropriate range of wave directions and wave energy spreading shall be considered.

Guidance note:

For weather waning units, and in lack of more detailed documentation, head sea direction may be considered with $\cos^2$ wave energy spreading.

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

The following dynamic loads shall be included in a FLS analysis as relevant:

- global wave bending moments
- external dynamic pressure due to wave and unit motion
- internal dynamic pressure due to unit motion
- sloshing pressures due to fluid motion in tanks for units with long or wide tanks
- loads from equipment and topside due to unit motion and acceleration.

D 300 Topside structures

301 The following loads shall be considered for the topside structure:

- vertical and horizontal hull deformations due to wave bending moment acting on the hull
- wave induced accelerations (inertia loads)
- vortex induced vibrations from wind
- vibrations caused by operation of topside equipment
- external dynamic pressure due to wave and unit motion.

302 Additionally, the following low cycle loads should be considered where relevant for the topside structure:

- hull deformations due to temperature differences
- hull deformations due to change in filling condition e.g. ballasting or deballasting.

D 400 Turret structure, bow recess and moonpool area

401 The following loads shall be considered for the fatigue design of turret structures:

- dynamic loads of mooring lines
- dynamic loads (tension and bending moment) from risers
- varying hydrodynamic pressure due to wave load
- varying hydrodynamic pressure due to unit accelerations, including added mass effects
- bearing reactions loads
- inertia loads due to accelerations of the unit
- fluctuating reactions in pipe supports due to thermal and pressure induced pipe deflections.

D 500 Calculation of global dynamic stress ranges

501 Global stress ranges shall be determined from the global hull bending stresses, axial stresses and torsional stresses. Torsional stresses may be relevant for structures with extremely large deck openings. If applicable, both vertical and horizontal bending moments shall be included. Shear lag effects and stress concentrations shall be considered.

D 600 Calculation of local dynamic stress ranges

601 Local stress ranges are determined from dynamic pressures acting on panels, accelerations acting on equipment and topside and other environmental loads resulting in local stresses in parts of the structure.

602 Dynamic pressures shall be calculated by means of the hydrodynamic model. The transfer function for the dynamic pressure can be used to calculate local stress transfer functions. As a minimum, the following dynamic local stress components shall be considered:

- double hull stresses due to bending of double hull sections between bulkheads
- panel stresses due to bending of stiffened plate panels
- plate bending stresses due to local plate bending
- deflection induced stresses.

603 Further details regarding calculation of local stress components is given in Classification Note 30.7.

D 700 Combination of stress components

701 Global and local stresses shall be combined to give the total stress range for the detail in question. In general, the global and the local stress components differ in amplitude and phase. The method of combining these stresses for the fatigue damage calculation will depend on the location of the structural detail. A method for combination of loads is given in Classification Note 30.7.

E. Calculation of Fatigue Damage

E 100 Environmental loads

101 Fatigue analyses shall be based on the site specific environmental data and, take appropriate consideration of both global and local (e.g. pressure fluctuation) dynamic responses.

Guidance note:

These responses do not necessarily have to be evaluated in the same model but the cumulative damage from all relevant effects should be considered when evaluating the total fatigue damage.

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

E 200 Methodology

201 The long term stress range distribution required for the fatigue analysis can either be established based on spectral methods or on a postulated form of the long-term stress range distribution defined by a maximum stress amplitude and a Weibull shape parameter.

202 Principal stresses should be used as basis for fatigue life calculations. Local plate surface stresses due to plate bending shall be used in the calculations.

203 Simplified fatigue life calculations based on a Weibull shape distribution of the long term response is acceptable for well defined structural details, i.e. with known stress concentration factors, primarily exposed to hull global bending stresses, provided ample fatigue life is documented.

204 Fatigue life calculations based on spectral methods are either employing component stochastic or full stochastic analysis, see Classification Note 30.7. A component based stochastic analysis implies that non linear effects can be applied to the relevant load component.

