OFFSHORE STANDARD

DNVGL-OS-C104 Edition July 2015

Structural design of self-elevating units - LRFD method

DNV GL AS

FOREWORD

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

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

General

This document supersedes DNV-OS-C104, October 2014.

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

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

Main changes July 2015

- General

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

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

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

- Ch.2 Sec.2 Design principles

- [2.2.6]: Reduced acceleration forces from 120% to 100% and guidance note updated.

Editorial corrections

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

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CHAPTER 1 INTRODUCTION

SECTION 1 INTRODUCTION

1 General

1.1 Introduction

1.1.1 This standard provides principles, technical requirements and guidance for the design and construction of self-elevating units.

1.1.2 This standard is based on the load and resistance factor design (LRFD). LRFD is defined in DNVGL-OS-C101.

1.1.3 Self-elevating units may alternatively be designed according to working stress design principles, which is defined in DNVGL-OS-C201.

1.1.4 The standard has been written for general world-wide application. Coastal State 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.

1.2 Objectives

The objectives of this standard are to:

- provide an internationally acceptable standard of safety for self-elevating units by defining minimum requirements for the structural design, materials and construction
- serve as a technical reference document in contractual matters between purchaser and manufacturer
- serve as a guideline for designers, purchasers, contractors and regulators.
- specify procedures and requirements for units and installations subject to DNV GL verification and classification services.

1.3 Scope and application

1.3.1 This standard applies to all types of self-elevating units constructed in steel.

1.3.2 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 experiences.

1.3.3 A self-elevating unit is designed to function in a number of modes, e.g. transit, operational and survival. Design criteria for the different modes shall define and include relevant consideration of the following items:

- intact condition, structural strength
- damaged condition, structural strength
- fatigue strength
- accidental damage
- air gap
- overturning stability
- watertight integrity and hydrostatic stability.

Limiting design criteria when going from one mode to another shall be established and clearly documented.

Watertight integrity and hydrostatic stability shall comply with requirements given in DNVGL-OS-C301.

1.3.4 For novel designs, or unproven 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 is obtained.

1.3.5 Requirements concerning riser systems are not considered in this standard.

1.3.6 Structural design covering marine operation sequences is not covered in this standard and shall be undertaken in accordance with the requirements stated in DNV Marine Operation (VMO) standards (ref DNV-OS-H101 to H206).

2 References

2.1 Offshore standards

2.1.1 The standards listed in Table 1 include provisions, which through reference in this text constitute provisions for this standard.

2.1.2 Other recognised standards may be used provided it is demonstrated that these meet or exceed the requirements of the standards referenced in Table 1.

Table 1 DNV GL offshore standards

Reference	*Title*
DNVGL-OS-A101	Safety principles and arrangement
DNVGL-OS-B101	Metallic materials
DNVGL-OS-C101	Design of offshore steel structures, general - LRFD method
DNVGL-OS-C301	Stability and watertight integrity
DNVGL-OS-C401	Fabrication and testing of offshore structures
DNVGL-OS-D101	Marine and machinery systems and equipment
DNVGL-OS-D301	Fire protection

2.2 Recommended practices, classification notes and other references

The documents listed in Table 2 include acceptable methods for fulfilling the requirements in the standard and may be used as a source of supplementary information. Only the referenced parts of the documents apply for fulfilment of the present standard.

Table 2 Recommended practices, classification notes and other references

Reference	*Title*
DNVGL-RP-C104	Self-elevating units
DNVGL-RP-C201	Buckling strength of plated structures
DNV-RP-C202	Buckling strength of shells
DNVGL-RP-C203	Fatigue strength analysis of offshore steel structures
DNV-RP-C205	Environmental conditions and environmental loads
DNV Classification Notes 30.1	Buckling Strength Analysis of Bars and Frames, and Spherical Shells
DNV Classification Notes 30.4	Foundations
DNV Classification Notes 30.6	Structural Reliability Analysis of Marine Structures
DNV-OS-H101 to H206	DNV Marine Operation (VMO) standards
SNAME 5-5A	Site Specific Assessment of Mobile Jack-Up Units

3 Definitions

3.1 Verbal forms

Table 3 Verbal forms

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

3.2 Terms

Table 4 Terms

Term	*Definition*
dry transit	a transit where the unit is transported on a heavy lift unit
field move	a wet transit that would require no more than a 12-hour voyage to a location where the unit could be elevated, or to a protected location
gust wind velocity	the average wind velocity during a time interval of 3 s. The «N years gust wind velocity» is the most probable highest gust velocity in a period of N years.
installation condition	a condition during which a unit is lowering the legs and elevating the hull
moulded baseline	a horizontal line extending through the upper surface of hull bottom shell
ocean transit	a wet transit that would require more than a 12-hour voyage to a location where the unit could be elevated, or to a protected location
one hour wind velocity	the average wind velocity during a time interval of one hour
operating conditions	conditions wherein a unit is on location for purposes of drilling or other similar operations, and combined environmental and operational loadings are within the appropriate design limits established for such operations The unit is supported on the seabed.
retrieval conditions	conditions during which a unit is lowering the hull and elevating the legs
self-elevating unit or jack-up	a mobile unit having hull with sufficient buoyancy to transport the unit to the desired location, and that is bottom founded in its operation mode The unit reaches its operation mode by lowering the legs to the seabed and then jacking the hull to the required elevation.
survival conditions	conditions wherein a unit is on location subjected to the most severe environmental loadings for which the unit is designed Drilling or similar operations may have been discontinued due to the severity of the environmental loadings. The unit is supported on the seabed.
sustained wind velocity	the average wind velocity during a time interval (sampling time) of 1 minute The most probable highest sustained wind velocity in a period of N years will be referred to as the «N years sustained wind». This is equivalent to a wind velocity with a recurrence period of N years.
transportation or transit conditions	all unit movements from one geographical location to another
wet transit	a transit where the unit is floating during the move

4 Abbreviations and symbols

4.1 Abbreviations

Abbreviations used in this standard are given in DNVGL-OS-C101 or in Table 5.

Table 5 Abbreviations

Abbreviation	*In full*
LAT	lowest astronomical tide
MWL	mean still water level
SNAME	Society of Naval Architects and Marine Engineers

4.2 Symbols

4.2.1 *Latin characters:*

a_h = horizontal acceleration
a_v = vertical acceleration
$\bar{a}$ = the intercept of the design S-N curve with the log N axis
g_o = acceleration due to gravity
h = the shape parameter of the Weibull stress range distribution
h_{op} = vertical distance from the load point to the position of maximum filling height
k = the roughness height
m = inverse slope of the S-N curve
n_i = the number of stress variations in i years appropriate to the global analysis.
n_0 = total number of stress variations during the lifetime of the structure
p_d = design pressure
p_{dyn} = pressure head due to flow through pipes
p_e = dynamic pressure
p_s = static pressure
q_d = critical contact pressure of spudcan
z_b = vertical distance from moulded baseline to load point
A = area of spudcan in contact with seabed
C_D = drag coefficient
C_M = inertia coefficient
C_S = shape coefficient
D = member diameter
D_B = depth of barge
F_V = maximum design axial load in one leg (without load factors)
F_{vd} = maximum design axial load in one leg (with load factors)
F_{VP} = minimum required pre-load on one leg
H_S = significant wave height
K_C = Keulegan-Carpenter number
L = length or breadth of barge
M = mass of unit, cargo, equipment or other components
M_{ed} = maximum design eccentricity moment
M_O = overturning moment
M_S = stabilising moment
M_U = minimum design moment restraint of the leg at the seabed
P = static axial load on one leg
P_E = Euler buckling load for one leg

P_{Hd} = horizontal design force on heavy component
P_{Vd} = vertical design force on heavy component
R = equivalent radius of spudcan contact area
T = wave period
T_{TH} = transit draught
T_Z = zero-upcrossing period
U_m = the maximum orbital particle velocity

4.2.2 Greek characters:

α = amplification factor for leg bending response
$\Delta\sigma_{n0}$ = extreme stress range that is exceeded once out of n_0 stress variations
$\Delta\sigma_{ni}$ = extreme stress range that is exceeded once out of ni stress variations.
ρ = density
$\gamma_{f,D}$ = partial load factor for deformation loads
$\gamma_{f,E}$ = partial load factor for environmental loads
$\gamma_{f,G,Q}$ = partial load factor for permanent loads
γ_M = material factor for steel
γ_s = safety coefficient against overturning

CHAPTER 2 TECHNICAL CONTENT

SECTION 1 STRUCTURAL CATEGORISATION, MATERIAL SELECTION AND INSPECTION PRINCIPLES

1 General

1.1 Scope

1.1.1 This section describes the structural categorisation, selection of steel materials and inspection principles to be applied in design and construction of self-elevating units.

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

1.1.3 The steel grades selected for structural components shall be related to calculated stresses and requirements for toughness properties and shall be in compliance with the requirements given in DNVGL-OS-B101 and DNVGL-OS-C101.

2 Structural categorisation

Application categories for structural components are defined in DNVGL-OS-C101 Ch.2 Sec.3. Structural members of self-elevating units are grouped as follows:

Special category

1) Vertical columns in way of intersection with the mat structure.
2) Highly stressed elements at bottom leg connection to spudcan or mat.
3) Intersections of lattice type leg structure that incorporates novel construction, including the use of steel castings.
4) Highly stressed elements of guide structures, jacking and locking system(s), jackhouse and support structure.
5) Highly stressed elements of crane pedestals, etc. and their supporting structure.

Guidance note:
Highly stressed elements are normally considered to be areas utilised more than 85% of the allowable yield capacity.

