



OFFSHORE STANDARD

DNV-OS-H102

Marine Operations, Design and Fabrication

JANUARY 2012

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FOREWORD

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- *Standards*. Technical requirements.
- *Recommended Practices*. Guidance.

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- B) Materials Technology
- C) Structures
- D) Systems
- E) Special Facilities
- F) Pipelines and Risers
- G) Asset Operation
- H) Marine Operations
- J) Cleaner Energy
- O) Subsea Systems

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CHANGES

General

This is a new document in a series of documents replacing “Rules for Planning and Execution of Marine Operations” (1996/2000). This Standard replaces Pt.1 Ch.3 Sec.3 and Pt.1 Ch.4 (all sections) in the referred Rules.

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SECTION 1 INTRODUCTION

A. Application

A 100 General

101 This standard gives general requirements and recommendations for selection of loads, design (verification) and fabrication of structures involved in marine operations.

102 The requirements in this standard are intended applied for:

- design of temporary structures
- verification of objects for temporary phases
- verification of vessels
- design of reinforcements in objects and vessels

for a specific marine operation carried out according to the VMO Standard, see 201.

Guidance note:

Design of objects, other structures or vessels for permanent phases is not covered by this Standard. However, any design modifications required due to verification of the objects for the temporary (marine operation) phases are covered.

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A 200 Complementary standards and codes

201 All the DNV offshore standards (including this) covering marine operation, i.e. DNV-OS-H101, DNV-OS-H102 and DNV-OS-H201 through DNV-OS-H206, will be referred to as the VMO Standard.

202 General recommendations for planning of marine operations and for establishing environmental conditions are given in DNV-OS-H101.

203 Operation specific requirements and recommendations are given in DNV-OS-H201 through DNV-OS-H206.

204 This standard shall be used together with recognised codes and standards for design and fabrication, e.g. the DNV offshore standards DNV-OS-C101 and DNV-OS-C401. Other recognised codes or standards may also be applied.

Guidance note:

By recognised codes or standards are meant national or international codes or standards applied by the majority of professional people and institutions in the marine and offshore industry.

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205 In case of conflict between other codes or standards and this document, the latter shall override if this provide a higher level of safety or more rigorous requirements to serviceability.

206 Combining requirements in different codes should be done with due consideration to the desired safety level.

A 300 Objectives and conditions

301 The general conditions for using this Standard are stated in DNV-OS-H101, Sec.1 B200.

The objectives for this standard are stated in DNV-OS-H101, Sec.1 A.

302 Alternative methods may be used, see DNV-OS-H101, Sec.1 A300.

B. References

B 100 Referenced Documents

101 For the OS numbering system and cross references, see DNV-OS H101, Sec.1 C101 and C102.

102 The text in this standard includes references to the documents listed in Table 1-1. If indicated where the reference is given, the text in the referenced service document shall be considered as a requirement of this standard.

Guidance note:

I.e. it will be stated in each specific service document if the referenced document shall be considered a requirement in the same way as the requirements in this standard. If not stated, the referenced document is (could be) considered informative only.

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Table 1-1 References including requirements

Reference	Revision	Title
DNV-OS-C101	April 2011	Design of Offshore Steel Structures, General
DNV-OS-C401	Oct. 2010	Fabrication and Testing of Offshore Structures
DNV-OS-H101	Oct. 2011	Marine Operations, General
DNV-OS-H201	See note below	Load Transfer Operations
DNV-OS-H202	See note below	Sea Transports
DNV-OS-H203	See note below	Transit and Positioning of Mobile Offshore Units
DNV-OS-H204	See note below	Offshore Installation Operations
DNV-OS-H205	See note below	Lifting Operations
DNV-OS-H206	See note below	Sub Sea Operations
<p>Note: The DNV-OS H-series are planned issued in the period October 2011 through April 2012. Each OS will enter into force at the date of publication. Until the OS is published the relevant requirements in “DNV - Rules for Planning and Execution of Marine Operations” shall be considered governing.</p> <p style="text-align: center;">---e-n-d---of---N-o-t-e---</p>		

103 The referred requirements are based on the document revisions indicated in Table 1-1. Any modifications of the referred requirements in later revisions of references shall be considered and normally used unless otherwise agreed.

Guidance note:

The agreement should be made between involved (normally through contracts) parties as Company, Contractors and MWS.

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104 The documents listed in Table 1-2 include information that through references in this text, clarify and indicate acceptable methods of fulfilling the requirements given in this standard.

105 The latest revision of the informative references should normally be considered.

Table 1-2 Informative references

Reference	Title
DNV-OS-A101	Safety Principles and Arrangements
DNV-OS-B101	Metallic Materials
DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
DNV-RP-C204	Design Against Accidental Loads
DNV-RP-H101	Risk Management in Marine- and Subsea Operations
DNV-RP-H102	Marine Operations during Removal of Offshore Installations
DNV-RP-H103	Modelling and Analysis of Marine Operations
DNV-RP-C205	Environmental Conditions and Environmental Loads
DNV CN 30.7	Fatigue Assessment of Ship Structures
DNV Ship Rules	Rules for Classification of Ships
DNV 2.22	Standard for Certification of Lifting Appliances
DNV 2.7-3	Standard for Certification of Portable Offshore Units
NORSOK M-101	Structural Steel Fabrication
NORSOK M-120	Material Data Sheets for Structural Steel
NORSOK N-003	Action and Action Effects
NORSOK N-004	Design of Steel Structures
EN 1993	Eurocode 3: Design of steel structures

C. Definitions

C 100 Verbal forms

101 Verbal forms of special importance are defined as indicated below in this standard.

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

Should: Indicates 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. Other possibilities may be applied subject to agreement.

C 200 Terminology

201 Terms of special importance are defined as indicated below in this standard.

Characteristic condition: A condition which has a defined probability of being exceeded within a defined time period.

Characteristic load: The reference value of a load to be used in the determination of load effects. See also Table 3-1.

Characteristic resistance: The reference value of (structural) resistance to be used in determination of the design resistance.

Characteristic strength: The nominal value of material strength to be used in the determination of characteristic (structural) resistance. The characteristic material strength is normally based upon a 5% fractile in the lower end of the distribution function for material strength.

Design: An activity to create or form layouts, concepts, arrangements or structures.

Design criteria: The criteria applied for verification of systems, equipment, structures etc. for the planned marine operation.

Design load: The design value of a load found by combining the relevant characteristic load(s) multiplied by the appropriate load factor(s).

Design load effect: The load effects calculated on the basis of the design load.

Design resistance: The resistance to be used in the safety evaluation of a structure or part of a structure, i.e., characteristic resistance divided by the material factor.

Design strength: The material strength to be used in the determination of the design resistance of a structure or part of a structure, i.e., characteristic strength divided by the material factor.

Dynamic load: A load or the part of a load that is varying with a plus/minus amplitude from a mean value during a marine operation.

Dynamic effect: Dynamic response of a structural element causing similar structural stress effects as a dynamic load.

Limit state: A state in which a structure ceases to fulfil its design requirements.

Load factor: Factor by which the characteristic load is multiplied to obtain the design load.

Load effect: Effect of load on the structure, such as stresses and stress resultants (internal forces and moments), strain, deflections and deformations.

Recognised code or standard: National or international, code or standard, which is recognised by the majority of professional people and institutions in the marine and offshore industry.

Static load: A load (or the part of a load) that may be considered constant during a (part of a) marine operation.

Temporary structure: A structure made (only) to fulfil a clearly defined purpose during a planned marine operation.

Verification: Activity to confirm that a design, product/equipment, structure or procedure complies with defined standards and/or specifications. Verification may be documented by calculations, analysis, certificates, survey reports and inspection reports.