205 Local, detailed finite element analysis (e.g. unconventional details with insufficient knowledge about typical stress distribution) should be undertaken in order to identify local stress distributions, appropriate SCFs, and/or extrapolated stresses to be utilised in the fatigue evaluation, see Classification Note 30.7 for further details. Dynamic stress variations through the plate thickness may have to be considered in such evaluations.

206 Explicit account shall be taken for local details such as access openings, cut-outs and penetrations.

E 300 Applicable S-N-curves

301 The S-N curves, as defined in Classification Note 30.7, to be used in the fatigue calculation are given in Table E1.

302 Fatigue calculations for conversions of old tankers to production or storage units shall be based on the stresses from the actual scantlings.

Table E1 Applicable S-N curves

Elements	*S-N curve for air or cathodic protection*	*S-N curve for corrosive environment*	*S-N curve for air or cathodic protection, one slope curve*
Void spaces, external dry areas	x		x
Ballast or cargo tanks with acceptable corrosion protection system 1)	x		x
Unprotected surfaces in tanks		x 2)	
Shell plating below ballast waterline with acceptable corrosion protection system 1)	x		x

1) Corrosion protection system according to requirements in DNV-OS-C101

2) The stresses shall be based on net thicknesses

SECTION 8
ACCIDENTAL LIMIT STATES (ALS)

A. Introduction

A 100 General

101 The assessment of the structural capacity shall be based on the principles given in DNV-OS-C101. Relevant loads shall be determined based on DNV-OS-A101 unless otherwise documented in a risk analysis.

B. Dropped Objects

B 100 General

101 The possibility of dropped objects impacting on the structural components of the unit shall be considered in design. Resistance to dropped objects may be accounted for by indirect means, such as, using redundant framing configurations, or by using materials with sufficient toughness in affected areas.

102 The masses of the dropped objects from crane operation to be considered for design of the units are normally based on operational hook loads of the platform crane. Critical areas of dropped objects are to be determined based on crane operation sectors, crane reach and actual movement of slings assuming a drop direction within an angle to the vertical direction of 5 º in air and 15 º in water.

C. Fire

C 100 General

101 General guidance and requirements concerning accidental limit state events involving fire are given DNV-OS-A101.

D. Explosion

D 100 General

101 In respect to design considering loads resulting from explosions one, or a combination of the following main design philosophies are relevant:

— ensure that the probability of explosion is reduced to a level where it is not required to be considered as a relevant design load
— 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 overpressures
— locate hazardous areas in enclosed locations and install pressure relief mechanisms (e.g. blast panels) and design for the resulting overpressure.

102 Structural design accounting for large plate field rupture resulting from explosion loads should be avoided.

103 Structural support of the blast walls and the transmission of the blast load into main structural members shall be evaluated.

E. Loss of Heading Control

E 100 General

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

102 The loss of heading control condition shall be considered in the topside and turret structure design.

F. Collision and Accidental Flooding

F 100 General

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

SECTION 9
SPECIAL CONSIDERATIONS

A. Structural Details

A 100 General

101 For the design of structural details consideration should be given to the following:

- the thickness of internal structure in locations susceptible to excessive corrosion
- the design of structural details, such as those noted below, against the detrimental effects of stress concentrations and notches:
  - details of the ends and intersections of members and associated brackets
  - shape and location of air, drainage, and lightening holes
  - shape and reinforcement of slots and cut-outs for inspection
  - elimination or closing of weld scallops in way of butts, “softening” bracket toes, reducing abrupt changes of section or structural discontinuities.
- proportions and thickness of structural members to reduce fatigue damage due to engine, propeller or wave-induced cyclic stresses, particularly for higher strength steel members.

B. Bilge Keels

B 100 General

101 The requirements for design of bilge keels apply to turret moored units and to spread moored units.

Guidance note:

The bilge keel should normally be welded directly onto the shell plate without doubling plates. Adequate transverse supporting brackets, or an equivalent arrangement, are to be provided.

