OFFSHORE STANDARD
DNV-OS-C106

STRUCTURAL DESIGN OF DEEP DRAUGHT FLOATING UNITS (LRFD METHOD)

JANUARY 2001

Since issued in print (January 2001), this booklet has been amended, latest in April 2007.
See the reference to "Amendments and Corrections" on the next page.

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.

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H) Marine Operations

J) Wind Turbines

Amendments and Corrections

This document is valid until superseded by a new revision. Minor amendments and corrections will be published in a separate document normally updated twice per year (April and October).

For a complete listing of the changes, see the “Amendments and Corrections” document located at:
http://webshop.dnv.com/global/, under category “Offshore Codes”.

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

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CONTENTS

Sec. 1 Introduction 5

A. General 5
A 100 Introduction 5
A 200 Objectives 5
A 300 Scope and application 5
A 400 Classification 5

B. Normative References 5
B 100 General 5
B 200 Offshore service specifications and rules 5
B 300 Offshore Standards 5

C. Informative References 5
C 100 General 5

D. Definitions 6
D 100 Verbal forms 6
D 200 Terms 6
D 300 Abbreviations 6
D 400 Symbols 6

E. Non-Operational Phases 7
E 100 General 7
E 200 Fabrication 7
E 300 Mating 7
E 400 Sea transportation 7
E 500 Installation 7
E 600 Decommissioning 7

Sec. 2 Structural Categorisation, Selection of Material and Extent of Inspection 8

A. Introduction 8
A 100 General 8

B. Structural Categorisation 8
B 100 General 8

C. Material Selection 8
C 100 General 8
C 200 Design temperatures 8

D. Inspection Categories 9
D 100 General 9

E. Guidance to Minimum Requirements 9
E 100 General 9

Sec. 3 Design Loads 10

A. General 10
A 100 Objective 10
A 200 Application 10

B. Permanent Loads 10
B 100 Permanent ballast 10

C. Variable Functional Loads 10
C 100 Hydrostatic pressures 10
C 200 Differential pressures 10

D. Environmental Loads 10
D 100 Environmental conditions 10
D 200 Determination of characteristic loads 10
D 300 Hydrodynamic loads 10
D 400 Combination of environmental loads 10

Sec. 4 Load Effects 11

A. General 11
A 100 Objective 11
A 200 Application 11

B. Load Effect Analysis in the Operational Phase 11
B 100 General 11
B 200 Global bending effects 11

C. Load Effect Analysis in the Non-Operational Phases 11
C 100 General 11
C 200 Transportation 11
C 300 Launching 11
C 400 Upending 11
C 500 Deck mating 12

Sec. 5 Ultimate Limit States (ULS) 13

A. General 13
A 100 Objective 13

B. Hull 13
B 100 Operational phase 13
B 200 Non-operational phases 13

C. Deck or Topside 13
C 100 Operation phase 13
C 200 Non-operational phases 13

D. Scantlings and Weld Connections 13
D 100 General 13

Sec. 6 Fatigue Limit States (FLS) 14

A. General 14
A 100 General 14

B. Hull 14
B 100 Operation phase 14
B 200 Non-operational phases 14
B 300 Splash zone 14

C. Deck or Topside 15
C 100 Operation phase 15
C 200 Non-operational phases 15

Sec. 7 Accidental Limit States (ALS) 16

A. General 16
A 100 Objective 16

B. General Requirements 16
B 100 General 16

C. Fire 16
C 100 General 16

D. Explosion 16
D 100 General 16

E. Collision 16
E 100 General 16

F. Dropped Objects 16
F 100 General 16

G. Unintended Flooding 16
G 100 General 16

H. Abnormal Wave Events 17
H 100 General 17

SECTION 1
INTRODUCTION

A. General

A 100 Introduction

101 This document provides requirements for the structural design of DDF units, fabricated in steel, in accordance with the provisions of DNV-OS-C101.

102 A Deep Draught Floater (DDF) is categorised with a relative large draught. This large draught is mainly introduced to obtain sufficiently high eigenperiod in heave and reduced wave excitation in heave such that resonant responses in heave can be omitted or minimised.

103 A DDF can have multi vertical columns, single column without, or with (e.g. classic and truss spar) moonpool.

104 The unit is usually kept in position by a passive mooring system. The mooring system may also be activated in case of horizontal movements above wells (drilling riser placed vertically above well).

105 The deck or topside solution may be modular, or integrated type.

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

A 200 Objectives

The objectives of the standard are to:

— provide an internationally acceptable standard for structural design of DDFs
— serve as a conctractual reference document for suppliers, yards and owners
— serve as guidance for designers, suppliers, owners and regulators
— specify procedures and requirements for units and installations subject to DNV verification and classification services.

A 300 Scope and application

301 The DDF unit may be applied for drilling, production, export and storage.

302 A DDF unit may be designed to function in different modes, typically operational (inclusive horizontal movement above wells) and survival. Limiting design criteria when going from one mode of operation to another shall be established.

303 The DDF unit should also be designed for transit relocation, if relevant.

304 For novel designs or unproved applications of designs where limited, or no direct experience exists, relevant analyses and model testing shall be performed which clearly demonstrate that an acceptable level of safety can be obtained, i.e. safety level is not inferior to that obtained when applying this standard to traditional designs.