C 300 Symbols

The list below defines the symbols used in this standard:

A	Accidental load, see Sec.3 B600
ALS	Accidental limit states
CoG	Centre of gravity
D	Deformation load, see Sec.3 B400
E	Environmental load, see Sec.3 B500
F	Load
F_{act}	Characteristic load
F_d	Design load
F_{def}	Maximum loads due to deflections
$F_{i,mean}$	Characteristic static load components
$F_{i,amp}$	Amplitude of dynamic load components
F_{mot}	Maximum inertia loads due to motion
F_{tot}	Total design load
F_{wx}	Wind force in x direction
F_{wy}	Wind force in y direction
F_x	Inertia force in x direction

F_y	Inertia force in y direction
F_z	Inertia force in z direction
F _{LS}	Fatigue limit states
f_c	Characteristic strength
f_{cr}	Critical buckling stress
f_d	Design strength
f_e	Critical elastic buckling stress
f_y	Yield strength
G	Permanent loads
HAZOP	Hazard and operability study, See DNV-RP-H101
H_s	Significant wave height
$H_{s,c}$	Characteristic significant wave height
Q	Variable functional load
LRFD	Load- and resistance factor design
NDT	Non-destructive testing. NDT is also called NDE (Non-destructive examination) in some codes
P	Permanent load
PWHT	Post weld heat treatment
q	Usage factor
q_o	Permissible usage factor
R	Resistance
RAO	Response amplitude operator
R_d	Design resistance
R_c	Characteristic resistance
S	Loading effect
S_d	Design load effect
SLS	Serviceability limit states
SMYS	Specified minimum yield stress
T_z	Mean zero up-crossing period
ULS	Ultimate limit states
UT	Ultrasonic testing
W	Load due to self-weight
γ_f	Load factor
γ_m	Material factor
$\gamma_{m,uls}$	Material factor for ULS
λ	Reduced slenderness
μ_{ld}	Lower bound design friction factor
μ_{lc}	Characteristic lower bound friction factor
μ_{ud}	Upper bound design friction factor
μ_{uc}	Characteristic upper bound friction factor.

SECTION 2 DESIGN PRINCIPLES

A. Introduction

A 100 Design methods

101 This section describes general design considerations and the following design methods, see D:

- load- and resistance factor design method
- permissible stress method
- probability based design.

102 The design process may be assisted by testing, see E.

103 This standard is based on the load- and resistance factor design method referred to as the LRFD method.

A 200 Aim of the design

201 The design shall be such that acceptable safety is achieved during the marine operations. Acceptable safety shall normally be provided against:

- loss of human lives or injury of human health
- loss and damage of property
- pollution or other damage of the environment.

B. Design Considerations

B 100 General

101 The overall design shall be performed with due consideration to the execution of marine operations.

102 Structures shall be robustly designed such that an incident does not lead to consequences disproportional to the original cause.

103 Simple load and stress patterns shall be aimed for in the design.

104 Structural elements should be fabricated according to the requirements given in DNV-OS-C401 or other recognized standard.

B 200 Compressed air

201 Structures shall normally not be designed to rely on compressed air such as internal overpressure in buoyant members or under-base air cushions to obtain sufficient safety against structural failure.

Guidance note:

The above requirement may be exempted from in special cases upon thorough consideration of the systems involved, including back-up systems, redundancy, failure consequences, duration of the operation, etc.

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B 300 Structural details

301 Structural components and details should be so designed that the structure as far as possible will behave in a ductile manner.

Guidance note:

A structure or a structural element, may behave brittle even if it is made of ductile materials e.g. when there are sudden changes in section properties, or in low temperatures.

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302 Connections should be designed with smooth transitions and proper alignment of elements. Stress concentrations should as far as possible be avoided.

303 Transmission of tensile stresses through the thickness of rolled steel elements (plates, beams etc.) should as far as possible be avoided unless materials with proven (tested) z-quality is applied.

Guidance note:

NDT (UT check of lamellar tearing) may also be found acceptable as a means to document the material. See also Sec.6 B305.

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304 Structural details above the waterline shall be so arranged that water will not be trapped in the structure if this may cause damages such as e.g. rupture due to freezing of the water.

B 400 Inspection

401 To the extent relevant or practicable, access for inspection, maintenance, and repair shall be provided.

402 Instrumentation which gives information on the performance may be used as a supplement to other inspection.

B 500 Existing structures

501 Strength calculations for marine operations will often include verification of existing steel structures including barges (vessels). Possible reduction in design capacity due to e.g.:

- corrosion
- damages
- modifications not shown on drawings,

needs to be considered.

502 Existing structures should normally be inspected in order to assess possible reductions in the design capacity.

Guidance note:

DNV-RP-H102 gives more advice related to existing structures and inspections of these.

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503 Project related strength verifications of vessels should normally be carried out without the class corrosion allowance. I.e. the plate thickness indicated on the drawings should be subtracted the class corrosion allowance.

Guidance note 1:

Based on detailed inspections normally including thickness measurements, of the vessels the above requirement may be disregarded. In case detailed inspections of existing structures in barges are not carried out, a reduction of the plate thickness indicated on barge drawings of minimum 0.2 mm per year from the barge was new is recommended. This indicated value is assumed to account for corrosion on both sides of the plate. For new barges with a proper corrosion protection system, e.g. painting or coating, no thickness reduction need to be considered for the first five years of the barge life.

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Guidance note 2:

The requirements to corrosion allowance to DNV classed vessels may be found in the DNV Ship Rules (Pt.3 Ch.1 Sec.2 D200 in July 2011). Normally an allowance of 3 mm is applicable for the top (within 1.5m) area of the ballast tanks.

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B 600 Protection against accidental damage

601 The structure shall be protected against accidental damage by the following two principles:

- reduction of damage probability
- reduction of damage consequences.

602 Pipes, equipment, structures etc. that if damaged could lead to severe consequences (e.g. accidental flooding, explosion, fire or pollution) shall be protected to minimise the risk of accidental damage.

Guidance note:

Protection may be established e.g. by providing a sheltered location, by local strengthening of the structure, or by appropriate fender systems.

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C. Design Analysis and Criteria

C 100 Analysis

101 The analytic models used for evaluation of loads, responses, structural behaviour and resistance must be relevant considering the design philosophy, type of operation and possible failure modes. They should satisfactorily simulate the behaviour of the structures, its supports, and the environment.

102 Design analyses shall be carried out considering all relevant loads and failure modes, see C200.

103 It shall be thoroughly documented that the results of the design analysis satisfy the relevant requirements and criteria.

Guidance note:

The detailed requirements and criteria depend on the design method used. See e.g. Sec.5 for the LRFD method.

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C 200 Failure modes

201 All relevant failure modes shall be investigated. A failure mode is relevant if it is considered possible and the anticipated consequence(s) of the failure cannot be disregarded.

202 The relevant failure modes may be grouped according to their nature, either as global (total system, see 203) or local (individual members, see 204) modes of failure.

203 Global modes of failure may be:

- structural collapse
- overturning
- sliding
- lift-off
- loss of hydrostatic or hydrodynamic stability
- sinking
- settlement
- free drift.

204 Local modes of failure may be:

- plastic deformation (yield)
- buckling
- fracture
- large deflections
- excessive vibration.

Guidance note:

More information related to relevant (especially for removal operations) failure modes could be found in DNV-RP-H102, Table 2-6.

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D. Design Methods

D 100 LRFD method

101 In the LRFD (load- and resistance factor design) method the target safety is obtained by multiplying or dividing characteristic values (reference values) of loads and structural (or material) resistance by deterministic load and material factors.

102 How partial factors are applied to obtain design values for load and structural resistance and to ensure adequate safety is explained in Sec.5 A400.

103 Characteristic values of loads and structural resistance parameters are defined in Sec.3 and Sec.5 A500 respectively.

D 200 Permissible stress method

201 By the permissible stress method the target safety is obtained by calibrating an inverted safety factor which is applied to the characteristic value of the structural resistance. The inverted safety factor is normally referred to as the permissible usage factor.

Guidance note:

The Permissible Stress Method is also known as Working Stress Design (WSD) method.

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202 Generally the factors should be defined such that the safety level will be equal or greater than obtained with the LRFD method.