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

102 The loads due to ship motions shall be determined from the wave load analysis employing a viscous damping coefficient representative for seastates which contribute most to fatigue damage. The damping coefficient used in fatigue capacity assessment should be determined at 10^{-2} probability of exceedance.

103 Fatigue calculations should be carried out by means of a spectral analysis. A component stochastic analysis as described in Classification Notes 30.7 is acceptable.

104 For bilge keels of a closed type design, both ULS and FLS shall be considered. The transfer functions for stress responses from the wave dynamics and motion induced drag forces shall be determined separately. The transfer functions shall be combined in the cumulative damage calculations.

C. Structure in Way of a Fixed Mooring System

C 100 General

101 Local structure in way of fairleads, winches, etc. forming part of the position mooring system is, as a minimum, to be capable of withstanding forces equivalent to 1.25 times the breaking strength of any individual mooring line. The strength evaluation should be undertaken utilising the most unfavourable operational direction of the anchor line. In the evaluation of the most unfavourable direction, account shall be taken of relative angular motion of the unit in addition to possible line lead directions. The material factor γ_m is 1.0 in this special case.

D. Loading Instrument

D 100 General

101 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 Rules for Classification of Ships.

102 The limitations for still water bending moments and shear forces shall be in accordance with maximum allowable still water bending moments and shear forces specified in the operating manual.

E. Corrosion Protection

E 100 General

101 The corrosion protection arrangements shall be consistent with DNV-OS-C101.

F. Support of Mooring Equipment, Towing brackets etc.

F 100 General

101 Structure supporting mooring equipment such as fairleads and winches, towing brackets etc. shall be designed for the loads and acceptance criteria specified in DNV-OS-E301, Ch.2 Sec.4.

SECTION 10
WELDING AND WELD CONNECTIONS

A. Introduction

A 100 General requirements

101 The technical requirements for the welding and weld connections shall, as a minimum, comply with the Rules for Classification of Ships Pt.3 Ch.1 Sec.12.

102 The extent and means of inspection during fabrication is defined in DNV-OS-C401.

B. Size of Welds

B 100 Direct calculations

101 As an alternative to the weld size according to this section, the welds may be designed according to the principles given in DNV-OS-C101 Sec.9 C600.

B 200 Double continuous fillet welds

201 Dimensioning of double continuous fillet welds are referred to the Rules for Classification of Ships Pt.3 Ch.1 Sec.12 Table C1. This table has been extended to include typical structural members for units covered by this standard. The C factors to be used are given in Table B1.

Table B1 Weld factor C

Item	*60% of span*	*At ends*
Local buckling stiffeners	0.14	0.14
Stiffeners, frames, beams or longitudinals to shell, deck, oil tight or water tight girders or bulkhead plating, except in after peaks. Secondary stiffeners in turret.	0.16	0.26
Web plates of non-watertight girders except in after peak.	0.20	0.32
Girder webs and floors in double bottom. Stiffeners and girders in after peaks. Main girder system and decks in turret. Horizontal stringers on transverse bulkheads.	0.26	0.43
Watertight centre line girder to bottom and inner bottom plating. Boundary connection of ballast and liquid cargo bulkhead: — longitudinal bulkheads — transverse bulkheads. 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. Shell plating of turret.	0.52	
Fillet welds subject to compressive stresses only.	0.25	
All other welds not specified above.	0.43	

B 300 Fillet welds and deep penetration welds subject to high tensile stresses

301 Dimensioning of such welds are referred to Rules for Classification of Ships Pt.3 Ch.1 Sec.12 C200. Examples of welds in this category are:

— transverse bulkhead connection to the double bottom
— vertical corrugated bulkhead connection to the top of stooltank or directly to the inner bottom
— stooltanks to inner bottom and hopper tank
— structural elements in double bottom below bulkheads and stooltanks
— transverse girders in centre tanks to longitudinal bulkheads
— side shell, inner side and longitudinal bulkheads to double bottom.