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Primary category

1) Combination of bulkhead, deck, side and bottom plating within the hull which forms «Box» or «I» type main supporting structure.
2) All components of lattice type legs and external plating of cylindrical legs.
3) Jackhouse supporting structure and bottom footing structure that receives initial transfer of load from legs.
4) Internal bulkheads, shell and deck of spudcan or bottom mat supporting structures which are designed to distribute major loads, either uniform or concentrated, into the mat structure.
5) Main support structure of heavy substructures and equipment e.g. cranes, drill floor substructure, lifeboat platform and helicopter deck.

Guidance note:
Fatigue critical details within structural category primary are inspected according to requirements in category I as stated in DNVGL-OS-C101 Ch. 2, Sec. 3 [3.3].

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Secondary category

1) Deck, side and bottom plating of hull except areas where the structure is considered for primary or special application.
2) Bulkheads, stiffeners, decks and girders in hull that are not considered as primary or special application.
3) Internal bulkheads and girders in cylindrical legs.
4) Internal bulkheads, stiffeners and girders of spudcan or bottom mat supporting structures except where the structures are considered primary or special application.

Guidance note:

Fatigue critical details within structural category secondary are inspected according to requirements in category I as stated in DNVGL-OS-C101 Ch.2, Sec. 3 [3.3].

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3 Material selection

3.1 General

3.1.1 Material specifications shall be established for all structural materials. 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 DNVGL-OS-C101.

3.1.2 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.)

3.1.3 In ‘special areas’ structural cross-joints essential for the overall structural integrity where high tensile stresses are acting perpendicular to the plane of the plate, the plate material shall be documented with proven through thickness properties, e.g. by utilising Z-quality steel.

3.1.4 Material designations are defined in DNVGL-OS-C101 Ch.2 Sec.3.

3.2 Design and service temperatures

3.2.1 The design temperature for a unit is the reference temperature for assessing areas where the unit may be transported, installed and operated. The design temperature shall be lower or equal to the *lowest mean daily temperature* in air for the relevant areas. For seasonal restricted operations the *lowest mean daily temperature* in air for the season may be applied.

3.2.2 The service temperatures for different parts of a unit apply for selection of structural steel. The service temperatures are defined as presented in [3.2.3] to [3.2.6]. In case different service temperatures are defined in [3.2.3] to [3.2.6] for a structural part the lower specified value shall be applied.

3.2.3 External structures above the lowest astronomical tide (LAT) for the unit in elevated operation or above the light transit waterline during transportation shall not be designed for a service temperature higher than the design temperature for the unit.

3.2.4 External structures below the lowest astronomical tide (LAT) during elevated operation and below the light transit waterline during transportation need not to be designed for service temperatures lower than 0°C.

3.2.5 Internal structures of mats, spudcans, legs and hull shall have the same service temperature as the adjacent external structure if not otherwise documented.

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

3.3 Selection of structural steel

3.3.1 The grade of steel to be used is in general to be related to the service temperature and thickness as shown in the tables in DNVGL-OS-C101 Sec.4 for the various application categories.

3.3.2 For rack plates with specified minimum yield stress equal to 690 N/mm^2 in rack and pinion jacking systems steel grade NV E690 is acceptable for rack plates with thickness up to 250 mm and for service temperature down to -20°C.

3.3.3 When post weld heat treatment is carried out in agreement with customer, steel grades may be selected according to a higher service temperature than stipulated in DNVGL-OS-C101 Ch.2 Sec.3 Table 3.

Guidance note:
In such cases the thickness limitations in Table D3 may be selected one column left of the actual service temperature for the structure, i.e. for service temperatures 0°C, -10°C, -20°C, -25°C and -30°C the thickness limitation can be based on ≥10°C, 0°C, -10°C, -20°C and -25°C, respectively.

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3.3.4 For areas subjected to compressive and/or low tensile stresses, consideration may be given to the use of lower steel grades than stated in the tables of DNVGL-OS-C101 Ch.2 Sec.3.

3.3.5 The toughness requirements for steel plates, sections and weldments exceeding the thickness limits in the table shall be evaluated in each separate case.

3.3.6 Grade of steel to be used for thicknesses less than 10 mm and/or design temperature above 0 °C should be specially considered in each case.

3.3.7 Use of steels in anaerobic conditions or steels susceptible to hydrogen induced stress cracking (HISC) should be specially considered as specified in DNVGL-OS-C101 Ch.2 Sec.3.

4 Inspection categories

4.1 General

4.1.1 Welding and the extent of non-destructive examination during fabrication, shall be in accordance with the requirements stipulated for the appropriate inspection category as defined in DNVGL-OS-C101.

4.1.2 Inspection categories determined in accordance with DNVGL-OS-C101 Ch.2 Sec.3 provide requirements for the minimum extent of required inspection.

Guidance note:
When considering the economic consequence that repair 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.

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4.1.3 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 or section joints
- manual versus automatic welding
- start and stop of weld etc.

SECTION 2 DESIGN PRINCIPLES

1 Introduction

1.1 General

1.1.1 The structure shall be designed according to the LRFD method with limit states and design conditions as described in the present standard. A general description of the format of LRFD method is given in DNVGL-OS-C101.

1.1.2 Relevant load combinations shall be established for the various design conditions and limit states based on the most unfavourable combinations of functional loads, environmental loads and/or accidental loads.

1.1.3 Modelling and analysis of the structure shall satisfactorily simulate the behaviour of the actual structure, including its supporting system, and the relevant environmental conditions. Reasonable simplifications may be introduced as a part of structural idealisation.

1.1.4 Limiting environmental and operating conditions (design data) for the different design conditions shall be specified by the customer.

1.1.5 Requirements regarding certification of jacking gear machinery are given in DNVGL-OS-D101.

1.1.6 The effect of earthquakes may be of significance for operations of self-elevating units in some regions. For loads and design against seismic events see DNVGL-OS-C101 and Ch.3 Sec.1 [1.2.6].

1.2 Overall design

1.2.1 The overall structural safety shall be evaluated on the basis of preventive measures against structural failure put into design, fabrication and in-service inspection as well as the unit's residual strength against total collapse in the case of structural failure of vital elements.

For vital elements, which are designed according to criteria given for intact structure, the likelihood and consequence of failure should be considered as part of the redundancy evaluations. The consequence of credible accidental events shall be documented according to the ALS, see Sec.6.

1.2.2 When determining the overall structural design, particular care shall be taken such that the solution does not lead to unnecessarily complicated connections.

1.3 Details design

1.3.1 Structural connections should, in general, be designed with the aim to minimise stress concentrations and reduce complex stress flow patterns. Connections should be designed with smooth transitions and proper alignment of elements. Large cut-outs should be kept away from flanges and webs of primary girders in regions with high stresses.

1.3.2 Transmission of tensile stresses through the thickness of plates should be avoided as far as possible. In cases where transmission of tensile stresses through the thickness cannot be avoided, structural steel with improved through thickness properties may be required, see Sec.1 [3].

1.3.3 Units intended for operations in cold areas shall be so arranged that water cannot be trapped in local structures or machinery exposed to the ambient temperature.

1.3.4 If the unit is intended to be dry-docked the footing structure (i.e. mat or spudcans) shall be suitably strengthened to withstand associated loads.

2 Design conditions

2.1 Basic conditions

The following design conditions, as defined in Sec.1 [3], shall be considered as relevant for the unit:

- transit condition(s)
- installation condition
- operating condition(s)
- survival condition
- retrieval condition.

2.2 Transit

2.2.1 The present standard considers requirements for wet transits, i.e. field moves or ocean transits as defined in Sec.1 [3]. Requirements in case of dry transit on a heavy lift vessel are considered to be covered by the warranty authority for the operation.

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

Guidance note:
For guidance on global analysis for the transit condition see DNVGL-RP-C104 Sec.4.5 and for environmental loading see DNV-RP-C205.

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2.2.3 The structure may be analysed for zero forward speed in analysis of wet transits.

2.2.4 The legs shall be designed for the static and inertia forces resulting from the motions in the most severe environmental transit conditions, combined with wind forces resulting from the maximum wind velocity.

2.2.5 The leg positions for both field moves and ocean moves shall be assessed when considering structural strength for transit condition.

2.2.6 In lieu of a more accurate analysis, for the ocean transit condition the legs shall be designed for the following forces considered to act simultaneously:

- 100% of the acceleration forces from a 15° single amplitude roll or pitch at a 10 second period.
- 120% of the static forces at the maximum amplitude of roll or pitch.

Guidance note:
These criteria define a reference design case for the ocean transit condition. As wind loads are not included, it is assumed that loads/ moments on the legs from gravity, wave and wind loads are not exceeding forces/moments caused by design values from the simplified motions above.

Roll or pitch of 15° at 10 sec. is assumed to include the load effect from heave, sway and surge motions.

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A more accurate alternative is that the roll and pitch motions are determined by hydrodynamic calculation (motion analyses) or model test methods. The sea state(s) (Hs/Tz) used in determination for these motions are to be specified in line with [1.1.4]. These motions are to be combined with a reference wind speed = 45 m/s in the check of leg strength, unless other wind speeds are specified by the customer. Wind velocity profile shall be taken according to DNVGL-RP-C104 Sec.2.4.

2.2.7 For the field move position the legs may be designed for the acceleration forces caused by a 6° single amplitude roll or pitch at the natural period of the unit plus 120% of the static forces at a 6° inclination of the legs unless otherwise verified by model tests or calculations.

2.2.8 Dynamic amplification of the acceleration forces on the legs shall be accounted for if the natural periods of the legs are such that significant amplification may occur.

2.2.9 If considered relevant, the effect of vortex shedding induced vibrations of the legs due to wind shall be taken into account.

Guidance note:
For guidance relating to vortex induced oscillations see DNV-RP-C205 Sec.9.

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2.2.10 The hull shall be designed for global mass and sea pressure loads, local loads and leg loads during transit.