Guidance note:

The common used basic usage factors in ULS are 0.6 considering G and Q loads only and 0.8 when (extreme) E loads are included as well.

The graphs in Fig. 1 compare the safety level (i.e. characteristic load/characteristic resistance) applying the LRFD and the "Permissible Stress Method". Usage factors are as indicated above, $\gamma_m = 1.15$, equal characteristic loads and load factors according to Table 5-1 are assumed.

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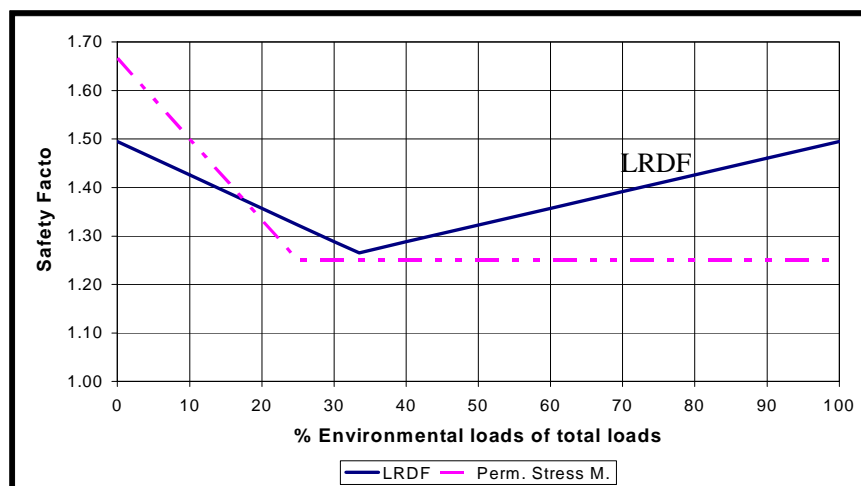


Figure 1
Comparing safety levels

The graphs in Fig. 1 indicate that the safety level obtained by applying a 1/3 allowable stress increase, i.e. from 0.6 to 0.8, due to the presence of E loads, are not generally acceptable. An acceptable safety level may be obtained by increasing the characteristic E loads or decreasing the basic usage factor.

For non-linear problems (e.g. buckling and uplift) an additional reduction in the permissible usage factor may be applicable in order to ensure an acceptable safety level.

D 300 Probabilistic methods

301 The evaluation of safety may be based on probabilistic methods. In these methods calculations are made to determine the probability of failure making use of a probabilistic description of the joint occurrence of the relevant parameters involved, taking into account the true nature of the failure domain. All relevant failure modes shall be considered, see C200.

302 All parameters which are essential in the analysis of an actual failure criterion shall be described as stochastic variables. Such parameters are loads and materials' strength, geometry, imperfections, uncertainties in the failure criterion model used, etc.

303 Probabilistic analyses may be directly used as a design method or it may be used in combination with another method. Particular benefit of this method may be achieved for the determination of partial factors, see D100, to be used in dynamic problems, associated with the determination of design loads for floating and compliant structures.

304 In probabilistic design analyses the design criteria are normally that calculated probabilities of failures shall not exceed specified target probabilities, see also DNV-OS-H101, Sec.1 A.

305 The target probability of failure for an individual structural element shall never be higher than that the target value for the total system will be met.

E. Design Assisted by Testing

E 100 General

101 This section describes testing that is carried out in order to establish or verify design parameters. DNV-OS-H101, Sec.4F describes required testing during preparations for a marine operation.

102 Requirements to standardised testing, e.g. material and weld testing, are not described in this standard. Such testing should be carried out according to a relevant recognized standard, e.g. DNV-OS-C401.

103 Adequate and reliable test data should be used to verify/correlate values that are considered unreliable based on theoretically calculations only. This is particularly relevant for geometrically complex structures and for new design- or operational concepts.

104 For marine operations such (project) specific testing are normally most relevant in order to determine or verify:

- response, e.g. motions by model testing,
- loads, e.g. by direct measuring of loads in model tests and
- resistance, e.g. by load testing or testing of friction.

E 200 Model testing

201 Model testing is most frequently used for determination of response and loading effects but may also be used for determination of structural resistance.

202 Model tests should be carried out according to a verified test program/procedure applying

- models representing the object(s), vessel(s) and real conditions as accurately as required,
- qualified test personnel,
- adequate testing facilities, and
- calibrated monitoring equipment with sufficient accuracy.

203 Normally the testing should be combined with theoretical calculations.

204 In model testing the laws of similarity shall be considered in order to ensure that the measured quantities can be correctly transformed.

205 Effects that may influence the measured quantity and that are not represented in the model test shall be identified and consequences of these effects should be evaluated.

Guidance note:

E.g. correct relative stiffness (of vessels/structures) will normally not be obtainable in model tests and effects of this on the results should be evaluated.

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E 300 Full scale load testing

301 All full scale load testing should be carried out according to agreed procedures.

302 Requirements to standardised load testing, e.g. of lifting appliances, are not described in this standard. Such testing should be carried out as described in the relevant standard, e.g. DNV 2.22 and DNV 2.7-3.

303 Full scale load testing may be carried out by testing of test pieces to destruction. The characteristic strength should normally be defined based on the 5th or the 95th percentile of the test results, whichever is the most conservative.

304 If not sufficient design documentation is available to verify the strength (capacity) of an item, it could be acceptable to document the item strength by a load test.

Guidance note:

Typical items that could be applicable for this type of testing are:

- Anchors for which no holding power calculations have been carried out.
- Shore bollards without relevant certificate or no documentation of underground design and workmanship.
- Holding power of clamps or other types of connections.
- Local soil capacity (deflection), e.g. in loadout tracks.
- Existing (steel) structures with no/limited inspection access.

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305 The test load for test according to 304 above should normally not be taken less than 0.9 times the maximum design (i.e. included load factor) load for the item. All relevant load directions should be tested.

306 A thorough inspection shall be carried out of all items that have been subject to testing. No defects that could reduce the strength (capacity) shall be allowed.

E 400 Testing of friction

401 Testing may be carried out in order to establish applicable friction coefficients. The testing conditions should represent the expected friction surface and load intensity as close as possible.

402 In marine operations the dynamic friction coefficient will normally be the most relevant and testing of this should hence be included.

403 A detailed test procedure shall be made and verified.

Guidance note:

The test procedure should consider the following:

- a) Possible variations in applicable conditions (e.g. wet and dry surfaces). See 401 and 402 above.
- b) Dynamic friction, if applicable, to be tested and measured by a recognised method.
- c) The characteristic friction coefficient should be defined based on the 5th or the 95th percentile confidence level of the test results, whichever is the most conservative.
- d) At least 5 test pieces should be made, and each tested minimum twice for each actual condition.
- e) The design friction coefficient shall be taken as the characteristic friction coefficient divided (or multiplied) by

an appropriate material factor. See Sec.5 B600, Sec.5 D300 and Sec.5 E200.

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E 500 Full scale monitoring

501 All full scale monitoring should be carried out according to agreed procedures, see e.g. DNV-OS-H101, section 4D.

Guidance note:

Full scale monitoring is normally carried out due to one or a combination of the following:

- To obtain valuable design information for future projects.
- To control that design criteria (ULS or FLS) are not exceeded during an operation.

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502 Full scale monitoring may be used for determination of response (e.g. accelerations on a vessel) or loading effect (e.g. strain-gauge measurements).

503 During full scale monitoring it may be difficult to measure accurately the load which causes the measured response. The information obtained may therefore be of statistical nature, and statistical methods may be necessary in order to draw conclusions.

Guidance note:

Full scale monitoring has limitations, e.g. as indicated above, that need to be duly considered if such monitoring is used as (an assisting) operational mean of control.

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SECTION 3 LOADS

A. Introduction

A 100 General

101 This section defines load categories and describes loads of general interest for marine operations.

102 The appropriate characteristic value should be defined (calculated) for all relevant loads.

103 More detailed descriptions of loads to be considered are given for each type of marine operations in DNV-OS-H201 through DNV-OS-H206.