B 400 Full penetration welds

401 In addition to the full penetration welds required for joint specified by the Rules for Classification of Ships Pt.3 Ch.1 Sec.12, full penetration welds shall be used for the following connections:

— crane pedestal to deck plating
— topside support stools to main deck flare to hull structure
— drillfloor support structure to main deck [1)]
— turret bearing support structure to main deck.

1) Deep penetration weld are acceptable in areas where the design load is primarily static. As a guide, if the static compression stress constitutes more than 35% of the yield stress, deep penetration welds may be used.

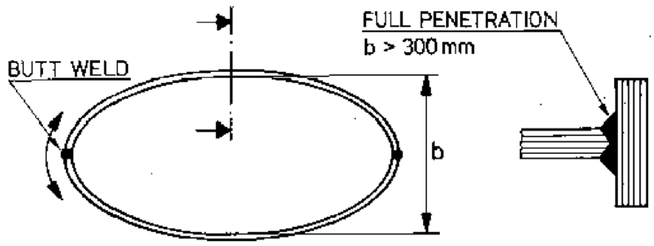

Figure 1
Deck and bottom penetrations

OFFSHORE STANDARD
DNV-OS-C102

STRUCTURAL DESIGN OF OFFSHORE SHIPS

CHAPTER 2

BENIGN WATERS

CONTENTS PAGE

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

SECTION 1 INTRODUCTION

A. General

A 100 Assumptions and applications

101 This Chapter provides requirements and guidance for offshore ships constructed in steel restricted to operate in “benign waters”.

102 Ch.2 is also applicable to conversions of old tankers to production or storage units.

A 200 Assumptions

201 In addition to the requirements given in Ch.2 of this standard Ch.1 Sec.9 and Ch.1 Sec.10 shall be complied with.

B. Definitions

B 100 Benign waters

101 Benign waters is defined as the environments where required hull girder capacity calculated according to the LRFD method is less than the minimum section modulus calculated according to the “main class requirements”.

See Ch.0 of this standard for further explanations.

SECTION 2
SELECTION OF MATERIAL AND EXTENT OF INSPECTION

A. Selection of Material

A 100 General

101 Material specifications 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.

102 For design temperatures higher than, or equal to -15°C, selection of steel grade may be based on the principles and requirements given by the main class or Ch.1 Sec.2. For temperatures lower than -15°C, the material shall be selected according to Ch.1 Sec.2.

103 In structural cross-joints where high tensile stresses are acting perpendicular to the plane of the plate, the plate material shall be tested to prove the ability to resist lamellar tearing (Z-quality).

104 Structural elements used only in temporary conditions, like fabrication, are not considered.

A 200 Material classes

201 In addition to the structural elements given in Rules for Classification of Ships Pt.3 Ch.1 Sec.2 Table B1 and Table B2 respectively, Table A1 gives requirements for materials for some other structural elements.

Table A1 Application of material classes

Structural member	*Within 0.4 L amidships*	*Outside 0.4 L amidships*
— highly stressed [1] elements in way of moonpool such as corner plates in rectangular moonpools — highly stressed [1] elements in way of support structure for turret — highly stressed [1] elements in way of main supporting structures of heavy substructures and equipment e.g. topside support structure, support of chain stoppers, support of offloading riser fairleads, anchor line fairleads, supporting structure for winches, crane pedestals, flare boom, davits, hawser brackets for shuttle tanker, towing brackets etc.	V [2]	V [2]
— non-highly-stressed group V elements given above — topside support stools — gantry structure — turret structure — pipe rack stanchions — drillfloor substructure — helicopter deck substructure — flare supporting structure.	III	III

1) Highly stressed elements are elements utilised more than 85% of the allowable structural capacity.

2) Not to be less than grade D/DH.

Guidance note:

If the stresses induced by environmental loads small, and the permanent and variable functional loads cause compression stresses, the materials can be considered as *primary* category.

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

A 300 Service temperatures

301 The *service temperature* for external structures above the lowest ballast waterline shall be set equal to the lowest mean daily temperature for the area(s) in which the unit is specified to operate.