305 Requirements concerning mooring are given in DNV-OS-E301 and riser systems are given in DNV-OS-F201.

306 Requirements related to floating stability are given in DNV-OS-C301.

A 400 Classification

401 For use of this standard as technical basis for offshore classification as well as descriptions of principles, procedures and applicable class notations related to classification services see, DNV Offshore Service Specification given in Table B1.

402 Documentation for classification shall be in accordance with the NPS DocReq (DNV Nauticus Production System for documentation requirements) and Guideline No.17.

B. Normative References

B 100 General

101 The standards given in Table B1 and Table B2 include provisions, which through reference in this text constitute provisions for this standard.

B 200 Offshore service specifications and rules

201 The offshore service specifications and rules given in Table B1 are referred to in this standard.

Table B1 DNV Offshore Service Specifications and rules

Reference	*Title*
DNV-OSS-101	Rules for Classification of Offshore Drilling and Support Units
DNV-OSS-102	Rules for Classification of Floating Production, Storage and Loading Units
	Rules for Planning and Execution of Marine Operations

B 300 Offshore Standards

301 The offshore standards given in Table B2 are referred to in this standard.

Table B2 DNV Offshore Standards

Reference	*Title*
DNV-OS-A101	Safety Principles and Arrangement
DNV-OS-B101	Metallic Materials
DNV-OS-C101	Design of Offshore Steel Structures, General (LRFD method)
DNV-OS-C103	Structural Design of Column Stabilised Units (LRFD method)
DNV-OS-C301	Stability and Watertight Integrity
DNV-OS-C401	Fabrication and Testing of Offshore Structures
DNV-OS-E301	Position Mooring
DNV-OS-E401	Helicopter Decks
DNV-OS-F201	Dynamic Risers

C. Informative References

C 100 General

101 The documents listed in Table C1 include acceptable methods for fulfilling the requirements in the standard and may be used as a source of supplementary information.

Table C1 DNV Recommended Practices, Classification Notes and other references	
Reference	*Title*
DNV-RP-C202	Buckling Strength of Shells
DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
DNV Classification Note 30.1	Buckling Strength Analysis
DNV Classification Note 30.5	Environmental Conditions and Environmental Loads
DNV Classification Note 30.6	Structural Reliability Analysis of Marine Structures
SNAME 5-5A	Site Specific Assessment of Mobile Jack-Up Units
API RP 2T	Planning, Designing and Constructing Tension Leg Platforms
N-004	NORSOK - Design of Steel Structures

D. Definitions

D 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.

104 *Can:* Can-requirements are conditional and indicate a possibility to the user of the standard.

D 200 Terms

201 *Classic spar:* Shell type hull structure.

202 *Collision ring:* Inner bulkhead in the splash zone area with the purpose of providing a second barrier in case of damage or rupture to outer hull skin.

203 *Damping plates*: Horizontal decks or plates introduced in the truss area of e.g. a truss spar with the purpose of creating additional heave damping and increased added mass in heave.

204 *Dynamic upending:* A process where seawater is filled or flooded into the bottom section of a horizontally floating DDF hull and creating a trim condition and subsequent water filling of hull or moonpool and dynamic upending to bring the hull in vertical position.

205 H*ard tank area:* Usually upper part of the hull providing sufficient buoyancy for a DDF unit.

206 *Launching:* Similar to a traditional launching of for example a jacket. May be applicable for example for a truss spar.

207 *Low frequency (LF) responses:* Defined as DDF rigid body motions at, or near system eigenperiods.

208 *Pre-upending:* The phase prior to dynamic upending.

209 *P-delta effect:* Global bending or shear effects in DDF units due to relatively high roll or pitch angles in harsh environment.

210 *Riser frame:* Framed steel structures installed at different vertical elevations along the hull or moonpool in order to separate the different risers.

211 *Roll, pitch, yaw:* Rotational modes around surge, sway and heave axis, respectively.

212 *Skirt area:* Stiffened single shell area below hard tank for a classic spar.

213 *Soft tank area:* Bottom section of a spar concept. Flooded during upending and used as storage of potential fixed ballast.

214 *Strake:* Usually helical devices (strake) welded to outer hull with the purpose of reducing the cross-flow motion (VIV induced) of DDF hull due to current (mainly). Also the term *suppression device* may be used to describe the strake.

215 *Surge, sway, heave:* Translatory displacements of DDF in horizontal planes (surge, sway) and vertical plane (heave).

216 *Truss spar:* Truss structure for the hull part below hard tank area.

217 *Vortex induced vibrations (VIV):* The in-line and transverse (cross) oscillation of the hull, riser, or other structure in a current, induced by the periodic shedding of vortices.

218 *Wave frequency (WF) responses:* DDF linear rigid body motions at the dominating wave periods.