A 200 Load effects

201 Sec.4 in this standard indicates how to analyse load effects and acceptable combinations of loads.

B. Load Categories

B 100 Definitions and characteristic values

101 Loads and load effects shall be categorised into the following groups:

- Permanent Loads - G
- Variable Functional Loads - Q
- Deformation Loads - D
- Environmental Loads - E
- Accidental Loads - A.

102 The characteristic values of loads shall be selected as indicated in Table 3-1 for all applicable loads.

Table 3-1 Characteristic load selections					
<i>Load category¹⁾</i>	<i>Limit states²⁾ – Temporary design conditions</i>				
	<i>ULS</i>	<i>FLS</i>	<i>ALS</i>		<i>SLS</i>
			<i>Intact structure</i>	<i>Damaged structure</i>	
Permanent (G)	Expected value (weight/buoyancy)				
Variable (Q)	Specified ³⁾ value	Specified ³⁾ load history	Specified ³⁾ value(s)		
Environmental (E) – Weather Restricted	Specified value	Specified load history		Specified value(s)	
Environmental (E) – Unrestricted Operations ⁴⁾	Based on statistical data ⁵⁾	Expected load history		Based on statistical data ⁵⁾ & 6)	
Accidental (A)			Specified value		
Deformation (D)	Expected extreme value	Expected load history	Specified value(s)		

1) See B for definitions of load categories
 2) See Sec.5 A200 for definitions of limit states.
 3) The specified value (load history) shall, if relevant be justified by calculations. See also F100.
 4) See DNV-OS-H101.
 5) See DNV-OS-H101 Sec.3.
 6) Joint probability of accident and environmental condition could be considered.

B 200 Permanent loads (G)

201 Permanent loads are loads which will not be moved or removed during the phase considered. Such load may be due to:

- weight of stationary structures
- weight of permanent ballast and equipment that cannot be removed
- external/internal hydrostatic pressure of permanent nature
- pretensions.

202 Characteristic permanent loads shall be based on reliable data. For weight see C.

B 300 Variable functional loads (Q)

301 Variable functional loads are loads that can be moved, removed or added. Such loads may be due to:

- operation of winches
- pull/push forces
- weight of moving structures
- loads from alongside vessels
- differential ballasting
- operational impact loads
- stored materials, equipment or liquids.

302 Characteristic variable functional loads shall be specified with maximum and minimum values, both values may be necessary to consider.

B 400 Deformation loads (D)

401 Deformation loads are associated with inflicted deformations. Such loads may be caused by:

- installation or set down tolerances
- barge hull beam global deformations caused by moving ballast water (or temperature)
- structural restraints between structures
- differential settlements
- temperature deformations.

402 Characteristic deformation loads shall be maximum or minimum specified values. The specified values shall, if applicable, be based on results from analysis considering extreme conditions.

B 500 Environmental loads (E)

501 All loads caused by environmental phenomena shall be categorised as environmental loads. Such loads may be due to

- wind
- waves
- current
- storm surge
- tide
- ice.

502 Seafastening (and grillage) reactions due to barge hull beam global deformations caused by waves should be considered as environmental loads. See also Sec.4 C400.

503 Gravity load components caused by the roll- and pitch angles due to wind and waves of a floating object, shall be categorised as environmental loads.

504 The environmental design loads shall be calculated based on a process involving, as applicable:

- definition of characteristic conditions (see DNV-OS-H101)
- calculation of characteristic loads (see D and E)
- load analysis (see Sec.4 A)
- motion analysis (see Sec.4 B)
- selection of load cases (see Sec.4 C)
- load factors (see Sec.5).

B 600 Accidental loads (A)

601 Accidental loads are loads associated with exceptional or unexpected events or conditions. Such loads may be:

- collisions from vessels
- dropped objects
- loss of hydrostatic stability
- flooding
- loss of internal pressure.

602 Characteristic accidental loads shall be based on realistic accidental scenarios. See also F.

C. Weight and Buoyancy

C 100 Characteristic weight

101 According to recognized codes (and Table 3-1) the characteristic value for the weight should be taken as the “expected weight”.

Guidance note:

Normal practice is to define the “expected weight” as “maximum (minimum) expected weight”. Hence, it is recommended that the “expected weight” is taken as the “best estimate” weight multiplied (or divided) by a contingency factor.

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102 For designs where a minimum weight could be critical, the possible minimum weight should also (i.e. in addition to the maximum weight) be considered in the design/engineering phases, i.e. characteristic weight divided by the contingency factor.

103 If the characteristic weight is found by weighing with a documented tolerance less than $\pm 3\%$ (and if applicable a strict weight control after the final weighing is applied) a contingency factor of maximum 1.03 needs to be applied.

Guidance note:

Weighing equipment with inaccuracy higher than 3% is not recommended. If weighing equipment with inaccuracy higher than 3% is used the characteristic weight should be adjusted, e.g. by application of an inaccuracy factor. This factor should be defined considering the weighing arrangement and procedures.

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104 The not to be exceeded budget weight may normally be defined as a “maximum expected weight”. However, see 102.

105 If the “expected (maximum/minimum) weight” is based on a weight control system with inherent contingency factors, see 301 and 304, no *additional* contingency factor are normally required.

106 For characteristic weights based on estimated weight a weight inaccuracy factor of minimum 1.1 should be applied.

C 200 Centre of gravity

201 Inaccuracy in CoG position shall be considered in the design loads.

202 To allow for CoG inaccuracies a CoG envelope or box is recommended. The size of the envelope/box should reflect the operational and structural sensitivity to CoG variations. Also the object shape, size, type of operation, control possibilities (weighing, transfer operations) etc., should be considered when establishing the CoG box.

Guidance note 1:

For early design phases too small envelope/box should be avoided. Box sizes less than $0.05L \times 0.05B \times 0.05H$ are normally not recommended. L, B and H are the length, breadth and height of the main body of the object.

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Guidance note 2:

For operations with a linear relation between shift in CoG and resulting load effects, or operations less sensitive to CoG shifts, inaccuracy in estimated CoG may be accounted for by an inaccuracy factor. This factor should normally not be taken less than 1.05.

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Guidance note 3:

Note that normal weighing operations only identify the CoG position in a horizontal plane. Inaccuracies in vertical CoG position should hence be specially considered for operations sensitive to vertical CoG position. If applicable the vertical CoG could be verified by an inclination test, see DNV-OS-H101 Sec.5.

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C 300 Weighing and weight control

301 Weight and position of centre of gravity should preferably be determined by weighing. A detailed weighing procedure, including equipment specifications, should be made. The weighing should normally be carried out at least three times. The weighing cells should if feasible be interchanged between each weighing.

302 If weighing is not feasible, the weight and centre of gravity should be calculated on basis of accurately specified weights and volumes, and/or weighed or estimated weights of parts of the object.

303 For larger objects a weight control system that continuously forecast final weight and CoG position is recommended.

Guidance note:

The system should include all components and consider weight uncertainties. It is recommended to establish and maintain an overall weight inaccuracy factor based on weight uncertainty factors for each object/component. The factor(s) should be changed (reduced) during the design/fabrication as found appropriate.

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304 Adequate quality control (verification) of the weight control system shall be documented.

Guidance note:

For weight/CoG critical objects the quality control should normally include calibration of the system by weighing.

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

305 The weight control system should be employed until the installation is completed. Weight estimates shall be corrected for remaining work.

C 400 Buoyancy

401 Buoyancy (hydrostatic external load) is normally counteracting another load and shall be categorised accordingly.

402 Characteristic buoyancy loads should be based on maximum and/or minimum expected values.

403 The buoyancy of the object and the position of the centre of buoyancy should be determined on the basis of an accurate geometric model.

D. Wave Loads

D 100 First order wave loads

101 Wave loads should be estimated according to a deterministic or stochastic design method. A wave period range according to DNV-OS-H101, Sec.3 C600 or C700 should be investigated.