302 The *service temperature* for external structures below the lowest ballast waterline needs normally not to be set lower than 0°C.

303 The *service temperature* for external structures below the lowest ballast waterline needs normally not to be set lower than 0°C.

304 The *service temperature* for internal structures in way of permanently heated rooms needs normally not to be set lower than 0 °C. Crude oil tanks may be considered to be permanently heated.

305 The *service temperature* for internal structures in oil storage tanks in FPSOs/FSUs needs normally not to be set lower than 0°C except for the upper strake in longitudinal bulkheads and top wing tanks.

B. Inspection Principles

B 100 General

101 The extent of non-destructive testing during fabrication shall be in accordance with the requirements for the appropriate inspection category as defined in DNV-OS-C101, Sec.4.

102 Requirements for type and extent of inspection are given in DNV-OS-C401, dependent on assigned inspection category for the welds. The requirements are based on the consideration of fatigue damage and general fabrication quality.

More detailed description of a typical extent of inspection is given in the DNV Recommended Practice DNV-RP-C102 Structural Design of Offshore Ships.

103 The inspection category for units covered by this standard shall relate to the structural category as shown in Table B1.

Table B1 Inspection categories

Inspection category	*Structural category*
I	Special
II	Primary
III [1]	Secondary

1) NDT acceptance criteria for ship side shall be taken according to Inspection category II.

104 When determining the locations of required non-destructive testing (NDT), consideration should be given to relevant fabrication parameters including; location of block (section) joints, manual versus automatic welding, start and stop of weld etc.

SECTION 3
DESIGN BASIS AND PRINCIPLES

A. Design Basis

A 100 Operational modes

101 A unit shall be designed for all relevant modes of operation. Typically, the assessment of the unit shall be based on the following operational modes:

— all operating conditions, intact and damaged, at the design location(s)
— all transit conditions
— docking condition afloat
— dry-docking condition.

A 200 Still water load conditions

201 All relevant still water loading conditions shall be considered to determine the limit curves for maximum permissible bending moments and shear forces.

A 300 Environmental loads

301 Environmental loads shall in principle be based on site specific data which is representative for the areas in which the unit is to operate. However, the ”main class requirements” to the midship section modulus are by definition more stringent than the design principles based on the LRFD method applied to “benign waters”. Provided the “main class requirements” to minimum midship section modulus and moment of inertia are complied with, the wave bending moments and shear forces may be based on the “main class requirements”. No direct calculations of wave bending moments and shear forces are required in such cases.

302 When the hull is designed according to the LRFD method (see B below), the wave loads shall be derived from direct calculations based on the dimensioning scatter diagram for the areas in which the unit is to operate. Individual environmental loads shall be based on an annual probability of exceedance equal to 10^{-2} (100 years return period) for hull girder structural response calculations.

303 The environmental loads for assessment of fatigue life may be based on the actual scatter diagrams for the areas in which the unit is to operate. Alternatively the worst scatter diagram can be used as basis for calculation of fatigue life.

A 400 Prolonged survey periods

401 Units intended to stay on location for a prolonged survey period, i.e. without dry-docking, shall also comply with the requirements in Appendix A.

B. Strength Assessment Principles

B 100 Alternative design procedure

101 Structural design of offshore units in “benign waters” accept two alternative design principles:

Alternative 1 - Ship Rules

The hull scantlings are based on the “main class requirements”. No direct calculations of wave bending moments and shear forces are required.

Alternative 2 - LRFD method

The hull is designed according to the principles given in Ch.1. The midship section modulus may be less than the ”main class requirements”.

102 For the operational load conditions, the accelerations for topside design and interface to hull may be based on direct calculations for the two alternative design principles. Optionally the accelerations may be based on the ship rules Pt.3 Ch.1 or Ch.2. In both cases the structural capacity of topside and hull supporting structure shall be based on the LRFD principles as given in Ch.1

103 Non-operating conditions like transit conditions, docking condition afloat and dry-docking condition are considered to be covered by the “main class requirements”.