D 300 Abbreviations

301 The abbreviations given in Table D1 are used in this standard.

Table D1 Abbreviations	
Abbreviation	*In full*
ALS	Accidental limit states
DDF	Deep draught floater
DFF	Design fatigue factors
DNV	Det Norske Veritas
FLS	Fatigue limit states
HF	High frequency
OS	Offshore standard
OSS	Offshore service specification
LF	Low frequency
LRFD	Load and resistance factor design
NDT	Non-destructive testing
QTF	Quadratic transfer function
RAO	Response amplitude operator
ROV	Remote operated vehicle
ULS	Ultimate limit states
VIV	Vortex induced vibrations
WF	Wave frequency

D 400 Symbols

401 The following Latin symbols are used:

x_D	load effect
D	number of years
$F_X(x)$	long-term peak distribution
H_s	significant wave height
N_D	total number of load effect maxima during D years
T_p	wave period

402 The following Greek symbols are used:

$\gamma_{f,D}$	load factor for deformation loads
$\gamma_{f,E}$	load factor for environmental loads
$\gamma_{f,G,Q}$	load factor for permanent and functional loads
γ_m	material factor

E. Non-Operational Phases

E 100 General

101 In general the unit shall be designed to resist relevant loads associated with conditions that may occur during all phases of the life-cycle of the unit. Such phases may include:

- fabrication
- load-out, load-on
- sea transportation (wet or dry)
- assembly of hull main sections
- installation (dynamic upending, launching, deck mating, jacking)
- relocation (drilling mode, new site)
- decommissioning.

102 Structural design covering marine operations and construction sequences shall be undertaken in accordance with DNV-OS-C101.

103 Marine operations may be undertaken in accordance with the requirements stated in Rules for Planning and Execution of Marine Operations.

104 All marine operations shall, as far as practicable, be based upon well proven principles, techniques, systems and equipment and shall be undertaken by qualified, competent personnel possessing relevant experience.

105 Structural responses resulting from one temporary phase condition (e.g. construction or assembly, or transportation) that may influence design criteria in another phase shall be clearly documented and considered in all relevant design workings.

E 200 Fabrication

201 The planning of fabrication sequences and the methods of fabrication shall be performed. Loads occurring in fabrication phases shall be assessed and, when necessary, the structure and the structural support arrangement shall be evaluated for structural adequacy.

202 Major lifting operations shall be evaluated to ensure that deformations are within acceptable levels, and that relevant strength criteria are satisfied.

E 300 Mating

301 All relevant load effects incurred during mating operations shall be considered in the design process. Particular attention should be given to hydrostatic loads imposed during mating sequences.

E 400 Sea transportation

401 A detailed transportation assessment shall be undertaken which includes determination of the limiting environmental criteria, evaluation of intact and damage stability characteristics, motion response of the global system and the resulting, induced load effects. The occurrence of slamming loads on the structure and the effects of fatigue during transport phases shall be evaluated when relevant.

402 Satisfactory compartmentation and stability during all floating operations shall be ensured.

403 All aspects of the transportation, including planning and procedures, preparations, seafastenings and marine operations should comply with the requirements of the warranty authority.

E 500 Installation

501 Installation procedures of foundations (e.g. piles, suction anchor or gravity based structures) shall consider relevant static and dynamic loads, including consideration of the maximum environmental conditions expected for the operations.

502 For novel installation activities, relevant model testing should be considered.

503 The loads induced by the marine spread mooring involved in the operations, and the forces exerted on the structures utilised in positioning the unit, such as fairleads and padeyes, shall be considered for local strength checks.

E 600 Decommissioning

601 Abandonment of the unit shall be planned for in the design stage.

SECTION 2 STRUCTURAL CATEGORISATION, SELECTION OF MATERIAL AND EXTENT OF INSPECTION

A. Introduction

A 100 General

101 Selection of materials and inspection principles shall be based on a systematic categorisation of the structure according to the structural significance and the complexity of the joints or connections as given in DNV-OS-C101 Sec.4.

102 In addition to in-service operational phases, consideration shall be given to structural members and details utilised for temporary conditions, e.g. fabrication, lifting arrangements, towing and installation arrangements, etc.

103 The structural application categories are determined based on the structural significance, consequences of failure and the complexity of the joints. The structural application category set the selection of steel quality and the extent of inspection for the welds.

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

105 Special consideration shall be given to ensure the appropriate inspection category for welds with high utilisation in fatigue if the coverage with standard local area allocation is insufficient.

106 Examples of typical structural categories applicable to DDF are stated in B. These examples provide minimum requirements and are not intended to restrict the designer in applying more stringent requirements should such requirements be desirable.

B. Structural Categorisation

B 100 General

101 Application categories for structural components are defined in DNV-OS-C101 Sec.4. Structural members of a DDF unit are grouped as follows:

Special category

a) Portions of deck plating, heavy flanges, and bulkheads within the structure which receive major concentrated loads.

b) External shell structure in way of highly stressed connections to the deck structure.

c) Major intersections of bracing members.

d) External brackets, portions of bulkheads, and frames which are designed to receive concentrated loads at intersections of major structural members.

e) Highly stressed elements of anchor line fairleads, crane pedestals, flare boom, etc. and their supporting structure.

Primary category

a) Deck plating, heavy flanges, transverse frames, stringers, and bulkhead structure that do not receive major concentrated loads.

b) Moonpool shell.

c) External shell and diagonal and horizontal braces.

d) Bulkheads, decks, stiffeners and girders that provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered special application.

e) Main support structure of heavy substructures and equipment, e.g. anchor line fairleads, cranes, drill floor substructure, lifeboat platform, thruster well and helicopter deck.