Guidance note:

If any responses are found governing for $T_z < 8.9\sqrt{H_{s,c}/g}$ the response should be checked in these areas with $H_s=0.123T_z^2$.

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102 Wave loads shall be determined by use of methods applicable for the location and operation, taking into account the type of structure, size, shape and response characteristics.

103 Effects of wave elevation shall be evaluated, and if necessary included in the design verification.

104 Wave slamming-, see D300, hydrodynamic- and hydrostatic loads on members protruding over the vessel side shall be considered. The effect of such loads on motion characteristics and on seafastening /grillage shall be accounted for.

D 200 Second order wave loads

201 Second order wave drift forces may be important for design of certain marine operations. The effect of second order drift forces shall be considered for these cases.

Guidance note:

Drift forces are particular important for large volume structures, design of moorings and positioning systems, towing resistance estimates, etc.

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202 Second order wave loads may be assumed to consist of:

- mean wave drift forces
- slow varying wave drift forces.

203 Long period responses excited by slow drift forces shall be investigated.

D 300 Slamming loads and breaking waves

301 Elements in the splash zone or overhanging the outer borders of the floating body shall be investigated with regards to possibility and effect of slamming loads.

302 Shock pressures on surfaces in the splash zone, caused by breaking waves, shall be investigated.

303 Loads due to slamming and breaking waves should normally be calculated according to DNV-RP-C205.

Guidance note:

More information regarding slamming loads and breaking waves may be found in DNV Rules for Classification of Ships and NORSOK N-003.

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D 400 Green water

401 The possibility and effects of green water, i.e. extensive amounts of water on deck due to waves, shall be considered. Both structural and stability (weight and free surface) effects shall be investigated.

Guidance note:

See e.g. NORSOK N-003 for more information regarding green water effects. Design forces for sea pressure from green water may be based on requirements to deck houses, see DNV Rules for Classification of Ships, Pt.3 Ch.1 Sec.10 C.

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D 500 Swell

501 Loads and motion effects of swell shall be duly considered. See DNV-OS-H101, Sec.3 C900. See also Sec.4 C500.

Guidance note:

Swell may be governing for towing operations designed for small irregular waves (I.e. weather restricted tows). Hence, swell operational limits and -forecasts need to be established.

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E. Wind and Current Loads

E 100 Wind load components

101 Wind loads shall be calculated based on characteristic wind speed, see DNV-OS-H101, and recognised calculation methods.

102 Wind induced loads shall be based on projected area. Total wind load shall consider both lateral and parallel load components.

103 Possibility and magnitude of lift effects shall be considered.

104 The gravity components due to wind induced heeling shall be considered.

Guidance note:

DNV-RP-C205 gives further information with respect to shape coefficients as well as to effects of wind direction relative to member, solidification and shielding.

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E 200 Current loads

201 Current loads shall be calculated based on characteristic current velocity, see DNV-OS-H101, and recognised methods.

202 Combined wave and current induced drag loads shall be calculated considering the sum of current and wave particle velocity.

203 Increased current velocities/loads due to shallow waters or narrow passages shall be considered.

F. Accidental Loads

F 100 General

101 Accidental loads should be defined based on relevant accidental scenarios, see Sec.4 A300.

102 The accidental load design principles indicated in DNV-OS-A101 should be considered as applicable for the planned marine operation. DNV-RP-C204 gives further guidance related to design philosophy and calculation of relevant accidental loads due to e.g. collisions and dropped objects

Guidance note:

Note that DNV-OS-A101 in general is based on yearly probabilities, while the VMO-Standard is based on probability per operation. This may be considered when the (magnitude of) applicable accidental loads are defined. However, if no justifications for lower loads are presented the loads indicated in DNV-OS-A101 should normally be considered.

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F 200 Vessel collision

201 Characteristic collision loads shall be estimated from energy considerations. Estimates of collision energy should be based on reasonable assumptions of possible collision scenarios, velocities, directions, ship or object type, size, mass and added mass. Estimates of deformation energy should be based on most likely impact points and probable deformation patterns.

202 The behaviour of the vessels or structures during the impact, and thus the distribution of impact energy between kinetic rotation and translation and deformation energy, should be considered by dynamic equilibrium or energy considerations.

203 Both local effects (deformation, damage, etc.) and global load effects (acceleration, global stress, etc.) shall be considered.

F 300 Dropped objects

301 Loads caused by dropped objects may be relevant for some ALS load cases. Characteristic loads due to dropped object should be based on the weight of possible falling objects and their potential fall height.

302 For objects falling through water maximum possible impact velocity should be considered.

Guidance note:

The maximum velocity will normally be the terminal (free fall in water) velocity. See DNV-RP-H103, 4.7.3 and DNV-RP-F107, 5.3 for guidance.

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303 Loads on subsea items due to dropped objects may be omitted if operations that could cause dropped objects are carried out in a safe distance.

Guidance note 1:

The safe distance should be calculated considering the maximum possible dispersion angle for each type of object falling through the water. Effect of current should be considered. Risk analysis may be used in order to eliminate physical possible high dispersion angles by showing that the risk of hitting specified critical locations is acceptably low for such high angles. See DNV-RP-F107 for further risk assessment guidance.

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Guidance note 2:

If no detailed assessments are made the safe distance should normally be 50 meters or based on a dispersion angle of 20° if this gives a greater distance.

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SECTION 4 LOAD EFFECTS

A. Load Analysis

A 100 General

101 All loads and load effects which during the marine operation may influence operational procedure, design or the dimensioning of structures shall be analysed and considered in planning and preparation for marine operations.

Guidance note:

See DNV-RP-H103 for more information regarding modelling and analysis of marine operations.

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102 Testing to determine motions or loads may be required, see Sec.2 E.

A 200 Sensitivity studies

201 Parametric sensitivity studies should be performed if any one load or operational parameter significantly affects the design or the selection of method and equipment.

Guidance note:

The objective of a sensitivity study is to reveal if minor changes of input parameters significantly affect the design.

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202 If a sensitivity study indicates that the operational safety is critically dependent on any parameters, increased reliability shall be obtained for the design solution e.g. by using conservative characteristic values.

203 Consequences of unexpected values of parameters and loads with regards to structural capacity and failure modes should be investigated. Emphasis shall be put on possible non-linear load effects.

Guidance note:

Examples of parameters for which it could be relevant to analyse the effect of unexpected values are:

- a) deformations and load distributions
- b) friction coefficients
- c) vessel data as GM
- d) tide variations
- e) weights and CoG positions
- f) buoyancy and centre of buoyancy.

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204 Consequences of malfunctioning equipment and erroneous operation of equipment or systems shall be evaluated.

Guidance note:

Examples of malfunctioning equipment may be leaking valves, valves impossible to close, pipeline fracture and unexpected deformation pattern of load distribution elements.

Examples of erroneous operation of equipment may be opening/closing of wrong ballast valve.

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205 The variations of input parameters should be within realistic limits. However, too small variations shall be avoided.

206 All realistic combinations of input parameters variations shall be investigated.

A 300 Accidental scenarios

301 Load effects due to all possible accidental scenarios/conditions shall be considered. Accidental cases and contingency situations may be defined or excluded based on results from HAZOP's or risk evaluations/assessments. See DNV-OS-H101, Sec.2 C100.

Guidance note:

Possible accidental conditions could be defined based on:

- Risk identification activities as described in DNV-OS-H101, Sec.2 C.

- Accidental design conditions normally recommended considered as e.g. “one line broken” or “one compartment damaged stability”.

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302 In order to cover accidental scenarios it should be considered to include variation of sensitivity input parameters outside the limits normally considered realistic, see 205.

303 Malfunction of critical equipment/systems, e.g. of heave compensation systems, should normally be considered as a possible accidental scenario.

Guidance note:

An accidental scenario may be disregarded if a malfunction probability of less than 10^{-4} per operation can be documented.