2.2.11 Satisfactory compartmentation and stability during all floating operations shall be ensured, see DNVGL-OS-C301.

2.2.12 Unless satisfactory documentation exists demonstrating that shimming is not necessary, relevant leg interfaces (e.g. leg and upper guide) shall be shimmed in the transit condition.

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

2.2.14 The structural strength of the hull, legs and footings during transit shall comply with the ULS, FLS and ALS given in Sec.4, Sec.5 and Sec.6, respectively.

2.3 Installation and retrieval

2.3.1 Relevant static and dynamic loads during installation and retrieval shall be accounted for in the design, including consideration of the maximum environmental conditions expected for the operations and leg impact on the seabed.

In lieu of more accurate analysis the single amplitude for roll or pitch and period can be specified by the customer, followed by a calculation according to DNVGL-RP-C104 Sec.4.6 to derive the design capacity for the leg. The design capacity for the leg is to be documented and is to be presented as maximum leg force/moments for the leg at connection to the hull structure. Alternatively the design capacity may be presented as horizontal and vertical point load at the spudcan tip for the relevant water depths.

Guidance note:
Guidance relating to simplified and conservative analytical methodology for bottom impact on the legs is given in DNVGL-RP-C104 Sec.4.6.

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2.3.2 The capacity of the unit during pre-loading must be assessed. The purpose of pre-loading is to develop adequate foundation capacity to resist the extreme vertical and horizontal loadings. The unit should be capable of pre-loading to exceed the maximum vertical soil loadings associated with the worst storm loading.

Guidance note:
Guidance relating to pre-loading is given in DNV Classification Notes 30.4 Sec.1 and Sec.8.

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2.3.3 The hull structure shall be analysed to ensure it can withstand the maximum pre-loading condition.

2.3.4 The structural strength of the hull, legs and footings during installation and retrieval shall comply with the ULS given in Sec.4.

2.4 Operation and survival

2.4.1 The operation and survival conditions cover the unit in the hull elevated mode.

2.4.2 A detailed assessment shall be undertaken which includes determination of the limiting soils, environmental and mass criteria and the resulting, induced loads.

2.4.3 Dynamic structural deflection and stresses due to wave loading shall be accounted for if the natural periods of the unit are such that significant dynamic amplification may occur.

Guidance note:
It is not necessary to include dynamic amplification for the ULS checks (yield and buckling) when DAF ≤ 1.10.
DAF = Dynamic Amplification Factor obtained as described in DNVGL-RP-C104 Sec.4.4.4, item (i).

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2.4.4 Non-linear amplification (large displacement effects) of the overall deflections due to second order bending effects of the legs shall be accounted for whenever significant.

2.4.5 The effect of leg fabrication tolerances and guiding system clearances shall be accounted for.

2.4.6 The leg/soil interaction shall be varied as necessary within the design specifications to provide maximum stress in the legs, both at the bottom end and at the jackhouse level.

2.4.7 Critical aspects to be considered in the elevated condition are structural strength, overturning stability and air gap.

2.4.8 The structural strength of the hull, legs and footings during operation and survival shall comply with the ULS, FLS and ALS given in Sec.4, Sec.5 and Sec.6. The ULS assessment should be carried out for the most limiting conditions with the maximum storm condition and maximum operating condition examined as a minimum.

Guidance note:
The hull will typically comprise the following elements:

- decks
- sides and bottom plating
- longitudinal bulkheads
- transverse bulkheads and frames
- longitudinal girders and stringers
- stringers and web frames on the transverse bulkheads
- jackhouses.

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2.4.9 The strength of the hull shall be assessed based on the characteristic load conditions that result in maximum longitudinal tension and compression stresses (for yield and buckling assessment) in deck and bottom plating.

2.4.10 The effect of large openings in the hull (e.g. drill slot) that affect the distribution of global stresses should be determined by a finite element model accounting for three dimensional effects.

3 Environmental conditions

3.1 General

3.1.1 All environmental phenomena that may contribute to structural damages shall be considered. Such phenomena are wind, waves, currents, ice, earthquake, soil conditions, temperature, fouling, corrosion, etc.

3.1.2 The specified environmental design data used for calculating design loads for intact structure are to correspond with the most probable largest values for a return period of 100 years, see DNVGL-OS-C101.

3.1.3 For damaged structure calculations a return period of one year shall be used, see DNVGL-OS-C101.

3.1.4 The environmental design data may be given as maximum wave heights with corresponding periods and wind- and current velocities and design temperatures or as acceptable geographical areas for operation. In the latter case the customer is to specify the operational areas and submit documentation showing that the environmental data for these areas are within the environmental design data.

3.1.5 The statistical data used as a basis for design must cover a sufficiently long period of time.

3.2 Wind

3.2.1 Wind velocity statistics shall be used as a basis for a description of wind conditions, if such data are available. Sustained, gust, and one hour wind are defined in Ch.1 Sec.1 [3].

3.2.2 Characteristic wind design velocities shall be based upon appropriate considerations of velocity and height profiles for the relevant averaging time.

Guidance note:
Practical information in respect to wind conditions, including velocity and height profiles, is documented in DNV-RP-C205 and DNVGL-RP-C104 Sec.2.4 and 3.4.

For units intended for unrestricted service (worldwide operation) a wind velocity v_R of not less than 51.5 m/s combined with maximum wave forces will cover most offshore locations. v_R = Reference 1 minute wind speed at a height 10m above the still water level. The corresponding wind force should be based on a wind velocity profile given by DNV-RP-C205 Chapter 2. Clause 2.3.2.12, or equivalent. See also the guidance given in DNVGL-RP-C104 Sec.2.4 and 3.4.

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3.2.3 When wind tunnel data obtained from reliable and adequate tests on a representative model of the unit are available, these data will be considered for the determination of pressures and resulting forces.

3.3 Waves

3.3.1 Wave conditions which shall be considered for design purposes may be described either by deterministic (regular) design wave methods or by stochastic (irregular seastate) methods applying wave energy spectra.

3.3.2 Short term irregular seastates are described by means of wave energy spectra that are characterised by significant wave height (H_S), and average zero-upcrossing period (T_Z).

Analytical spectrum expressions are to reflect the width and shape of typical spectra for the considered height.

The shortcrestedness of waves in a seaway, i.e. the directional dispersion of wave energy, may be taken into account. The principal direction of wave encounter is defined as the direction of maximum wave energy density.

Guidance note:

For open sea locations the Pierson-Moskowitz (P-M) type of spectrum may be applied. For shallow water, or locations with a narrow “fetch”, a narrower spectrum should be considered (e.g. Jonswap spectrum).

Practical information in respect to wave conditions is documented in DNV-RP-C205 Sec.3 and DNVGL-RP-C104 Sec.2.2.

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3.3.3 The long term behaviour of the sea is described by means of a family of wave spectra, the probability of occurrence for each spectrum being taken into account.

3.3.4 For this purpose one needs the joint probability density function for H_S and T_Z, which may be obtained from wave statistics. A description of the long term seastates based on the use of hindcastings may also be accepted. Wave statistics for individual principal directions of wave encounter should be used, otherwise conservative assumptions shall be introduced.

Extreme wave heights are expressed in terms of wave heights having a low probability of occurrence.

The «*N* year wave height» is the most probable largest individual wave height during *N* years. This is equivalent to a wave height with a return period of *N* years.

3.3.5 In deterministic design procedures, based on regular wave considerations, the wave shall be described by the following parameters:

- wave period
- wave height
- wave direction
- still-water depth.

The choice of an appropriate design wave formulation has to be based on particular considerations for the problem in question. Shallow water effects shall be accounted for.

3.3.6 The design waves shall be those that produce the most unfavourable loads on the considered structure, taking into account the shape and size of structure, etc.

The wave period shall be specified in each case of application. It may be necessary to investigate a representative number of wave periods, in order to ensure a sufficiently accurate determination of the maximum loads.

3.4 Current

3.4.1 Adequate current velocity data shall be selected from the statistics available. Different components of current shall be considered, such as tidal current and wind generated current.

3.4.2 The variation of current velocity over the water depth shall be considered when this is relevant.

3.5 Temperature

The design temperature shall be specified as necessary for the areas where the unit is to operate or be transported, Sec.1 [3.2].

3.6 Snow and ice

Snow and ice shall be considered as necessary for the areas where the unit is to operate or be transported.

4 Method of analysis

4.1 General

4.1.1 Structural analysis shall be performed to evaluate the structural strength due to global and local effects.

4.1.2 The following responses shall be considered in the structural design whenever significant:

- dynamic stresses for all limit states
- non-linear wave loading effects, (e.g. effect of drag and finite wave elevation)
- non-linear amplification due to second order bending effects of the legs (P-delta effect)
- effects of leg fabrication tolerances and leg guiding system clearances
- slamming induced vibrations
- vortex induced vibrations (e.g. resulting from wind loads on structural elements in a flare tower or in lattice legs above jackhouses)
- friction and wear (e.g. at leg guiding system or at riser system interfaces with hull structures).

4.1.3 Non-linear amplification of the overall deflections due to second order bending effects of the legs shall be accounted for whenever significant. The non-linear bending response may be calculated by multiplying the linear leg response by an amplification factor as follows:

$$\alpha = \frac{1}{1 - P/P_E}$$

P = static axial load on one leg

P_E = Euler buckling load for one leg.

4.1.4 In the unit elevated mode the global structural behaviour may be calculated by deterministic quasi-static analysis, directly considering non-linear wave and leg bending effects. The effect of dynamics should be represented by an inertia force contribution at the level of the hull centre of gravity or by a dynamic amplification factor, as specified in DNVGL-RP-C104.

4.1.5 In case of significant uncertainties related to the non-linear, dynamic behaviour, stochastic time domain analysis may be performed. The selection of critical seastate for the analysis should be properly considered.