Secondary category

a) Upper platform decks, or decks of upper hulls except areas where the structure is considered primary or special application.

b) Bulkheads, stiffeners, flats or decks and girders, diagonal and horizontal bracing, which are not considered as primary or special application.

c) Non-watertight bulkheads internal outfitting structure in general, and other non-load bearing components.

d) Certain large diameter vertical columns with low length to diameter ratios, except at intersections.

C. Material Selection

C 100 General

101 Material specifications shall be established for all structural materials utilised in a DDF unit. Such materials shall be suitable for their intended purpose and have adequate properties in all relevant design conditions. Material selection shall be undertaken in accordance with the principles given in DNV-OS-C101.

102 When considering criteria appropriate to material grade selection, adequate consideration shall be given to all relevant phases in the life cycle of the unit. In this connection there may be conditions and criteria, other than those from the in-service, operational phase, that provide the design requirements in respect to the selection of material. (Such criteria may, for example, be design temperature and/or stress levels during marine operations.)

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

104 Material designations are defined in DNV-OS-C101.

C 200 Design temperatures

201 External structures above the inspection waterline are to be designed for service temperatures down to the lowest mean daily temperature for the area(s) where the unit is to operate.

202 External structures below the inspection waterline need normally not be designed for service temperatures lower than 0 °C.

203 Internal structures are assumed to have the same service temperature as the adjacent external structure if not otherwise documented.

204 Internal structures in way of permanently heated rooms need normally not be designed for service temperatures lower than 0°C

D. Inspection Categories

D 100 General

101 Welding, and the extent of non-destructive examination during fabrication, shall be in accordance with the requirements stipulated for the structural categorisation designation as defined in DNV-OS-C101, Sec. 4.

102 Inspection categories determined in accordance with DNV-OS-C101 provide requirements for the minimum extent of required inspection. When considering the economic consequence that repair during in-service operation may entail, for example, in way of complex connections with limited or difficult access, it may be considered prudent engineering practice to require more demanding requirements for inspection than the required minimum.

103 When determining the extent of inspection and the locations of required NDT, in additional to evaluating design parameters (for example fatigue utilisation), consideration should be given to relevant fabrication parameters including:

location of block (section) joints

— location of block (section) joints
— manual versus automatic welding
— start and stop of weld etc.

E. Guidance to Minimum Requirements

E 100 General

101 Fig.1 illustrates minimum requirements for selection of the structural category for one example of structural configurations of a DDF unit. The indicated structural categorisation should be regarded as guidance of how to apply the recommendations in DNV-OS-C101.

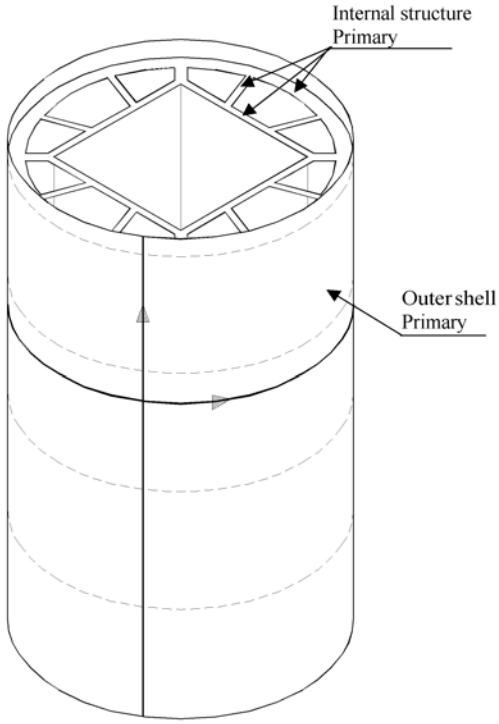

Figure 1
Example of structural categorisation in the hard tank area

SECTION 3
DESIGN LOADS

A. General

A 100 Objective

101 The objective of this section is to provide additional load provisions to DDF units not covered within DNV-OS-C101.

A 200 Application

201 Load descriptions are intended to cover operational as well as non-operational phases for the three limit states (ULS, FLS and ALS).

B. Permanent Loads

B 100 Permanent ballast

101 The type and use of permanent ballast (e.g. within soft tank of DDF units) for stability reasons must be carefully evaluated with respect to long term effects related to corrosion, wash out etc.

C. Variable Functional Loads

C 100 Hydrostatic pressures

101 All relevant combinations of filling of hard tanks for the operation phase shall be taken into account in design.

102 Hydrostatic or hydrodynamic differential pressures acting on the hull or buoyancy tanks during launch and upending sequences shall be analysed or determined and taken into account in design of the hull.

C 200 Differential pressures

201 All relevant combinations of differential pressures due to filling of ballast tanks, produced fluids, compressed air etc. shall be taken into account in design.

D. Environmental Loads

D 100 Environmental conditions

101 If sufficient environmental data is available, environmental joint probability models may be developed and applied in the design of DDF units. This is especially important in areas with e.g. high loop current and frequently occurring hurricanes.