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304 It shall be documented that single unplanned or unexpected events, see 203 and 204, will not lead to a progressive failure situation.

Guidance note 1:

The above requirement could be met by including the load effects due to such events in the relevant ALS analysis.

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Guidance note 2:

Simultaneous occurrence of two or more rare events does not normally need to be considered.

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A 400 Dynamic effects

401 Dynamic effects shall be investigated. Dynamic effects may typically be caused by wave forces, wind loads (gusts), vortex shedding in air or water, or slamming loads.

402 Dynamic effects shall be investigated by recognised methods, realistic assumptions of natural period, damping, material properties etc.

403 Special considerations should be made to the possibilities of dynamic amplification.

404 The structural stress and deflections caused by dynamic effects may be relevant for Ultimate-, Fatigue-, and Serviceability Limit States.

A 500 Non-linear effects

501 Non-linear effects shall be considered in cases where these significantly influence the load estimates. Non-linear effects are typically caused by

- non-linear materials
- non-linear geometry
- damping
- non-linear combination of load components or response components
- wave elevation.

502 Non-linear load effects due to combination of environmental conditions should be evaluated.

Guidance note:

The quadratic increase in drag loads due to combination of wave particle velocity and current velocity illustrates such an effect.

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A 600 Friction effects

601 Possible unfavourable effects of friction shall be considered. Well documented favourable effects of friction may be included in design verifications.

602 A friction coefficient range, i.e. both a maximum and a minimum friction coefficient, should be considered in the design calculations or it should be proven that a conservative minimum (or maximum) coefficient suffice.

603 The characteristic friction coefficient range shall be defined according to recognised industry standards or tests, see Sec.2 E200.

Guidance note:

Some applicable friction coefficients are indicated in DNV-OS-H201, Table 3-2. The conditions indicated for use of the values in the referred table shall be duly considered.

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604 The lower bound design friction coefficient (μ_{1d}) shall be the lower bound characteristic value (μ_{1c}) divided by a material factor. See 605 - Guidance Note.

605 The upper bound design friction coefficient (μ_{ud}) shall be the upper bound characteristic value (μ_{uc}) multiplied by a material factor.

Guidance note:

The appropriate material (safety) factor for friction will depend on the limit state considered and the risk involved in exceeding (or go below) the design friction. See Sec.5 B600, Sec.5 D301 and Sec.5 E200.

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

606 The minimum design friction force shall be taken as the minimum design load (i.e. including relevant load factors) perpendicular to the friction surface multiplied by μ_{1d} .

607 The maximum design friction force shall be taken as the maximum design load (i.e. including relevant load factors) perpendicular to the friction surface multiplied by μ_{ud} .

608 If the friction coefficient range is based on uncertain data the consequences of the maximum possible variation in friction coefficients shall be evaluated. See A200.

609 Vibrations, varying- or uncertain surface condition etc. affecting the friction shall be considered.

610 Restraint effects caused by combination of friction and global deflections shall be considered.

A 700 Tolerances

701 Loads caused by operational- or fabrication tolerances exceeding the tolerances stated in the design standards/codes shall be considered. Typical examples may be:

- set-down tolerances (loadout, positioning)
- shimming tolerances
- uncertain deformation (in load distributing material)
- fabrication tolerances, see Sec.6 A400.

702 Loads caused by effects described in 701 should normally be defined as D-loads, see Sec.3 B400.

A 800 Restraint effects

801 All possible effects due to interaction between structures deflecting as a result of loads due to e.g. waves, temperature and redistribution of ballast shall be considered.

Guidance note:

Such effects could be:

- restraint loads, which is described in this sub-section
- relative deflections that need to be considered during the operation.

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802 Restraint loads should be defined in the same category as the load that causes the restraint load, i.e. restrained loads caused by environmental conditions should be defined as E-loads, see Sec.3 B500.

803 For sea transports possible restraint loads shall always be evaluated.

Guidance note:

See DNV-OS-H202 for more detailed guidance. See also C400.

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

B. Motion Analysis

B 100 General

101 Motions of floating objects shall be determined for the relevant environmental conditions and loads.

Guidance note:

Simplified conservative estimates of motions may be applied, but it is normally recommended to carry out analysis (and tests) as described in this sub-section.

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

102 Inertia loads due to motion should be calculated for all six degrees of freedom.

Guidance note:

This includes also an evaluation of mass (rotational) inertia effects from roll and pitch. These effects should as a minimum be quantified, and the effect evaluated. This is particularly relevant for barge transports with large roll motions.

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103 Testing of models or full scale structures may be carried out where relevance of theoretical approaches is uncertain, or where the design is particularly sensitive for motions.

Guidance note:

Estimation of motions from model testing or by theoretical calculation has associated advantages and disadvantages. The two approaches are generally to be considered as complimentary rather than as alternatives.

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104 It is recommended to correlate theoretical calculations against relevant model test data (if available) in cases where strong non-linear behaviour may be expected. Such cases may be when:

- overhanging cargo is being occasionally submerged, or
- there are large changes in the water plane area with draught.

105 The analytic models should be checked with respect to sensitivity to input parameters, see A200.

106 Recognised and well proven six degrees of freedom linear or linearized computer programs, utilising the strip theory or 3D sink source techniques are generally recommended. Special considerations shall be made to the non-linear damping effects. The effect of forward speed shall be evaluated.

B 200 Wave headings

201 The full range of wave headings shall be analysed. Spacing between analysed wave headings should not exceed 45°.

Guidance note:

Also in the cases where reduced design wave heights are acceptable from some headings, see e.g. DNV-OS-H202, all wave headings shall be analysed. However, symmetry may be considered when relevant.

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202 Short crested sea shall be considered for wave analysis where all headings are not carried out with equal wave heights. I.e. typically motion analysis in order to find limiting installation wave heights for different vessel headings.

Guidance note:

If short crested waves are considered the spacing between analysed wave headings should normally not exceed 22.5°. See also DNV-OS-H101.

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

203 Short crested sea may be considered for wave analysis where all headings are included with equal wave height. I.e. typically motion analysis for sea transports without any heading restrictions.

B 300 Wave periods

301 A wave period range with corresponding wave heights, see DNV-OS-H101, shall be considered when evaluating characteristic motions and accelerations.

B 400 Response amplitude operators (RAO)

401 RAO's for the basic six degrees of freedom may be utilised to establish RAO's for displacements, velocities, accelerations, and reaction forces (for a body fixed co-ordinate system). These RAO's may be used for calculation of significant and maximum responses.

402 When combining different responses, the phase angle between the different components may be considered.

403 The gravity component shall be considered when determining the RAO's for inertia loads (e.g. transverse accelerations).

C. Load Cases

C 100 Load combinations

101 Loads and load effects shall be combined to load cases applicable and physically feasible, for the actual structures and type of operation.

102 All possible load cases which may influence the feasibility of the marine operation shall be considered in the design and design verification.

103 Characteristic loads may be combined taking into account their probability of simultaneous occurrence.

104 Characteristic static (mean) load components and characteristic dynamic (varying) load components which are statistically independent may be combined according to the formulae below.

$$F_{tot} = \sum_{i=1}^n F_{i,mean} + \sqrt{\sum_{i=1}^n F_{i,amp}^2}$$

where

$F_{i,mean}$ = Characteristic static load components
 $F_{i,amp}$ = Amplitude of dynamic load components

Guidance note:

Dynamic load components shall in the above formulae normally be restricted to loads with periods less than 10 minutes. Dynamic loads with periods greater than 10 minutes shall be added with their mean values (i.e. as static loads).

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

105 Correlated dynamic load components shall be added as vectors, unless statistical data of simultaneous occurrence are available.

Guidance note:

Note that load components due to first order motions are considered to be correlated. Combination of these components is described in C300.

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

C 200 Sensitivity analysis

201 Defining load cases shall include parametric sensitivity analyses whenever found relevant. The extent of such analysis shall comply with A200.