4.1.6 Where non-linear loads may be considered as being insignificant, or where such loads may be satisfactorily accounted for in a linearized analysis, a frequency domain analysis may be undertaken. Transfer functions for structural response shall be established by analysis of an adequate number of wave directions, with an appropriate radial spacing. A sufficient number of periods shall be analysed to:

- adequately cover the site specific wave conditions

- to satisfactorily describe transfer functions at, and around, the wave 'cancellation' and 'amplifying' periods
- to satisfactorily describe transfer functions at, and around, the resonance period of the unit.

4.1.7 As an alternative to time domain analysis model testing may be performed when non-linear effects cannot be adequately determined by direct calculations. Model tests should also be performed for new types of self-elevating units.

4.1.8 For independent leg units, the static inclination of the legs shall be accounted for. The inclination is defined as the static angle between the leg and a vertical line and may be due to fabrication tolerances, fixation system and hull inclination, as specified in DNVGL-RP-C104.

4.1.9 The seabed conditions, and therefore the leg and soil interaction, need to be considered as it affects the following:

- leg bending moment distribution
- overall structure stiffness and therefore the natural period of the unit
- load distribution on the spudcans.

The leg and soil interaction should be varied as necessary between an upper and lower bound to provide conservative response limits at the bottom leg and footing area and at the jackhouse level.

Guidance note:
As the leg and soil interaction is difficult to predict, it is acceptable and conservative to assume pinned and fixed conditions as the lower and upper bounds, respectively.

For further guidance see DNV Classification Notes 30.4 Sec.8, DNVGL-RP-C104 and SNAME 5-5A.

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4.1.10 The leg and hull connection may be designed by any of or combination of the following methods:

- a fixation system, i.e. rack chock
- a fixed jacking system, i.e. pinions rigidly mounted to the jackhouse
- a floating jacking system, i.e. pinions mounted to the jackhouse by means of flexible shock pads
- a guiding system by upper and lower guides.

The characteristics and behaviour of the actual leg and hull connection system need to be properly represented in the appropriate global and local analyses.

Guidance note:
Practical information in respect to modelling leg and hull interaction is documented in DNVGL-RP-C104 Sec.4.3 or SNAME 5-5A, Section 5.6.

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4.2 Global structural models

4.2.1 A global structural model shall represent the global stiffness and behaviour of the unit. The global model should usually represent the following:

- footing main plating and stiffeners
- leg truss or shell and stiffeners
- jackhouse and leg/hull interaction
- main bulkheads, frameworks and decks for the deck structure ("secondary" decks which are not taking part in the global structural capacity need not be modelled)
- mass model.

4.2.2 Depending on the purpose of the analysis and possible combination with further local analysis the different level of idealisation and detailing may be applied for a global structure. The hull may either be represented by a detailed plate and shell model or a model using grillage beams. The legs may be modelled by detailed structural models or equivalent beams, or a combination of such.

Guidance note:
For further guidance regarding modelling procedures see DNVGL-RP-C104 or SNAME 5-5A.

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4.3 Local structural models

4.3.1 An adequate number of local structural models should be created in order to evaluate response of the structure to variations in local loads. The model(s) should be sufficiently detailed such that resulting responses are obtained to the required degree of accuracy. A number of local models may be required in order to fully evaluate local response at all relevant sections.

The following local models should be analysed in the evaluation of ULS:

- footing, mat or spudcan. Including the lower part of the leg (typically at least 2 bays)
- stiffened plates subjected to tank pressures or deck area loads
- leg and hull connection system including jackhouse support structure
- support structure for heavy equipment such as drill floor and pipe racks
- riser hang off structure
- crane pedestal support structure
- helicopter deck support structure.

4.3.2 A detailed finite element model should be applied to calculate the transfer of leg axial forces, bending moments and shears between the upper and lower guide structures and the jacking and/or fixation system. The systems and interactions should be properly modelled in terms of stiffness, orientation and clearances. The analysis model should include a detailed model of the leg in the hull interface area, the guides, fixation and/or jacking system, together with the main jackhouse structure.

Guidance note:
The detailed leg model should normally extend 4 bays below and above the lower and upper guides, respectively.

For further guidance regarding modelling procedures see DNVGL-RP-C104 or SNAME 5-5A.

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4.4 Fatigue analysis

4.4.1 The fatigue life shall be calculated considering the combined effects of global and local structural response. The expected dynamic load history shall be specified in the design brief as basis for the calculations.

4.4.2 Stress concentration factors for fatigue sensitive structural details that cannot be obtained from standard tables, e.g. due to different structural arrangement or that dimensions are out of range of the formula, shall be determined by a finite element analysis.

SECTION 3 DESIGN LOADS

1 Introduction

1.1 General

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

1.1.2 Characteristic loads shall be used as reference loads. General description of load components and combinations are given in DNVGL-OS-C101. Details regarding environmental loads are described in DNV-RP-C205 and DNVGL-RP-C104 Sec.2 and 3.4. Presentation of load categories relevant for self-elevating units is given in [2] to [8].

2 Permanent loads

Permanent loads are loads that will not vary in magnitude, position, or direction during the period considered and include:

- 'lightweight' of the unit, including mass of permanently installed modules and equipment, such as accommodation, helicopter deck, drilling and production equipment
- permanent ballast
- hydrostatic pressures resulting from buoyancy
- pretension in respect to drilling and production systems (e.g. risers, etc.).

3 Variable functional loads

3.1 General

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

3.1.2 Except where analytical procedures or design specifications otherwise require, the value of the variable loads utilised in structural design should be taken as either the lower or upper design value, whichever gives the more unfavourable effect. Variable functional loads on deck areas may be found in DNVGL-OS-C101, Ch.2 Sec.2. These should be applied unless specified otherwise in deck load plans, design basis or design brief.

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

3.1.4 Design criteria resulting from operational requirements should be fully considered. Examples of such operations may be:

- drilling, production, workover, and combinations thereof
- consumable re-supply procedures
- maintenance procedures
- possible mass re-distributions in extreme conditions.

3.1.5 Dynamic loads resulting from flow through air pipes during filling operations shall be adequately considered in the design of tank structures.

3.2 Lifeboat platforms

Lifeboat platforms shall be checked for ULS and ALS if relevant. A dynamic factor of 0.2 g_0 due to retardation of the lifeboats when lowered shall be included.

3.3 Tank loads

3.3.1 A minimum design density (ρ) of 1.025 t/m^3 should be considered in the determination of the appropriate scantlings of tank arrangements.

3.3.2 The extent to which it is possible to fill sounding, venting or loading pipe arrangements shall be fully accounted for in determination of the maximum design pressure which a tank may be subjected to.

3.3.3 Dynamic pressure heads resulting from the filling of such pipes shall be included in the design pressure head where such load components are applicable.

3.3.4 All tanks shall be designed for the following internal design pressure:

$$p_d = \rho g_0 h_{op}\left(\gamma_{f,G,Q} + \frac{a_v}{g_0}\gamma_{f,E}\right) \quad (kN/m^2)$$

h_{op} = vertical distance (m) from the load point to the position of maximum filling height. For tanks adjacent to the sea and situated below the extreme operational draught (T_E) during wet transit, h_{op} should not be taken less than the distance from the load point to the static sea level.

a_v = maximum vertical acceleration, (m/s^2), being the coupled motion response applicable to the tank in question.
The vertical acceleration term only applies to transit conditions. For conditions with the deck elevated av may be taken equal to zero.

$\gamma_{f,G,Q}$ = partial load factor for permanent and functional loading, see Sec.4 Table 1.

$\gamma_{f,E}$ = partial load factor for environmental loads, see Sec.4 Table 1.

Descriptions and requirements related to different tank arrangements are given in DNVGL-OS-D101 Ch.2 Sec.3 [3.3].

A special tank filling design condition shall be checked according to ULS loading combination a) for tanks where the air-pipe may be filled during filling operations. The following additional internal design pressure conditions shall be used:

$$p_d = (\rho g_0 h_{op} + p_{dyn})\gamma_{f,G,Q} \quad (kN/m^2)$$

p_{dyn} = pressure (kN/m^2) due to flow through pipes, minimum 25 kN/m^2

Guidance note:
This internal pressure need not to be combined with extreme environmental loads. Normally only static global response need to be considered.

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3.3.5 Requirements for testing of tank tightness and structural strength are given in DNVGL-OS-C401 Ch.2 Sec.4.

4 Environmental loads

4.1 General

4.1.1 General considerations for environmental loads are given in DNVGL-OS-C101 Ch.2 Sec.2 [5] and [6], in DNV-RP-C205 and in DNVGL-RP-C104.

4.1.2 Combinations of environmental loads are stated in DNVGL-OS-C101 Ch.2 Sec.2 Table 4.

4.2 Wind loads

4.2.1 In conjunction with maximum wave forces the sustained wind velocity, i.e. the 1 minute average velocity, shall be used. If gust wind alone is more unfavourable than sustained wind in conjunction with wave forces, the gust wind velocity shall be used. For local load calculations gust wind velocity shall be used.

4.2.2 Formulas for calculation of wind loads may be taken from DNV-RP-C205 Sec.5. See also the guidance given in DNVGL-RP-C104 Sec.2.4 and 3.4.

4.2.3 Applicable shape coefficients for different structure parts are given in Table 1. For shapes or combination of shapes which do not readily fall into the categories in Table 1 the formulas in DNV-RP-C205 Sec.5 should be applied.

Table 1 Shape coefficient

Type of structure or member	C_S
Hull, based on total projected area	1.0
Deckhouses, jack-frame structure, sub-structure, draw-works house, and other above deck blocks, based on total projected area of the structure.	1.1
Leg sections projecting above the jack-frame and below the hull	See DNV-RP-C205.
Isolated tubulars, (e.g. crane pedestals, etc.)	0.5
Isolated structural shapes, (e.g. angles, channels, boxes, I-sections), based on member projected area	1.5
Derricks, crane booms, flare towers (open lattice sections only, not boxed-in sections)	According to DNV-RP-C205 or by use of the appropriate shape coefficient for the members concerned applied to 50% of the total projected area.