102 Due to the geometry (deep draught and large volume) of DDF units the current loading may be of high importance for design of mooring or riser systems and in relation to vortex induced vibrations (VIV) for e.g. hull and risers. Hence attention must be put on the description of magnitude and direction of current with depth.

D 200 Determination of characteristic loads

201 Calculation of characteristic hydrodynamic loads may be carried out according to Classification Note 30.5.

202 Hydrodynamic model tests should be carried out to:

— confirm that no important hydrodynamic feature has been overlooked (for new type of units, environmental conditions, adjacent structures, Mathieu instability etc.)
— support theoretical calculations when available analytical methods are susceptible to large uncertainties (e.g. in evaluating the need of VIV suppression devices, typically the strakes on DDF hull)
— verify theoretical methods or models on a general basis.

203 Wind tunnel tests should be performed when:

— wind loads are significant for overall stability, motions or structural response
— there is a danger of dynamic instability.

204 Models applied in model tests shall be sufficient (reasonable scale and controllable scaling effects) to represent the actual unit. The test set-up and registration system shall provide a sound basis for reliable, repeatable interpretations.

205 A correlation report (tests and calculations) shall be prepared for validation purposes (design documentation).

D 300 Hydrodynamic loads

301 Resonant excitation (e.g. internal moonpool resonance, sloshing and roll/pitch resonance) shall be carefully evaluated. Wave on deck via moonpool has to be considered for DDF concepts with relatively short distances between moonpool and the outer wave active zone.

302 If hydrodynamic analyses of a DDF are performed with the moonpool 'sealed' at the keel level it must be validated that the results are equivalent to 'open' DDF hydrodynamic analyses. Special focus should be placed on the heave motion prediction (important for riser system) by using consistent added mass, total damping and excitation forces such that the eigenperiod and response in heave can be determined correctly.

303 In case of a DDF with damping and added mass plates and where it is possible that resonant, or near resonant heave motion may occur, the theoretical predictions should be validated against model test results.

304 If VIV suppression devices (e.g. spiral strakes) are attached to the hull, the increased loads (drag, inertia) must be taken into account. This applies to the operational as well as non-operational phases.

305 Simulation of loads and responses on risers in the moonpool area shall be carried out according to a recognised code.

Guidance note:
DNV-OS-F201 may be applied for this purpose.

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

D 400 Combination of environmental loads

401 In areas with high current (e.g. loop current, or high subsurface current) special attention must be given to the joint occurrence of wind, waves and current. Joint probability models (loads and load effects) are recommended.

402 If not more accurate data are available, the combination of environmental loads may be taken according to DNV-OS-C101 Sec.3.

SECTION 4
LOAD EFFECTS

A. General

A 100 Objective

101 The objective of this Section is to provide additional load effect provisions to DDF units not covered within DNV-OS-C101.

A 200 Application

201 Load effect descriptions are intended to cover operational as well as non-operational phases for the three limit states (ULS, FLS and ALS).

B. Load Effect Analysis in the Operational Phase

B 100 General

101 Global, dynamic motion response analysis taking into account loads from wind (static and gust), waves (wave frequency and low frequency) and current shall be performed. Time domain analysis is the preferred option.

102 Coupled analyses may be performed for DDF units in order to determine the coupling effects due to the presence of mooring and risers. These coupled analyses will mainly provide viscous damping estimates for slowly varying motions (all six degrees of freedom). When utilising viscous damping estimates from coupled analyses the actual riser installation program must be taken into consideration.

103 Depending on actual water depth, dimensions or geometry and mooring system, DDF units will typically experience the following eigenmodes or eigenperiods:

— surge/sway; 120 to 300 s
— heave; 20 to 35 s
— roll/pitch; 50 to 90 s.

The simulation length for determination of the different load effects must be sufficient such that reliable extreme response statistics can be obtained.

Guidance note:

Combined loading.

Common practice to determine extreme responses has been to expose the dynamic system to multiple stationary design environmental conditions. Each design condition is then described in terms of a limited number of environmental parameters (e.g. Hs, Tp) and a given seastate duration (3 to 6 hours). Different combinations of wind, wave and current with nearly the same return period for the combined environmental condition are typically applied.

The main problem related to design criteria based on environmental statistics is that the return period for the characteristic load effect is unknown for non-linear dynamic systems. This will in general lead to an inconsistent safety level for different design concepts and failure modes.

A more consistent approach is to apply design based on response statistics. Consistent assessment of the D-year load effect will require a probabilistic response description due to the long-term environmental loads on the system. The load effect with a return period of D-year, denoted xD, can formally be found from the long-term load effect distribution as:

$F_X(x_D) = 1 - 1/N_D$

N_D = total number of load effect maxima during *D* years

$F_X(x)$ = long-term peak distribution of the (generalised) load effect

The main challenge related to this approach is to establish the long-term load effect distribution due to the non-linear behaviour. Design based on response statistics is in general the recommended procedure and should be considered whenever practicable for consistent assessment of characteristic load effects. Further details may be found in Appendices to DNV-OS-F201.

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

B 200 Global bending effects

201 Global bending and shear forces along the length of the structure due to environmental load effects shall be determined. This applies to first order wave effects, as well as P-delta effects due to platform heel or tilt.