C 300 Loads due to motions and wind

301 In lieu of a refined analysis the worst possible combination of the individual responses for the same heading, including components from the self-weight and wind, shall be combined, i.e.:

$$S_d = S(\pm(F_x + F_{wx}), \pm(F_y + F_{wy}), + (W \pm F_z))$$

where

S_d = Design load or load effect.
 $S()$ = Response/load effect function.
 F_x, F_y, F_z = Inertia forces (vectors), in x, y and z directions including relevant load factors and gravity components.
 F_{wx}, F_{wy} = Wind forces (vectors), in x and y directions including relevant load factors. The horizontal load components due to wind induced heel or trim shall be included.
 W = Load due to self-weight (vectors).

Guidance note:

Wind loads based on the one hour mean wind speed will normally be acceptable in the above load combination.

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

302 Where transfer functions for motions are available these may be combined to a transfer function for the actual response or load effect. The phasing between the different components may be considered.

Guidance note:

This method requires careful evaluations of the responses to be analysed. All responses which will be governing for the design shall be considered.

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

C 400 Restraint and inertia loads

401 Restraint loads due to barge deflecting in waves, see A800, and inertia loads due to barge motion may be combined as shown below.

$$F_{tot} = \sqrt{F_{mot}^2 + F_{def}^2 + F_{mot} \cdot F_{def}}$$

where

F_{tot} = Total design load
 F_{def} = Maximum loads due to deflections
 F_{mot} = Maximum inertia loads due to motions.

C 500 Loads due to irregular waves and swell

501 Combinations of load and load effects from irregular waves and swell shall be combined. These loads and load effects may normally be combined as statistically independent. See 104.

SECTION 5 DESIGN BY LRFD METHOD

A. Introduction

A 100 General

101 The “VMO-Standard” recommends the LRFD (load- and resistance factor design) method, see Sec.2 D100, for design verification. Load and material factors specified in this sub-section are according to the principles of this method.

102 Usage factors for the permissible stress method are not generally defined in the “VMO-Standard”. Permissible usage factors are to be agreed in each case.

Guidance note:

The safety factor format applied for lifting slings in DNV-OS-H205 could be regarded as a permissible stress method, but the safety level is correlated according to the applicable LRFD factors.

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

A 200 Limit state definition

201 A limit state is commonly defined as a state in which the structure ceases to fulfil the function, or to satisfy the conditions, for which it was designed. See also DNV-OS-C101, Sec.2 C.

202 The following limit states shall be considered in the strength verification:

- The Ultimate Limit States (ULS) related to the maximum load carrying capacity.
- The Fatigue Limit States (FLS) related to the capacity of the structure to resist accumulated effect of repeated loading.
- The Accidental Limit States – Intact Structure (ALS-I) related to capacity of the intact structure to resist loads from an accidental event or operational failure.
- The Accidental Limit States – Damaged Structure (ALS-D) related to the maximum load carrying capacity of the structure in a damaged condition.
- The Serviceability Limit States (SLS) corresponding to the criteria to normal use or durability.

203 Limit states shall be defined for all possible failure modes, see Sec.2 C200.

A 300 Design approach

301 The format of the LRFD method implies that strength/capacity verification of structures or systems involves the following steps:

- Identify all relevant limit states, see 203.
- For each limit state define the relevant characteristic loads, see Sec.3, and design conditions, see Table 3-1.
- For each limit state find the design loads by applying the relevant load/design factors, see B200, C200, D200 and E200.
- For each limit state determine the design load effect, see Sec.4 and 402.
- For each limit state determine the characteristic resistance, see 500.
- For each limit state determine the design resistance, see 404.
- Ensure adequate safety by proving that the design load effect does not exceed the design resistance, See 400.

A 400 Acceptance criteria

401 The level of safety is considered to be satisfactory if the design load effect, S_d , does not exceed the design resistance, R_d , i.e.:

$$S_d \leq R_d \text{ for all limit states}$$

The equation $S_d = R_d$ defines the respective limit state.

402 A design load effect is an effect (e.g. stress, mooring line-/sling load, deformation, overturning moment, cumulative damage) due to the most unfavourable combination of design load(s) i.e.:

$$S_d = S(F_{d1} \dots F_{dn})$$

where

- S_d = design load effect
- F_d = design load(s)
- S = load effect function.

403 A design load (F_d) is obtained by multiplying the characteristic load (F_c) by the appropriate load factor, see B200, C200, D200 and E200.

404 A design resistance (R_d) is obtained by dividing the characteristic resistance (R_c), see A500, by a material- or design factor, see B300, C200, D300 and E200.

A 500 Characteristic resistance

501 R_c may be calculated based on the characteristic values of the relevant parameters or determined by testing. Characteristic values should be based on the 5th or the 95th percentile of the test results, whichever is the most conservative. See also Sec.2 E300 and Sec.2 E400.

Guidance note:

The resistance for a particular load effect is, in general, a function of parameters such as structural geometry, material properties, environment and load effects (interaction effects).

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

Guidance note:

The characteristic static resistance of steel, f_c , is to be taken as the smaller of:

- the guaranteed minimum yield stress, f_y , or
- 0.85 times minimum tensile strength of the material.

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

Guidance note:

R_c for materials not mentioned e.g. concrete, concrete reinforcement, wood, synthetic materials, soil, etc. could normally be based on recommendations/requirements in the applied design code or standard.

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

502 R_c for (wire & fibre) ropes and chains should be taken as the certified MBL.

B. Ultimate Limit States – ULS

B 100 General

101 DNV-OS-C101, Sec.5 gives provisions for checking of ultimate limit states for typical structural elements used in offshore steel structures.

B 200 Load factors - ULS

201 For the ultimate limit states (ULS) the two load conditions "a" and "b" as given in the Table 5-1 below shall be considered.

Table 5-1 Load factors for ULS					
<i>Load Condition</i>	<i>Load Categories</i>				
	<i>G</i>	<i>Q</i>	<i>D</i>	<i>E</i>	<i>A</i>
a	1.3	1.3	1.0	0.7	NA
b	1.0	1.0	1.0	1.3	NA

Load categories G, Q, D, E and A are described in Sec.3 B

202 For loads and load effects that are well controlled a reduced load factor $\gamma_f = 1.2$ may be used for the G and Q loads instead of 1.3 in load condition a.

203 Where a permanent load G (e.g. self-weight or hydrostatic pressure) causes favourable load effects, a load factor $\gamma_f = 1.0$ shall be used for this load in load condition a. See also Sec.3 C102.

204 In cases where the load is the result of counteracting and independent large hydrostatic pressures the appropriate load factor shall be applied to the pressure difference. However, the pressure difference should not be taken less than 0.1 times the hydrostatic pressure.

205 In dynamic problems special considerations of application of the load factors are necessary. In lieu of a refined analysis, e.g. such as indicated in Sec.2 D300, the load effects may be found by application of load factors after having found the responses, e.g. after having solved the equations of motion for vessel motion response analysis.

B 300 ULS material factors

301 Applicable material factors in ULS are given in B400 to B600. Material factors for materials not mentioned in B400 through B600 e.g. concrete, concrete reinforcement, wood, synthetic materials, soil, etc. shall be in accordance with a recognised code or standard.

302 If a material factor $\gamma_m = 1.0$ is found more unfavourable than the indicated values, $\gamma_m = 1.0$ shall be used.

B 400 Material factors for structural steel

401 In ULS the material factors for steel structures should be taken as minimum:

$$\gamma_m = 1.15$$

402 For members in compression a higher material factor may be applicable. The material factor should normally be chosen according to the applied design code, but never smaller than 1.15.

403 The material factors listed in DNV-OS-C101 Sec.5 Table B1 shall be used if EN 1993 (Eurocode 3) is used for calculation of structural resistance.

Guidance note:

See also Table 6-1 in NORSOK N-004 for applicable material factors.

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

404 In ULS the material factor for static strength of tubular joints should be chosen according to the applied design code, but never smaller than 1.15.