4.2.4 For local design the pressure acting on vertical external bulkheads exposed to wind shall in general not be taken less than 2.5 kN/m^2.

4.2.5 For structures being sensitive to dynamic loads, for instance tall structures having long natural period of vibration, the stresses due to the gust wind pressure considered as static shall be multiplied by an appropriate dynamic amplification factor.

4.2.6 The possibility of vibrations due to instability in the flow pattern induced by the structure itself should also be considered.

4.3 Waves

4.3.1 The basic wave load parameters and response calculation methods in this standard shall be used in a wave load analysis where the most unfavourable combinations of height, period and direction of the waves are considered.

4.3.2 The liquid particle velocity and acceleration in regular waves shall be calculated according to recognised wave theories, taking into account the significance of shallow water and surface elevation.

Linearized wave theories may be used when appropriate. In such cases appropriate account shall be taken of the extrapolation of wave kinematics to the free surface.

4.3.3 The wave design data shall represent the maximum wave heights specified for the unit, as well as the maximum wave steepness according to the unit design basis.

The wave lengths shall be selected as the most critical ones for the response of the structure or structural part to be investigated.

Guidance note:

Practical information in respect to wave conditions, including wave steepness criteria and wave “stretching”, is documented in DNV-RP-C205, Sec.3. See also DNVGL-RP-C104 Sec.2.2 and 2.3.

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4.3.4 For a deterministic wave analysis using an appropriate non-linear wave theory for the water depth, i.e. Stokes' 5th or Dean's Stream Function, the fluid velocity of the maximum long-crested 100 year wave may be multiplied with a kinematic reduction factor of 0.86. The scaling of the velocity shall be used only in connection with hydrodynamic coefficients defined according to [4.5.3], i.e. $C_D \geq 1.0$ for submerged tubular members of self-elevating units.

Guidance note:

The kinematics reduction factor is introduced to account for the conservatism of deterministic, regular wave kinematics traditionally accomplished by adjusting the hydrodynamic properties.

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4.4 Current

Characteristic current design velocities shall be based upon appropriate consideration of velocity and height profiles. The variation in current profile with variation in water depth, due to wave action shall be appropriately accounted for.

Guidance note:

Practical information in respect to current conditions, including current stretching in the passage of a wave, is documented in DNV-RP-C205 Sec.4 and DNVGL-RP-C104 Sec.2.3 and 3.4.

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4.5 Wave and current loads

4.5.1 Wave and current loads should be calculated using Morison's equation.

Guidance note:

For information regarding use of Morison's equation see DNV-RP-C205 Sec.6 and DNVGL-RP-C104 Sec.3.4.

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4.5.2 Vector addition of the wave and current induced particle velocities should be used for calculation of the combined wave and current drag force. If available, computations of the total particle velocities and acceleration based on more exact theories of wave and current interaction may be preferred.

4.5.3 Hydrodynamic coefficients for circular cylinder in oscillatory flow with in-service marine roughness, and for high values of the Keulegan-Carpenter number, i.e. $K_C > 37$, may be taken as given in Table 2.

Table 2 Hydrodynamic coefficients

Surface condition	*Drag coefficient* $C_D(k/D)$	*Inertia coefficient* $C_M(k/D)$
Multiyear roughness $k/D > 1/100$	1.05	1.8
Mobile unit (cleaned) $k/D < 1/100$	1.0	1.8
Smooth member $k/D < 1/10000$	0.65	2.0

The Keulegan-Carpenter number is defined by:

$$K_c = \frac{U_m T}{D}$$

k = the roughness height
D = the member diameter
U_m = the maximum orbital particle velocity
T = the wave period

More detailed formulations for C_D of tubular members depending on surface condition and Keulegan-Carpenter number can be found in DNV-RP-C205 Sec.6.

4.5.4 The roughness for a "mobile unit (cleaned)" applies when marine growth roughness is removed between submersions of members.

4.5.5 The smooth values may apply above MWL + 2 m and the rough values below MWL + 2 m, where MWL is the mean still water level, as defined in DNV-RP-C205 Figure 4-2.

4.5.6 The above hydrodynamic coefficients apply both for deterministic wave analyses when the guidance given in [4.3.4] is followed and for stochastic wave analysis.

4.5.7 Assumptions regarding allowable marine growth shall be stated in the basis of design.

4.5.8 For non-tubular members the hydrodynamic coefficients should reflect the actual shape of the cross sections and member orientation relative to the wave direction.

Guidance note:

Hydrodynamic coefficients relevant to typical self-elevating unit chord designs are stated in DNV-RP-C205 Sec.5 and DNVGL-RP-C104 App.A [6]. See also SNAME 5-5A.

Equivalent single beam stiffness parameters for lattice-type legs may be obtained from DNVGL-RP-C104 App.A [1].

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4.6 Sea pressures during transit

4.6.1 Unless otherwise documented the characteristic sea pressure acting on the bottom, side and weather deck of a self-elevating unit in transit condition should be taken as:

$$p_d = p_s \gamma_{f,\,G,\,Q} + p_e \gamma_{f,\,E}$$

where the static pressure is:

$$p_s = \rho g_0 (T_{TH} - z_b) \quad (\mathrm{kN/m^2}) \qquad \text{for} \quad z_b \le T_{TH}$$

$$p_s = 0 \quad (\mathrm{kN/m^2}) \qquad \text{for} \quad z_b > T_{TH}$$

The dynamic pressure for sides and bottom is:

$$p_e = 0.07 \rho g_0 \, L \quad (\mathrm{kN/m^2}) \qquad \text{for} \quad z_b \le T_{TH}$$

$$p_e = \rho g_0 (T_{TH} + 0.07\, L - z_b) \quad (\mathrm{kN/m^2}) \qquad \text{for} \quad z_b > T_{TH}$$

and for weather decks:

$$p_e = \rho g_0 (0.75\, D_B + 0.07\, L - z_b) \quad (\mathrm{kN/m^2})$$

$$p_e \ge 6.0 \quad (\mathrm{kN/m^2})$$

T_{TH} = heavy transit draught (m) measured vertically from the moulded baseline to the uppermost transit waterline

z_b = vertical distance in m from the moulded baseline to the load point.

D_B = depth of barge (m)

L = greater of length of breadth (m)

4.6.2 In cases where pressure difference is investigated, i.e. transit condition, the pressures shall be combined in such a way that the largest pressure difference is used for design.

4.6.3 In case of pressure on both sides of bulkheads, the load factor shall be applied on the pressure difference. The case of a "permanently filled" tank being empty shall also be considered.

4.7 Heavy components during transit

The forces acting on supporting structures and lashing systems for rigid units of cargo, equipment or other structural components should be taken as:

$$P_{Vd} = (g_0 \gamma_{f,\,G,\,Q} \pm a_v \gamma_{f,\,E}) M \quad (kN)$$
$$P_{Hd} = a_h \gamma_{f,\,E} M \quad (kN)$$

a_v = vertical acceleration (m/s^2)

a_h = horizontal acceleration (m/s^2)

M = mass of cargo, equipment or other components (ton)

P_{Vd} = vertical design force

P_{Hd} = horizontal design force.

For units exposed to wind, a horizontal force due to the design gust wind shall be added to P_{Hd}.

Guidance note:
For self-elevating units in transit condition, α_h and α_v need not be taken larger than 0.5 g_0 (m/s^2).

P_{Hd} is applied at the vertical position of the load resultant(s) to account for the vertical force couple introduced at the foundations of the heavy equipment.

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5 Deformation loads

5.1 General

Deformation loads caused by inflicted deformations, such as temperature loads, built-in deformations, etc. should be considered as appropriate.

Further details and description of deformation loads are given in DNVGL-OS-C101 Ch.2 Sec.2 [8].

5.2 Displacement dependent loads

Load effects that are a consequence of the displacement of the unit in the elevated condition shall be accounted for. Such effects are due to the first order sway (P-delta), and its enhancement due to the increased flexibility of the legs in the presence of axial loads, i.e. Euler amplification.

Guidance note:
Simplified method to include the P-Δ effect is given in DNVGL-RP-C104 Sec.4.4.7.

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6 Accidental loads

6.1 General

6.1.1 The following ALS events shall be considered in respect to the structural design of a self-elevating unit:

- collision
- dropped objects (e.g. from crane handling)
- fire
- explosion
- unintended flooding during transit.

6.1.2 Requirements and guidance on accidental loads are given in DNVGL-OS-C101 and generic loads are given in DNVGL-OS-A101.

7 Fatigue loads

7.1 General

7.1.1 Repetitive loads, which may lead to possible significant fatigue damage, shall be evaluated. The following listed sources of fatigue loads shall, where relevant, be considered:

- waves (including loads caused by slamming and variable (dynamic) pressures)
- wind (especially when vortex induced vibrations may occur)
- currents (especially when vortex induced vibrations may occur)
- mechanical vibration (e.g. caused by operation of machinery)
- mechanical loading and unloading (e.g. due to jacking or crane operations).

The effects of both local and global dynamic response shall be properly accounted for when determining response distributions related to fatigue loads.

7.1.2 Further considerations with respect to fatigue loads are given in DNVGL-RP-C203.

8 Combination of loads

8.1 General

8.1.1 Load combinations for the design limit states are, in general given in DNVGL-OS-C101 Ch.2 Sec.2. Specific load factors for self-elevating units for the ULS are given in Sec.4.