202 Global bending and shear forces in the hull will be influenced by the non-linear restoring effect from the mooring system. This additional load effect shall be analysed and taken into account in design of the hull structure.

C. Load Effect Analysis in the Non-Operational Phases

C 100 General

101 All temporary phases shall be carefully evaluated and sufficient level and amount of analyses shall be performed according to this standard. Further details regarding non-operational conditions may be found in Rules for Planning and Execution of Marine Operations.

C 200 Transportation

201 In case of wet tow in harsh environment (e.g. overseas), model tests shall be performed as a supplement to motion response analyses. Non-linear effects (e.g. slamming, global bending or shear, green seas) shall be taken into account.

202 Motion response analyses shall be performed for dry transports on e.g. heavy lift vessel, or barge. Special attention shall be made to:

— roll motions (roll angles, accelerations, viscous roll damping)
— slamming pressures and areas and structural responses due to slamming
— global strength (vessel, DDF unit)
— strength of sea-fastening
— stability, overhang.

C 300 Launching

301 Launching may be an alternative way of installation or upending a DDF (e.g. truss spar). Model testing of the launch process may be required if there is limited or no experience with such operations for similar concepts.

C 400 Upending

401 Pre-upending phases shall be analysed with respect to global bending moments and shear forces in the hull. In case of wave load effects in this pre-upending phase may be relevant, this shall be analysed and taken into account.

402 In case of dynamic upending, analyses shall be performed in order to determine global and local load effects in the DDF unit with its appurtenances.

403 Hydrostatic or hydrodynamic differential (outside/inside) pressures during dynamic upending shall be determined and further used in design of the hull structure.

404 Model testing of the dynamic upending may be avoided if the applied simulation software has been validated against similar or relevant operations and showing good correlation.

405 In case of lift assisted upending offshore, the limiting environmental criteria must be carefully selected. Dynamic analyses of the system (lift vessel, lifting gear, DDF unit) will be required in order to determine responses in lifting gear and DDF unit.

C 500 Deck mating

501 Offshore installation of deck structure and modules will require refined analyses in order to determine the governing responses. This applies to lifting operations as well as float-over operations with barge. Important factors are limiting environmental criteria, impact responses and floating stability requirements.

502 Floating concepts ("Jack-up") utilising jacking of legs to desired draught and subsequent deballasting to obtain sufficient air-gap, shall be carefully evaluated or analysed with respect to limiting environmental criteria.

SECTION 5
ULTIMATE LIMIT STATES (ULS)

A. General

A 100 Objective

101 General considerations in respect to methods of analysis and capacity checks of structural elements are given in DNV-OS-C101.

102 This section applies for the hull and deck or modules and operational as well as non-operational phases.

103 The LRFD format shall be used when the ULS capacity of the structure is checked. Two combinations shall be checked, a) and b). The load factors are defined in DNV-OS-C101 Sec.2 D400 and values are given in Table A1.

Table A1 Load factors – ULS

Combination of design loads	*Load categories*		
	Permanent and variable functional loads, $\gamma_{f,G,Q}$	*Environmental loads,* $\gamma_{f,F}$	*Deformation loads,* $\gamma_{f,D}$
a)	1.2 [1)]	0.7	1.0
b)	1.0	1.3	1.0

1) If the load is not well defined e.g. masses or functional loads with great uncertainty, possible overfilling of tanks etc. the coefficient should be increased to 1.3.

104 The loads shall be combined in the most unfavourable way, provided that the combination is physically feasible and permitted according to the load specifications. For permanent loads, a load factor of 1.0 in load combination a) shall be used where this gives the most unfavourable response. Other considerations for the partial coefficients are given in DNV-OS-C101.

105 The material factor γ_m for ULS yield check should be 1.15 for steel. The material factor γ_m for ULS buckling check is given in DNV-OS-C101 Sec.5.

B. Hull

B 100 Operational phase

101 For global structural analysis, a complete three-dimensional structural model of the unit is required. This may be a complete shell type model, or a combined shell or space-frame model.

102 Additional detailed finite element analyses may be required for complex joints and other complicated structural parts (e.g. fairlead area, hard tank area, column and brace connections, strake terminations or interactions, deck and hull connections, riser frame and hull connections, curved flanges) to determine the local stress distribution more accurately.

Guidance note:

In order to be able to assess the effect of all possible tank filling configurations, a local finite element model covering the hard tank area may be utilised. Only those tanks used in the normal operation of the platform shall as a minimum be modelled. The stresses from a local finite element model should be superimposed to global stresses.

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103 The additional global bending and shear due to P-delta and mooring restoring effects are to be combined with first order wave effects in a consistent way.

104 The same applies to combining the loads from the risers on riser frames in the moonpool and transfer into the hull structure. Horizontal forces as well as vertical (friction from riser system) shall be taken into account.

105 If VIV suppression devices (e.g. strakes) are installed, both local (direct wave or current loads) and global bending effects should be considered in design of the suppression devices.

B 200 Non-operational phases

201 Finite element analyses will be required performed for overseas wet tow and dry tow in harsh environment.

202 For dry tow this implies that the complete structural system (hull sections, sea-fastening, transport vessel) shall be modelled such that reliable stress-distributions can be obtained.