104 In the transit condition, the design values of global accelerations for assessment of topside facilities and supporting structure may alternatively be derived from wave load analysis provided the structural capacity is assessment is in accordance with Ch.1 Sec.6. The wave load analysis shall in such cases be based on an annual probability of exceedance of $10^{-1.3}$ (20 year return period).

105 For units which are intended to operate on a specific location for the main part of the design life, wave loads in transit can be based on the actual transit route and season at an annual probability of exceedance of $10^{-1.0}$ (10 year return period) provided the structural capacity is assessment is in accordance with Ch.1 Sec.6, or on the rules from a recognised Marine Warranty.

106 When design Alternative 2, LRFD method, is applied, the minimum midship section modulus according to the ”main class requirements” may be reduced by maximum 25%.

107 The two different alternative design principles are further describes in Table B1 and Table B2.

Table B1 Hull design principles

Design basis	*Hull design*			
	Operating		*Transit*	
	Alt. 1	*Alt. 2*	*Alt. 1*	*Alt. 2*
Z_{20}	x		x	x
I_{20}	x		x	x
Z_{100}		x		
I_{100}		x		
a_{20}	x		x	x
a_{100}		x		
M_{w20}	x		x	x
M_{w100}		x		
Q_{w20}	x		x	x
Q_{w100}		x		

Z_{20} = minimum section modulus according to *main class requirements*
I_{20} = minimum moment of inertia according to *main class requirements*
Z_{100} = resulting section modulus according to Ch.1
I_{100} = resulting moment of inertia according to Ch.1
a_{20} = accelerations according to *main class requirements*
a_{100} = accelerations according to Ch.1 (direct calculations)
M_{w20} = wave bending moment according to *main class requirements*
M_{w100} = wave bending moment according to Ch.1 (direct calculations)
Q_{w20} = wave shear force according to *main class requirements*
Q_{w100} = wave shear force according to Ch.1 (direct calculations)

Table B2 Topside and topside support design principles		
Design basis	*Topside and topside support structure*	
	Operating	*Transit*
a_{20}		x 2) 3)
a_{100}	x 1)	
Ch.1 Sec.6	x	x

1) Accelerations a20 from the ship rules Pt.3 Ch.1 or Ch.2. may optionally be used.

2) Optionally the accelerations may be derived by a wave load analysis with an annual probability of exceedance of $10^{-1.3}$ (20 year return period).

3) For units which are intended to operate on a specific location for the main part of the design life, accelerations may optionally be derived from a wave loads for the actual transit route and season at an annual probability of exceedance of $10^{-1.0}$ (10 year return period or on the Rules from a recognised Marine Warranty.

108 Local requirements for plates and profiles shall be according to “main class requirements”.

B 200 Longitudinal strength

201 The effect of large openings in the hull (e.g. moonpool) which affect the distribution of global stresses, shall be considered accounting for three dimensional effects.

202 For the intact and damage operating conditions, the hull girder capacity is considered adequate if the main class requirements are complied with.

B 300 Transverse strength

301 The capacity of the main transverse stiffening system such as transverse bulkheads and transverse web frames shall comply with the main class requirements.

B 400 Local strength assessment

401 Local strength assessment shall be carried out in accordance with the principles given in Ch. 1 Sec.3.

Examples of typical local structural capacity assessment are:

— supporting structure for topside structure
— supporting structure for thrusters
— turret
— crane pedestals
— bilge keels (on turret-moored and spread moored units)
— bow recess area for submerged type of turrets.

402 Supporting structure for thrusters are normally considered for a specified thrust using the acceptance criteria given in Rules for Classification of Ships Pt.3 Ch.1.

403 Structural capacity of the turret shall be based on the specific loads from the mooring system in the operational mode. Both global and local response of the turret shall be considered. Hull deformations shall be considered. In addition, the local structure shall be considered for the special load cases as defined in Sec.4.