8.1.2 Structural strength shall be evaluated considering all relevant, realistic load conditions and combinations. Scantlings shall be determined on the basis of criteria that combine, in a rational manner, the effects of relevant global and local responses for each individual structural element.

8.1.3 A sufficient number of load conditions shall be evaluated to ensure that the characteristic largest (or smallest) response, for the appropriate return period, has been established.

Guidance note:
For example, maximum global, characteristic responses for a self-elevating unit may occur in environmental conditions that are not associated with the characteristic, largest, wave height. In such cases, wave period and associated wave steepness parameters are more likely to be governing factors in the determination of maximum and minimum responses.

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SECTION 4 ULTIMATE LIMIT STATES (ULS)

1 General

1.1 General

1.1.1 The ULS capacity of the structure shall be checked according to the LRFD format. General considerations with respect to definition of the design format, combination of loads, methods of analysis and capacity checks for the ULS are given in DNVGL-OS-C101.

1.1.2 Both global and local capacity shall be checked with respect to ULS. The global and local stresses shall be combined in an appropriate manner.

1.1.3 Analytical models shall adequately describe the relevant properties of loads, stiffness, displacement, satisfactorily account for the local system, effects of time dependency, damping, and inertia.

1.1.4 Two sets of design load combinations, a) and b) shall be checked. Partial load factors for ULS checks of self-elevating units according to the present standard are given in Table 1.

Table 1 Load factors - ultimate limit states

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

1) If the load is not well defined with an upper possible limit, e.g. masses with certain uncertainty, the coefficient should be increased to 1.3.

1.1.5 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 and variable functional loads, a load factor of 1.0 shall be used in load combination a) where this gives the most unfavourable response.

1.1.6 The material factor γ_M for ULS yield check should be 1.15 for steel structural elements. Material factors γ_M for ULS buckling checks and bolt connections are given in DNVGL-OS-C101 Ch.2 Sec.4. Material factors γ_M for ULS weld connections are given in DNVGL-OS-C101 Ch.2 Sec.8.

1.2 Global capacity

1.2.1 Gross scantlings may be utilised in the calculation of hull structural strength, provided a corrosion protection system in accordance with DNVGL-OS-C101 Ch.2 Sec.9 is installed and maintained.

1.2.2 Ultimate strength capacity check shall be performed for all structural members contributing to the global and local strength of the self-elevating unit. The structures to be checked include, but are not limited to, all plates and continuous stiffeners in the following:

- main load bearing plating in mat and spudcan type footings
- all leg members in truss type legs
- outer plating in column type legs
- jackhouse and supporting structure
- main load-bearing bulkheads, frameworks and decks in the hull structure
- girders in the hull structure.

2 Structural capacity

2.1 General

2.1.1 Design principles for strength analysis are given in DNVGL-OS-C101 Ch.2 Sec.4 and DNVGL-RP-C104.

2.1.2 Structural members shall be checked for the most unfavourable combinations of loadings. Girders, pillars, bulkheads, decks and other plate panels shall be checked for relevant combinations of global and local stresses. Buckling strength analysis shall be based on the characteristic buckling strength for the most unfavourable buckling mode.

Guidance note:
Acceptable calculation methods with respect to buckling strength are given in DNVGL-RP-C201, DNV-RP-C202 and DNV Classification Notes 30.1 Sec.2.

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2.1.3 Initial imperfections in structural members shall be accounted for. For lattice leg structure this will include imperfections for single beam elements as well as for complete leg assembly.

2.2 Footing strength

2.2.1 In the elevated condition account shall be taken of the loads transferred from the legs and the corresponding seabed reaction. The bottom mat or spudcan structure shall be designed to facilitate proper diffusion of these loads.

2.2.2 High stress concentrations at the connection between leg and mat or spudcan shall be avoided as far as possible.

2.2.3 The effect of an uneven distribution of critical contact stresses over the foundation area shall be examined taking into account a maximum eccentricity moment from the soil resulted from [2.2.4], uneven seabed conditions and scouring.

2.2.4 The strength checks for the spudcan, the leg-to-spudcan connections and the two lowest leg bays (lattice legs) for separate type spudcans should normally not be based on lower loads than given below:

i) The design load F_{vd} is evenly distributed over 50% of the bottom area:

$$M_{ed} = 0.425 F_{vd} R \text{ and } q_d = \frac{F_{vd}}{0.5\pi R^2}, \text{ where}$$

q_d = design contact pressure

M_{ed} = design eccentricity moment

F_{vd} = maximum design axial load in the leg accounting for functional loads and environmental overturning loads, including load factors

R = equivalent radius of spudcan contact area

ii) The design load Fvd is concentrically distributed over a range of bearing areas, from the minimum design penetration (supported on spudcan tip) up to and including full spudcan bottom area.

iii) If elevated condition is designed based on Pinned leg footings: The spudcan and the leg-to-spudcan connections are to be designed for the maximum vertical reaction and the associated horizontal reaction in conjunction with 35% of the maximum calculated moment at the lower guide (to account for the eccentric effects of possible scour and uneven bottom conditions) acting in the most unfavourable direction. The maximum lower guide bending moment is to be calculated with pin-ended conditions.

iv) If elevated condition is designed based on moment fixity at leg footings:

  a) The maximum vertical reaction, in conjunction with the associated horizontal reaction and spudcan-soil fixity moment, acting in the most unfavourable direction.
  b) The maximum spudcan-soil fixity moment in conjunction with the associated vertical and horizontal reactions, acting in the most unfavourable direction.

The design values in (i) to (iv) used as basis for design of the spudcan and lower leg shall be defined in the design basis or design brief, and stated in the unit's Operation Manual.

The design moments and soil pressures above are based on a relative homogenous seabed, for example for sand or clay seabed. Local stiff soil supporting in the bottom plate outside the strong tip should be avoided. It is assumed that this will be evaluated in the sea bed surveys in connection with site specific assessments when the unit is used on specific locations.

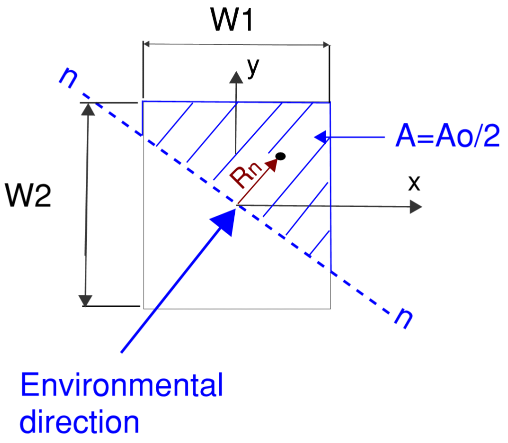
Guidance note:

Cases (i) and (ii) above are always to be checked together with one of the cases (iii) or (iv). Case (iii) or (iv) is checked based on the leg footing assumption used in design.

For rectangular shaped spudcans of area (A_o), the design eccentricity moment may be taken as: $M_{ed} = F_{vd} \times R_n$.

R_n: Depending on weather direction, i.e. the radius (R_n) determined on basis of the centre of gravity of half of the spudcans total foot print area (A_o).

Corresponding deign contac pressure: $q_d = 2\frac{F_{vd}}{A_o}$, where Ao= W1 × W2 see sketch below.



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For other types of bottom support, e.g. mats special considerations should be made.

2.2.5 For internal compartments which are not freely vented to the sea when the mat or spudcan is resting on the seabed, the design loads shall include a head of water equal to the design water level as well as any effects of wave pressure.

2.3 Leg strength

2.3.1 The boundary conditions for the legs at the seabed shall be varied within realistic upper and lower limits when the scantlings of the legs are determined. The variation in boundary conditions shall take into account uncertainties in the estimation of soil properties, non-linear soil-structure interaction, effects due to repeated loadings, possible scouring, etc.

2.3.2 When determining the forces and moments in the legs, different positions of the hull supports along the legs shall be considered.

2.3.3 Due attention shall be paid to the position and duration of load transfer between the leg and hull, including the shear force in the leg between supporting points in the hull structure.

2.3.4 Lattice-type legs shall be checked against overall buckling, buckling of single elements and punching strength of the nodes, see DNVGL-OS-C101 Ch.2 Sec.4.

2.3.5 Bottom impact forces occurring during installation and retrieval conditions shall be satisfactorily accounted in the design.

Guidance note:
A simplified analytical methodology relevant to installation and retrieval conditions is described in DNVGL-RP-C104.

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2.4 Jackhouse support strength

Special attention shall be paid to the means for the leg support, the jackhouses, the support of the jackhouse to the main hull, and the main load transfer girders between the jackhouses.

2.5 Hull strength

Scantlings of the hull shall be checked for the transit conditions with external hydrostatic pressure and inertia forces on the legs as well as for the pre-loading and elevated conditions, see DNVGL-OS-C101 Ch.2 Sec.4.

3 Scantlings and weld connections

Minimum scantlings for plate, stiffeners and girders are given in DNVGL-OS-C101 Ch.2 Sec.4.

The requirements for weld connections are given in DNVGL-OS-C101 Ch.2 Sec.8.

SECTION 5 FATIGUE LIMIT STATES (FLS)

1 General

1.1 General

1.1.1 General requirements for the FLS are given in DNVGL-OS-C101 Ch.2 Sec.5. Guidance concerning fatigue life calculation may be found in DNVGL-RP-C203 and DNVGL-RP-C104 Sec.7.

1.1.2 The design fatigue life of the unit shall be minimum 20 years.

1.1.3 For units intended to follow normal inspection requirements according to class requirements, i.e. 5 yearly inspections in dry dock or sheltered waters, a Design Fatigue Factor (DFF) of 1.0 may be applied for accessible members. For not accessible members DFF shall be applied to structural elements according to the principles in DNVGL-OS-C101.