203 For wet tow in harsh environment special emphasis must be put on the simulation or modelling of the hydrodynamic wave pressures or accelerations acting on the wet hull structure. Further the non-linear hogging and sagging bending or shear effects due to the shape of the hull should be properly simulated or accounted for in the design.

204 The level or amount of finite element analyses for the upending process needs to be evaluated. As a minimum, the following considerations shall be made:

a) Global bending moments and shear forces to be compared (location and level) for the operational phase and pre-upending and dynamic upending.

b) Possibilities for local and global buckling (e.g. skirt area for a classic spar) due to global load effects and lateral differential pressures needs to be assessed/analysed.

C. Deck or Topside

C 100 Operation phase

101 Structural analysis of deck structure shall, in general, follow the same principles as outlined for the hull.

102 Horizontal accelerations at deck level due to wave loading will be high for some DDF units in harsh environment. Detailed finite element analyses of the deck or hull connections shall be performed in such instances.

C 200 Non-operational phases

201 Typical non-operational phases as fabrication, transportation and installation of deck and topside modules shall be assessed and analysed to a sufficient level such that the actual stress level can be determined and further used in the design checks.

D. Scantlings and Weld Connections

D 100 General

101 Minimum scantlings for plate, stiffeners and girders are given in DNV-OS-C101 Sec.5.

102 The requirements for weld connections are given in DNV-OS-C101 Sec.9.

SECTION 6
FATIGUE LIMIT STATES (FLS)

A. General

A 100 General

101 The objective of this section is to provide supplemental guidance related to FLS design as outlined in DNV-OS-C101 Sec.6.

102 This section applies for the hull and deck or modules and operational as well as non-operational phases.

103 In general, all significant stress fluctuations (operational and temporary phases) which contribute to fatigue damage in parts of the unit shall be taken into account for the FLS condition.

104 Criteria related to DFFs are given in DNV-OS-C101 Sec.6.

105 DNV-RP-C203 presents recommendations in relation to fatigue analyses based on fatigue tests and fracture mechanics.

B. Hull

B 100 Operation phase

101 First order wave loads will usually be the dominating fatigue component for the hull in harsh environment. The long term distribution of wave induced stress fluctuations need to be determined with basis in the same type of load effect and finite element analyses as for ULS.

Guidance note:

Early phase evaluation or analysis of fatigue may incorporate modelling the hull as a beam with associated mass distribution and simulation of wave loads according to Morison formulation, or preferably, performing a radiation or diffraction analysis.

Final documentation related to first order wave induced fatigue damage should incorporate a stochastic approach. This implies establishing stress transfer functions, which are combined with relevant wave spectra (scatter diagram) in order to obtain long-term distribution of stresses. The stress transfer functions should be obtained from finite element analyses with appropriate simulation of wave loads (radiation/diffraction analysis). The P-delta effect due to platform roll and pitch shall be taken into account.

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102 As for ULS, the P-delta effect due to platform roll or pitch shall be taken into account. This implies that both first order and second order, slowly varying roll or pitch motions need to be considered and taken into account if contributing to fatigue damage in the hull.

103 For special fatigue sensitive areas, local stress concentrations shall be determined by detailed finite element analyses.

104 Typical fatigue sensitive areas for DDF units will be:

- hull and deck connections
- collision ring area
- hull and deck and stiffener connections at location of peak wave induced global bending moments
- fairlead area
- hard tank area
- column and brace connections
- strake and hull connections and strake terminations
- riser frame and hull connections
- hard tank and truss spar connections
- tubular joints.

105 Fatigue analyses shall be performed to check that the hull strakes have sufficient fatigue lives. Relative motions between the hull and disturbed wave kinematics around strakes must be properly taken into account. Hydrodynamic pressures from a radiation/diffraction analysis in combination with a Morison formulation (inertia and drag) will be sufficient to describe the environmental loads on the strakes.

106 VIV load effects from mooring system (global hull cross-flow motions) into the fairlead or hull areas shall be outlined and taken into account if significant. The same applies to VIV load effects from riser system into the riser frame or hull areas.

107 Allowance for wear and tear shall be taken into account in areas exposed to for example friction and abrasion. For a DDF unit this will typically be interfaces between hull and risers (keel level, intermediate riser-frames, deck level). These relative motions are caused by movements of the unit and risers and subsequent pullout and push-up of the risers in the moonpool.

B 200 Non-operational phases

201 Wet, overseas transports in harsh environment will require quite detailed analyses to determine the fatigue damage during this temporary phase. Both global and local wave load effects shall be taken into account. Some level of monitoring of weather and load effects during towage will be required such that it is possible to recalculate the actual fatigue contribution during wet tow.

202 Dry, overseas transports will usually be less exposed to fatigue damages. It is however, required almost the same level of finite element analyses as for wet tow in order to determine the stress fluctuations in hull, sea-fastenings and transport vessel.

B 300 Splash zone

301 The definition of ‘splash zone’ as given DNV-OS-C101 Sec.10 B200, relates to a highest and lowest tidal reference. For DDF units, for the evaluation of the fatigue limit state, reference to the tidal datum should be substituted by reference to the draught that is intended to be utilised when condition monitoring is to be undertaken. The requirement that the extent of the splash zone is to extend 5 m above and 4 m below this draught may then be applied.