C. Fatigue Assessment

C 100 General

101 The fatigue capacity shall be assessed according to the principles given in Ch.1 Sec.3 C.

102 Fatigue calculations for units converted from old tankers shall account for the load history of the unit and findings from the inspections. The S-N curves (for air or corrosive environments) used should consider the condition of the unit with respect to corrosion, original corrosion protection system and the corrosion protection system after the conversion. See Classification Note 30.7 for additional guidelines.

SECTION 4
DESIGN LOADS

A. Introduction

A 100 General

101 The loads shall in general be determined according to the principles in Ch.1 Sec.3.

102 Design load criteria given by operational requirements as described in Ch.1 Sec.4 shall be fully considered.

B. Still Water Loads

B 100 General

101 All relevant still water load conditions shall be defined and limit curves for hull girder bending moment and shear forces shall be established.

102 The shape of the limit curves for the still water bending moments and shear forces are defined in Rules for Classification of Ships Pt.3 Ch.1. If the extreme still water bending moment and/or shear exceed the main class minimum values, the limit curve should be based on all relevant load combinations.

103 Limit curves for the still water loading conditions shall be presented for operational and transit mode separately.

C. Environmental Loads

C 100 General

101 Definitions, general considerations and required methodology for determination of environmental loads are given in Ch.1 Sec.4.

C 200 Wave induced loads

201 If the structural assessment is based on direct calculated wave loads, bending moments, shear forces and accelerations, the wave loads shall be determined according to Ch.1 Sec.4.

C 300 Mooring loads

301 Mooring loads are to be determined according to Ch.1 Sec.4.

C 400 Sloshing loads in tanks

401 Sloshing in partly filled tanks is to be considered according to Ch.1 Sec.4 E400.

C 500 Green water

501 The effect of green water on weather deck and on deckhouses shall be considered according to Ch.1 Sec.4 E504.

D. Accidental Loads

D 100 General

101 Accidental loads shall be considered according to Ch.1 Sec.4 F.

E. Fatigue Loads

E 100 General

101 Fatigue loads shall be considered as in Ch.1 Sec.4.

SECTION 5
STRUCTURAL ANALYSES FOR CAPACITY CHECKS

A. Introduction

A 100 General requirements

101 The structural response shall be determined by recognised analytical methods. Computer programs used shall have documented test results.

102 The required types of analyses will depend on the structural design, but in general the following is required:

— finite element analysis for global hull girder strength assessment
— finite element analyses for strength assessment of local areas where the structural response cannot be adequately determined by the global analysis
— finite element analyses to determine stress concentration factors.

B. Longitudinal Stresses

B 100 General

101 Global longitudinal nominal stresses should normally be calculated by a finite element analysis. Typical extent of the model is three cargo tanks.

102 For units with moonpool or turret, a finite element analysis shall be carried out to describe the stress distribution in way of the openings, in particular in deck and bottom, and at termination of longitudinal strength elements.

C. Transverse Stresses

C 100 General

101 Transverse stresses shall normally be determined based on a 3-D finite element analysis. The transverse stresses are normally based on the three cargo tank model.

C 200 Global shear stresses

201 Global shear stresses shall be calculated considering the vertical shear force at the transverse section in question as well as the actual shear flow distribution in the section. The shear force shall be corrected according to Rules for Classification of Ships Pt.3 Ch.1 Sec.5 D.

SECTION 6
STRUCTURAL CAPACITY

A. General

A 100 General

101 The capacity of the hull girder can be assessed by alternative methods as given in Ch.1 Sec.3. The selected design principles shall be consistent.

102 The turret and turret or moonpool area, topside facilities' structural support and the fore and aft ship shall be assessed according to Ch.1 Sec.6.

B. Longitudinal Strength

B 100 Alternative 1 - Complying with the main class requirements

101 If the hull girder capacity is to be based on the main class requirements, the midship section modulus and moment of inertia shall comply with 102.

102 The midship section modulus about the transverse neutral axis is not to be less than:

$$Z_0 = \frac{C_{W0}}{f_1} L^2 (C_B + 0.7) \quad (\mathrm{cm}^3)$$

The material factor f_1 shall be determined according to Rules for Classification of Ships Pt.3 Ch.1 Sec.2 B200.