1.1.4 Units intended to stay on location for prolonged survey period, i.e. without planned dry dock or sheltered water inspection, shall comply with the requirements given in App.A.

1.1.5 Assumptions related to the resistance parameters adopted in the fatigue design, e.g. with respect to corrosion protection, shall be consistent with the unit's in-service inspection and maintenance plans (see DNVGL-RP-C203).

1.1.6 Local effects, for example, due to:

- slamming
- sloshing
- vortex shedding
- dynamic pressures

shall be included in the fatigue damage assessment when relevant.

1.1.7 In the assessment of fatigue resistance, relevant consideration shall be given to the effects of stress concentrations, including those occurring as a result of:

- fabrication tolerances, including due regard to tolerances in way of connections involved in fabrication sequences or section joints
- cut-outs
- details at connections of structural sections (e.g. cut-outs to facilitate construction welding)
- attachments.

1.1.8 Local, detailed finite element analysis of critical connections (e.g. leg and footing connection) should be performed in order to identify local stress distributions, appropriate SCFs, and/or extrapolated stresses to be utilised in the fatigue evaluation. Dynamic stress variations through the plate thickness shall be checked and considered in such evaluations when relevant, see DNVGL-RP-C203 Sec.2 for further details.

1.1.9 Principal stresses (see DNVGL-RP-C203 Sec.2.2) should be utilised in the evaluation of fatigue responses.

2 Fatigue analysis

2.1 General

The required models and methods for fatigue analysis for self-elevating units or jack-ups are dependent on type of operation, environment and design type of the unit. For units operating at deeper waters where the first natural periods are in a range with significant wave energy, e.g. for natural periods higher than 3 s, the dynamic structural response need to be considered in the fatigue analysis.

2.2 World-wide operation

For world wide operation the analyses shall be performed utilising environmental data (e.g. scatter diagram, spectrum) given in DNV-RP-C205. The North Atlantic scatter diagram shall be utilised.

2.3 Restricted operation

The analyses shall be performed utilising relevant site specific environmental data for the area(s) the unit will be operated. The restrictions shall be described in the operation manual for the unit.

2.4 Simplified fatigue analysis

2.4.1 Simplified fatigue analysis may be performed in order to establish the general acceptability of fatigue resistance, or as a screening process to identify the most critical details to be considered in a stochastic fatigue analysis, see [2.5].

2.4.2 Simplified fatigue analyses should be performed utilising appropriate conservative design parameters. Normally a two-parameter, Weibull distribution (see DNVGL-RP-C203 Sec.5.) may be utilised to describe the long-term stress range distribution, giving the following extreme stress range:

$$\Delta\sigma_{n_0} = \frac{(ln(n_0))^{\frac{1}{h}}}{(DFF)^{\frac{1}{m}}}\left[\frac{\bar{a}}{n_0\Gamma\left(1+\frac{m}{h}\right)}\right]^{\frac{1}{m}}$$

n_0 = the total number of stress variations during the lifetime of the structure

$\Delta\sigma_{n_0}$ = extreme stress range that is exceeded once out of n_0 stress variations.

The extreme stress amplitude

$\Delta\sigma_{ampl\_n_0}$ *is thus given by* $(\Delta\sigma_{n_0}/2)$

h = the shape parameter of the Weibull stress range distribution, see e.g. DNVGL-RP-C104 Sec.7.9

a = the intercept of the design S-N curve with the log N axis, see DNVGL-RP-C203

$\Gamma(1+m/h)$ = is the complete gamma function, see DNVGL-RP-C203

m = the inverse slope of the S-N curve, see DNVGL-RP-C203

DFF = Design Fatigue Factor.

2.4.3 When the simplified fatigue evaluation involves utilisation of the dynamic stress responses resulting from the global analysis, e.g. 100 years, the response should be suitably scaled to the return period of the basis, minimum fatigue life of the unit. In such cases, scaling may be undertaken utilising the appropriate factor found from the following:

$$\Delta\sigma_{n_0} = \Delta\sigma_{n_i}\left[\frac{log\,n_0}{log\,n_i}\right]^{\frac{1}{h}}$$

n_i = the number of stress variations in i years appropriate to the global analysis

$\Delta\sigma_{n_i}$ = the extreme stress range that is exceeded once out of n_i stress variations.

2.5 Stochastic fatigue analysis

2.5.1 Stochastic fatigue analyses shall be based upon recognised procedures and principles utilising relevant site specific data or world wide environmental data.

2.5.2 Simplified fatigue analyses should be used as a "screening" process to identify locations for which a detailed, stochastic fatigue analysis should be undertaken.

2.5.3 Fatigue analyses shall include consideration of the directional probability of the environmental data. Providing that it can be satisfactorily checked, scatter diagram data may be considered as being directionally specific. Scatter diagram for world wide operations (North Atlantic scatter diagram) is given in DNV-RP-C205. Relevant wave spectra and energy spreading shall be utilised. Normally a Pierson-Moskowitch spectrum and a $\cos^4$ spreading function is utilised in the evaluation of self-elevating units. Further details are given in DNVGL-RP-C104.

2.5.4 Structural response shall be determined based upon analyses of an adequate number of wave directions. Generally a maximum radial spacing of 15° should be considered. Transfer functions should be established based upon consideration of a sufficient number of periods, such that the number, and values of the periods analysed:

- adequately cover the wave data
- satisfactorily describe transfer functions at, and around, the wave ‘cancellation’ and ‘amplifying’ periods (consideration should be given to take account that such ‘cancellation’ and ‘amplifying’ periods may be different for different elements within the structure)
- satisfactorily describe transfer functions at, and around, the relevant excitation periods of the structure.

2.5.5 Stochastic fatigue analyses utilising simplified structural model representations of the unit (e.g. a space frame model) may form basis for identifying locations for which a stochastic fatigue analysis, utilising a detailed model of the structure, should be performed (e.g. at critical intersections).

SECTION 6 ACCIDENTAL LIMIT STATES (ALS)

1 General

1.1 General

1.1.1 ALS shall be assessed for relevant accidental events. Principally satisfactory protection against accidental damage should be obtained by the following two means:

- low damage probability
- acceptable damage consequences.

Further information about safety principles and arrangements with respect to design towards accidental events are given in DNVGL-OS-A101.

1.1.2 The capability of the structure to redistribute loads during and after accidents should be considered when designing the unit.

After damage requiring immediate repair, the unit is to resist functional and environmental loads corresponding to a return period of one year.

Guidance note:
Energy absorption by impact types of accidental events requires the structure to behave in a ductile manner. Measures to obtain adequate ductility are:

- make the strength of connections of primary members in excess of that of the member
- provide redundancy in the structure, so that alternate load redistribution paths may be developed
- avoid dependence on energy absorption in slender members with a non-ductile post buckling behaviour
- avoid pronounced weak sections and abrupt change in strength or stiffness
- use non-brittle materials.

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1.1.3 The loads and consequential damage due to accidental events such as:

- collision
- dropped objects (e.g. from crane handling)
- fire
- explosion
- unintended flooding during transit

shall be considered to avoid loss of floatability or capsizing during transit, on-bottom instability in elevated operation or survival conditions, pollution or loss of human life. Requirements for compartmentation and floating stability are given in DNVGL-OS-C301.

1.1.4 Analysis and requirements to satisfy strength criteria are given in the present standard and in DNVGL-OS-C101 Ch.2 Sec.6.

1.1.5 The damage consequences of accidental events other than those listed in [1.1.3] shall if relevant be specially considered in each case applying an equivalent standard of safety.

2 Collisions

2.1 General

2.1.1 Collision by a supply vessel against a leg of a self-elevating unit shall be considered for all elements that may be hit either by sideways, bow or stern collision. The vertical extent of the collision zone shall be based on the depth and draught of visiting supply vessels.

Guidance note:
Simplified procedures for calculation of vessel impact on self-elevating unit legs may be found in DNVGL-RP-C104 Sec.8.

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2.1.2 A collision will normally only cause local damage of the leg. However, the global strength and overturning stability of the unit shall also be checked. With lattice type legs the damaged chord or bracing and connections may be assumed to be non-effective for check of residual strength of the unit after collision.

2.1.3 Assessment of dynamic effects and non-linear structural response (geometrical and material) should be performed as part of the impact evaluation.

3 Dropped objects

3.1 General

3.1.1 Critical areas for dropped objects shall be determined on the basis of the actual movement of potential dropped objects (e.g. crane or other lifting operation mass) 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.

3.1.2 A dropped object impact against a chord or bracing will normally cause complete failure of the element or its connections. These parts should then be assumed to be non-effective for the check of the residual strength of the unit after the dropped object impact.

3.1.3 Critical areas for dropped objects shall be determined on the basis of the actual movement of loads assuming a minimum drop direction within an angle with the vertical direction:

- 5° in air
- 15° in water.

Dropped objects shall be considered for vital structural elements of the unit within the areas given above.

4 Fires

4.1 General

4.1.1 A structure that is subjected to a fire shall have sufficient structural capacity until completed evacuation. The following fire scenarios shall be considered:

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

4.1.2 Further requirements concerning accidental limit state events involving fire is given in DNVGL-OS-A101.

4.1.3 Structural assessment with respect to fire may be omitted provided fire protection requirements made in DNVGL-OS-D301 are met.

5 Explosions

5.1 General

5.1.1 With respect to design loads resulting from explosions, one or more of the following design philosophies are relevant:

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

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

5.1.3 Structural support of blast walls and the transmission of the blast loads into main structural members shall be evaluated when relevant.

6 Unintended flooding

6.1 General

6.1.1 For the transit condition, structural effects as a results of heeling of the unit after damage flooding as described in DNVGL-OS-C301 shall be accounted for in the structural strength assessment. Boundaries which shall remain watertight after unintended flooding shall be checked for external water pressure.