Guidance note:

If significant adjustment in draught is possible in order to provide for satisfactory accessibility in respect to inspection, maintenance and repair, a sufficient margin in respect to the minimum inspection draught should be considered when deciding upon the appropriate DFFs. As a minimum this margin is to be at least 1 m, however it is recommended that a larger value are considered especially in the early design stages where sufficient reserve should be allowed for to account for design changes (mass and centre of mass of the unit). Consideration should further be given to operational requirements that may limit the possibility for ballasting and deballasting operations.

When considering utilisation of remotely operated vehicle (ROV) inspection, consideration should be given to the limitations imposed on such inspection by the action of water particle motion (e.g. waves). The practicality of such a consideration may be that effective underwater inspection by ROV, in normal sea conditions, may not be achievable unless the inspection depth is at least 10 m below the sea surface.

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C. Deck or Topside

C 100 Operation phase

101 Wave induced horizontal accelerations and P-delta effects will usually be governing for FLS design of deck structure and topside modules and shall be duly taken into account.

102 A stochastic approach is the preferred option for determination of final fatigue damage for the deck or topside. See Guidance note to B101 for the hull.

103 Deck and hull connections, joints in deck structure, module supports etc. will typically be fatigue sensitive areas. The amount or level of detailed finite element analyses for these joints needs to be considered. For the deck and hull connection some level or amount of detailed finite element analyses shall be performed, at least for units located in harsh environment.

C 200 Non-operational phases

201 Fatigue damage of deck structure and topside modules shall be documented if the stress fluctuations in the different phases are significant.

SECTION 7
ACCIDENTAL LIMIT STATES (ALS)

A. General

A 100 Objective

101 The objective of this section is to provide supplemental guidance related to ALS design as outlined in DNV-OS-A101 and DNV-OS-C101 Sec.8.

102 This section applies for the hull and deck or modules and operational as well as non-operational phases.

103 General requirements concerning accidental events are given in DNV-OS-C101.

B. General Requirements

B 100 General

101 Units shall be designed to be damage tolerant, i.e. credible accidental damages, or events, should not cause loss of global structural integrity. The capability of the structure to redistribute loads should be considered when designing the structure.

C. Fire

C 100 General

101 Deck area will be limited for some DDF concepts. Potential fire scenarios shall therefore be carefully considered and taken into account in design and layout planning.

D. Explosion

D 100 General

101 As for fire, the limiting deck space and protected moonpool area (potential gas or oil leakage) for some DDF units require that explosions are carefully considered in the design process.

102 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 loadcase
— ensure that hazardous areas 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.

103 As far as practicable, structural design accounting for large plate field rupture resulting from explosion loads should normally be avoided due to the uncertainties of the loads and the consequence of the rupture itself.

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

E. Collision

E 100 General

101 Safety assessments will be the basis for determination of type and size of colliding vessel and impact speed.

102 Collision impact shall be considered for all elements of the unit, which may be impacted by sideways, bow or stern collision. The vertical extent of the collision zone shall be based on the depth and draught of attending vessels and the relative motion between the attending vessels and the unit.

103 Resistance to unit collisions may be accounted for by indirect means, such as, using redundant framing configurations, collision ring in splash zone and materials with sufficient toughness in affected areas.

F. Dropped Objects

F 100 General

101 Critical areas for dropped objects shall be determined on the basis of the actual movement of potential dropped objects (e.g. crane actions) relative to the structure of the unit itself. Where a dropped object is a relevant accidental event, the impact energy shall be established and the structural consequences of the impact assessed.

102 Generally, dropped object assessment will involve the following considerations:

a) Assessment of the risk and consequences of dropped objects impacting topside, wellhead, riser system in moonpool and safety systems and equipment. The assessment shall identify the necessity of any local structural reinforcement or protections to such arrangements.

b) Assessments of the risk and consequences of dropped objects impacting externally on the hull structure (shell, or bracings) and hull attachments such as strakes, fairleads and pipes. The structural consequences are normally fully accounted for by the requirements for watertight compartmentation and damage stability and the requirement for structural redundancy of slender structural members.

G. Unintended Flooding

G 100 General

101 A procedure describing actions to be taken after relevant unintended flooding shall be prepared. Unintended filling of hard tanks, collision ring and bracings for a DDF will be the most relevant scenarios for the operation phase.

102 It must be ensured that counter-filling of tanks and righting up the unit can be performed safely and without delays.

103 Structural aspects related to the tilted condition and counter-flooding (if relevant) shall be investigated. This applies to the complete unit including risers and mooring system.

104 If the unit can not be brought back to the design draught and verticality by counter-ballasting and redistribution of ballast water, this must be taken into account in design of the unit.

H. Abnormal Wave Events

H 100 General

101 Abnormal wave effects are partly related to air-gap and wave exposure to deck or topside structures. Consequences from such wave impacts shall be evaluated and taken into account in design of the relevant structural parts.

102 In areas with hurricanes, special considerations have to be made with respect to selection of relevant sea states to be applied in design of the unit.