The midship section moment of inertia about the transverse neutral axis is not to be less than:

$$I = 3C_{W0} L^3 B (C_B + 0.7) \quad (\mathrm{cm}^4)$$

C_{W0} = $10.75 - [(300 - L)/100]^{3/2}$ for $L < 300$
= 10.75 for $300 \leq L \leq 350$
= $10.75 - [(L - 350)/150]^{3/2}$ for $L > 350$

C_B = block coefficient, but not less than 0.6

103 The requirements given in 102 are normally satisfied when calculated for the midship section only, provided the following rules for tapering are complied with:

a) Scantlings of all continuous longitudinal strength members are to be maintained within 0.4 L amidships. In special cases, based on consideration of type of unit, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4 L amidship part, bearing in mind the desire not to inhibit the unit's loading flexibility.

b) Scantlings outside 0.4 L amidships are gradually reduced to the local requirements at the ends, and the same material strength group is applied over the full length of the unit.

104 The hull scantlings are to be based on wave loads and accelerations according to the main class requirements.

B 200 Alternative 2 - Hull girder capacity based on direct calculations of wave loads

201 If the hull girder capacity is to be based on calculated wave loads according to the principles given in Ch.1 Sec.3, the midship section modulus and moment of inertia given in 102 can be reduced by maximum 25% provided the hull capacity comply with all of the requirements given in Ch.1 Sec.6 B.

C. Transverse Structural Strength

C 100 General

101 Transverse strength means the strength of main transverse members such as transverse bulkheads and web frames. The transverse strength should be evaluated using a finite element model. The load effects of process equipment and deck loads shall be included. The transverse strength shall comply with the requirements in Rules for Classification of Ships Pt.3 Ch.1.

APPENDIX A
PERMANENTLY INSTALLED UNITS

A. Introduction

A 100 General

101 The requirements and guidance given in this Appendix are supplementary requirements for units that are intended to stay on location for prolonged periods.

102 The requirements apply in principle to all types of offshore ships.|

B. Inspection and Maintenance

B 100 Facilities for inspection on location

101 Inspections may be carried out on location based on approved procedures outlined in a maintenance system and inspection arrangement, without interrupting the function of the unit. The following matters should be taken into consideration to be able to carry out condition monitoring on location:

- arrangement for underwater inspection of hull, propellers, thrusters, rudder and openings affecting the units seaworthiness
- means of blanking of all openings including side thrusters
- use of corrosion resistant materials for shafts, and glands for propeller and rudder
- accessibility of all tanks and spaces for inspection
- corrosion protection of hull
- maintenance and inspection of thrusters
- ability to gas free and ventilate tanks
- provisions to ensure that all tank inlets are secured during inspection
- measurement of wear in the propulsion shaft and rudder bearings
- testing facilities of all important machinery.

C. Corrosion Protection

C 100 Maintenance program

101 A maintenance program shall be made taking into consideration that no dry-docking is planned for the unit.

D. Fatigue

D 100 Design fatigue factors

101 Design fatigue factors (DFF) are introduced as fatigue safety factors. DFF shall be applied to structural elements according to the principles given in DNV-OS-C101.

102 The DFF applied to the structural detail depend on the accessibility for inspection and repair.

103 The units can normally be ballasted to different draughts, and the term “splash” zone has thus no significance. Sufficient margin in respect to the lowest inspection waterline should however be considered depending on the expected wave heights during the inspection periods.

Guidance note:
Normally 1-2 m is considered sufficient margin on the lowest inspection waterline in world wide operation.

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

The DFF applied to offshore ships will therefore be dependent on the accessibility for inspection and repair and the position of the lowest inspection waterline.

104 Examples of DFF assigned to different structural elements according to the principles given above are given in DNV-OS-C101.

105 Substantial consequences other than pure strength considerations may require higher design fatigue factors. Such factors should be given in the design brief.

106 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 affect 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.