6.1.2 The unit shall be designed for environmental condition corresponding to 1 year return period after damage flooding, see DNVGL-OS-C101.

Guidance note:
The environmental loads may be disregarded if the material factor γ_M is set to 1.33.

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6.1.3 Local exceeding of the structural resistance level may be acceptable provided redistribution of forces due to yielding, buckling and fracture is accounted for.

6.1.4 Wave pressure, slamming forces and green sea shall be accounted for in all relevant areas. Local damage may be accepted provided progressive structural collapse and damage of vital equipment is avoided.

6.1.5 Position of air-intakes and openings to areas with vital equipment which need to be available during an emergency situation e.g. emergency generators, shall be considered taking into account the wave elevation in a 1 year storm condition.

SECTION 7 SPECIAL CONSIDERATIONS

1 General

Some special items to be considered in relation to robust design and safe operation of self-elevating units are described in this section.

2 Pre-load capacity

2.1 General

2.1.1 Minimum required pre-load capacity with reference to the global strength and the seabed design assumptions for units with separate footings shall be accounted for in the design.

> **Guidance note:**
> It should be noted that actual soil conditions at operation sites may require higher pre-loads than those set up by the leg strength, e.g. to secure against sudden penetration.
>
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2.1.2 The assessment of pre-load capacity given in [2.1.3] and [2.1.4] should be performed with the characteristic functional and environmental loads, i.e. without load factors.

2.1.3 Units with separate footings which are designed for a pinned leg-bottom connection are to have a capability to pre-load the legs up to at least 100% of the maximum design axial loads in the legs accounting for functional loads and environmental overturning loads.

For units that shall operate in soil conditions where exceeding of the soil capacity will result in large penetrations, a pre-load higher than the maximum survival axial load case axial load will be required. Examples of such soils are generally soft clays, or conditions where hard soils are underlain by softer soils and there is a risk of a punch-through failure.

A recommended approach for determination of required pre-load is given in DNV Classification Notes 30.4.

2.1.4 Units with separate footings where the design is based on a specified moment restraint of the legs at the seabed are to have a capability to pre-load the legs up to a level which shall account for the maximum design axial loads in the legs due to functional loads and environmental overturning loads plus the specified moment restraint at the bottom.

In lieu of a detailed soil/structure interaction analysis the required pre-load may in this case be determined by the following factor:

For cohesive soils, e.g. clay:

$$\frac{F_{VP}}{F_V} = \frac{1}{1 - \dfrac{2\sqrt{A}}{\pi R^2}\dfrac{M_U}{F_V}}$$

For cohesionless soils, e.g. sand:

$$\frac{F_{VP}}{F_V} = \left(\frac{1}{1 - \dfrac{2\sqrt{A}}{\pi R^2}\dfrac{M_U}{F_V}}\right)^2$$

F_{VP} = minimum required pre-load on one leg

F_V = maximum design axial load in the leg accounting for functional loads and environmental overturning loads

M_U = minimum design moment restraint of the leg at the seabed

A = area of spudcan in contact with soil

R = equivalent radius of spudcan contact area.

2.1.5 For cohesionless soils, the above requirement to pre-load capacity may be departed from in case where a jetting system is installed which will provide penetration to full soil contact of the total spudcan area.

2.1.6 The potential of scour at each location should be evaluated. If scour takes place, the beneficial effect of pre-loading related to moment restraint capacity may be destroyed. At locations with scour potential, scour protection should normally be provided in order to rely on a permanent moment restraint.

3 Overturning stability

3.1 General

3.1.1 The safety against overturning is determined by the equation:

$$\gamma_s \leq \frac{M_s}{M_O}$$

M_O = overturning moment, i.e. caused by environmental loads
M_S = stabilising moment, i.e. caused by functional loads
γ_S = safety coefficient against overturning
= 1.1.

Guidance note:
It is allowed to use load factor = 1.0 on all loads contributing to M_S and M_O in the overturning stability check above.

If the design is based on a specified moment restraint of the legs at the seabed, the calculated leg footing moments are not to be included in M_S above.

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3.1.2 The stabilising moment due to functional loads shall be calculated with respect to the assumed axis of rotation, and with the unit's lateral deflections taken into consideration.

For self-elevating units with separate footings the axis of rotation may, in lieu of a detailed soil-structure interacting analysis, be assumed to be a horizontal axis intersecting the axis of two of the legs. It may further be assumed that the vertical position of the axis of rotation is located at a distance above the spudcan tip equivalent to the lesser of:

- half the maximum predicted penetration or
- half the height of the spudcan.

For self-elevating units with mat support, the location of the axis of rotation may have to be specially considered.

3.1.3 The overturning moment due to wind, waves and current should be calculated with respect to the axis of rotation defined in [3.1.2].

The overturning stability shall be calculated for the most unfavourable direction and combination of environmental and functional loads according to the load plan for the unit. The dynamic amplification of the combined wave and current load effect shall be taken into account.

3.1.4 The lower ends of separate legs shall be prevented from sideway slipping by ensuring sufficient horizontal leg and soil support.

4 Air gap

4.1 General

4.1.1 Clearance between the hull structure and the wave crest is normally to be ensured for the operating position.

4.1.2 The requirement to the length of the leg is that the distance between the lower part of the deck structure in the operating position and the crest of the maximum design wave, including astronomical and storm tides, is not to be less than 10% of the combined storm tide, astronomical tide and height of the design wave above the mean low water level, or 1.2 m, whichever is smaller. Expected subsidence of the structure shall be taken into account.

4.1.3 Crest elevation above still water level is given in DNVGL-RP-C104 Sec.10.

4.1.4 A smaller distance may be accepted if wave impact forces on the deck structure are taken into account in the strength and overturning analysis.

4.1.5 Clearance between the structure and wave shall be ensured in floating condition for appurtenances such as helicopter deck, etc.

CHAPTER 3 CLASSIFICATION AND CERTIFICATION

SECTION 1 CLASSIFICATION

1 General

1.1 Introduction

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

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

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

Table 1 DNV GL Rules for classification - Offshore units

Reference	*Title*
DNV-RU-OU-0101	Offshore drilling and support units
DNV-RU-OU-0102	Floating production, storage and loading units
DNV-RU-OU-0103	Floating LNG/LPG production, storage and loading units
DNV-RU-OU-0104	Self-elevating units

Guidance note:
The RU-OU-0104 provides an overview of convectional self-elevating units (i.e. independent legs, not self-propelled and with rack and pinion jacking system). All other design alternatives are covered by DNVGL-RU-OU-0101.

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1.2 Application

1.2.1 It is assumed that the units will comply with the requirement for retention of the class as defined in the above listed service specifications.

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

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

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

1.2.5 Technical requirements given in DNVGL-OS-C101 Ch.2 Sec.7, related to serviceability limit states, are not mandatory as part of classification.

1.2.6 Technical requirements given in DNVGL-OS-C101 related to design for earthquakes are not mandatory as part of classification.

1.2.7 It is the operator's responsibility to secure that loads/moments on the legs from gravity, wave and wind loads do not exceed (documented) design limitations as applied in line with Ch.2 Sec. 2 (see also Rules for offshore drilling and support units Ch.1 Sec. 5 [1.1.2]).

1.3 Documentation

1.3.1 Documentation for classification shall be in accordance with the NPS DocReq (DNV GL Nauticus Production System for documentation requirements) and DNVGL-RP-A201.

1.3.2 Limiting environment conditions and design capacities as used for basis of class approval shall be documented in the Appendix to class (ref. Ch.2 Sec. 2. See also Rules for offshore drilling and support units Ch.1 Sec. 4 [3.1.6]).

Guidance note:
Statutory regulations may require these design limitations to be included in the operation manual, e.g. MODU code 14.1.2.8.

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APPENDIX A PERMANENTLY INSTALLED SELF-ELEVATING UNITS

1 Introduction

1.1 General

1.1.1 The requirements and guidance given in this Appendix are supplementary requirements for units that are intended to stay on location for prolonged periods, normally more than 5 years.

1.1.2 The requirements apply to all types of self-elevating units.

1.1.3 Permanently installed self-elevating units shall be designed or documented for the site specific environmental and soil conditions. Fatigue properties and facilities for survey on location shall be specially considered.

1.1.4 Adequate corrosion protection shall be implemented to cover the entire prolonged operation period.

2 Fatigue

2.1 General

2.1.1 Design Fatigue Factors (DFF) are introduced as fatigue safety factors. DFF shall be applied to structural elements according to the principles in DNVGL-OS-C101.

2.1.2 Fatigue safety factors applied for permanently installed self-elevating units shall be given dependent on the criticality of the detail and accessibility for inspection and repair. Special considerations should be made for the leg in the splash zone, submerged parts legs and spudcan, and possible inaccessible parts of the spudcan.

2.1.3 The fatigue analysis should focus on members that are essential to the overall structural integrity of the unit.

Fatigue susceptible areas may include:

- the leg to hull holding system
- the leg members and joints in the vicinity of the upper and lower guides
- the leg members and joints in the splashing zone
- the leg members and joints in the lower part of the leg near the spudcan
- the spudcan to leg connection.

Guidance note:
See DNVGL-OS-C101 Ch.2 Sec.9 [2.2] with respect to vertical extent of splash zone.

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3 Inspection and maintenance

3.1 Facilities for survey

3.1.1 Surveys may be carried out on location based on agreed procedures outlined in a maintenance system and survey arrangement, without interrupting the function of the unit. The following matters shall be taken into consideration to be able to carry out surveys on location:

- arrangements and methods for survey of hull, legs and seabed foundation structure
- corrosion protection of hull, legs and seabed foundation structure
- underwater cleaning facilities.

3.1.2 The In Service Inspection program (IIP) should reflect possible stress concentrations in critical areas, fatigue criticality, and the previous operational and inspection histories.