405 An increased (i.e. larger than 1.15) material factor shall be considered if the production are carried out in an environment where a reduced control with dimensions, materials and fabrication could be expected, e.g. welding on-board barges.

B 500 Material factors for ropes, chain and bolts

501 In ULS the material factor for certified steel wire ropes and chains should normally be taken as:

$$\gamma_m = 1.5$$

Guidance note:

$$\gamma_m = 1.15/0.85/0.9 = 1.5$$

where

1.15 is the general steel material factor,

0.85 is a factor to account for that the characteristic strength, see A501 Guidance Note 2, of the ropes and chains is based on the tensile strength (MBL), and

0.9 is a general factor to account for that wire ropes are considered more vulnerable for “undetectable” wear and material irregularities than regular steel structures. For new ropes with a 3.1.C certificate it may be acceptable to use 1.0, see DNV-OS-H205. (Note also that an additional wear factor could be applicable).

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

502 For fibre ropes the material factor will depend on the material and relevant failure mode. The following minimum factors apply:

- Polyester: 1.65
- HMPE and Aramid: 2.0
- Other fibre materials: 2.5.

503 The material for slip resistant bolt connections shall be taken as minimum:

- $\gamma_m = 1.25$ for standard clearances in the direction of the force
- $\gamma_m = 1.4$ for oversize holes or long slotted holes in the direction of the force

Guidance note:

See DNV-OS-C101 Sec.5 H for information regarding slip resistant bolt connections.

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

B 600 Material factors for friction

601 A material factor of minimum $\gamma_m = 1.4$ should normally be used to calculate the lower bound friction coefficient for load bearing friction effects.

602 In upper bound friction coefficient calculations $\gamma_m = 1.25$ is normally acceptable. In this case the characteristic friction should be multiplied with γ_m to find the design friction. See Sec.2 E400.

C. Fatigue Limit States - FLS

C 100 General

101 For all structures exposed to significant cyclic loads during a marine operation the possibilities and effects of fatigue should be considered.

102 The FLS design conditions should be based on the defined operation period and the anticipated- or expected load history during the marine operation. See Table 3-1.

103 Possible dynamic load effects due to e.g. slamming and vortex shedding should be investigated. See Sec.4 A400.

104 Restraint loads, see Sec.4 A800, could be important and shall hence be thoroughly evaluated and included in the FLS calculations.

105 The FLS shall be evaluated according to procedures given in a recognised code or standard. See e.g. DNV-OS-C101, Sec.6 for general requirements for checking of fatigue limit states.

Guidance note:

Reference is made to DNV-RP-C203 and DNV CN 30.7 for practical details with respect to fatigue design.

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

106 For mooring systems FLS is mainly of concern for steel components where fatigue endurance may be limiting the design. For fibre-rope segments, the time-dependent strength may be limiting the design, thus stress rupture or creep failure should be incorporated in the checks for ULS and ALS as appropriate. See also DNV-OS-E301.

C 200 Design factors - FLS

201 All load factors shall be:

$$\gamma_f = 1.0$$

202 Design fatigue factors (DFF) shall be applied to increase the probability of avoiding fatigue failures.

203 The calculated cumulative damage ratios for the defined design conditions times the applicable DFF, see Table 5-2, shall be less or equal to 1.0.

Table 5-2 Design fatigue factors (DFF)		
<i>Inspection during operation (and repair) planned</i>	<i>Elements in inspection category I</i>	<i>Elements in inspection categories II & III</i>
Yes	2.0	1.0
No	3.0	2.0

The elements shall be categorised according to definition in Sec.6 A200 (Table 6-1).

204 Lower values for the Miner sums than 1.0 may be relevant if the structure has been or will be subjected to fatigue loading before or after the considered marine operation. In such cases the maximum allowable Miner sum for the actual marine operations shall be determined by considering the total load history the structure will be exposed to.

D. Accidental Limit States – ALS

D 100 General

101 Accidental limit states for marine operations include verification of:

- 1) ALS-I: The intact structure or system for the defined accidental load effect(s) combined with other relevant load effects. See condition c in Table 5-3. (I.e. note that loads of type E may be ignored).
- 2) ALS-D: A damaged, see 102 structure or system for relevant design load effects. See Table 5-3, loading condition d.

Guidance note:

See also Table 3-1 for definition of conditions c (ALS-I) and d (ALS-D).

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

102 The damage to the structure or system in ALS-D is normally defined by either:

- the damage caused by the defined accidental load effect(s) or,
- a defined damaged or an accidental condition/ scenario, see Sec.4 A300.

D 200 Design approach and load factors

201 Accidental loads are defined in Sec.3 F.

202 Design against accidental loads shall primarily consider global failure modes, see Sec.2 C203. E.g. increasing of local strength which may reduce the safety against overall failure of the structure should be avoided.

203 Load factors should in ALS normally, see 204, be taken according to Table 5-3.

Table 5-3 Load factors for ALS					
<i>Load Condition</i>	<i>Load Categories</i>				
	<i>G</i>	<i>Q</i>	<i>D</i>	<i>E</i>	<i>A</i>
c	1.0	1.0	1.0	NA	1.0
d	1.0	1.0	1.0	1.0	NA

Load categories G, Q, D, E and A are described in Sec.3 B

204 Load factors greater than 1.0 shall be considered if an ALS load or condition is not considered to have a sufficient low, i.e. $\leq 10^{-4}$ per operation, probability.

205 The characteristic environmental load (E) in load condition d should/may be defined considering the probability of the analysed accident/damage and the anticipated maximum period (i.e. T_R , see DNV-OS-H101) the damaged situation will remain.

D 300 Material factor - ALS

301 The material factor may in ALS generally be taken equal to:

$$\gamma_m = \gamma_{m,ULS}/1.15$$

where $\gamma_{m,ULS}$ = the applicable material factor in ULS, see B300.

Guidance note:

E.g. the material factor for steel wire ropes may in ALS be taken equal to $\gamma_m = 1.5/1.15 = 1.3$.

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

E. Serviceability Limit States - SLS

E 100 General

101 For some marine operations it is relevant to check SLS related to the feasibility of the operation. Such serviceability limit states could be associated with required clearances, push/pull capacities and vessel (barge) level (compared e.g. with quay height).

102 See DNV-OS-C101, Sec.8 for typical SLS requirements to offshore steel structures.

E 200 Safety factors

201 For SLS related to feasibility the load factors are normally equal to 1.0. Relevant safety factors/margins should be defined considering the actual operation. See DNV-OS-H201 through DNV-OS-H206 for guidance.

202 SLS for structural elements shall normally be checked applying load- and material factors equal to 1.0.

Guidance note:

In SLS the object (or equipment/vessel) owner is free to define higher load- and material factors if this is found applicable.

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

SECTION 6 MATERIALS AND FABRICATION

A. Design Considerations

A 100 Applicable codes

101 In general material selection, fabrication method, and non-destructive testing should be carried out according to a recognised code, see Sec.1 A200 for guidance.

102 Independently of the applied code it shall be documented that the requirements in this section 6 are fulfilled.

A 200 Structural categories

201 Structural elements and connections shall be grouped in categories determined according to:

- type of stress
- presence of cyclic loading
- presence of stress concentrations
- presence of restraint
- loading rate
- consequences of failure
- redundancy.

202 Guidelines for selection of applicable materials for offshore steel structures could be found in DNV-OS-C101, Sec.4.

203 For materials in temporary structures used for marine operations the following apply:

- The design temperature, see DNV-OS-C101, Sec.4 B, should be defined based on the season and location of the marine operation. Note that a design temperature above 0°C could be applicable.
- See Table 6-1 for guidelines regarding selection of structural category. See also DNV-OS-C101, Sec.4 C.
- For materials that will (may) be welded under adverse conditions it is not recommended to specify yield strength (SMYS) above 355 MPa.

A 300 Material quality

301 Selection of steel types shall be decided based on structural application and the required category see A200 and Table 6-1.

Table 6-1 Structural categories					
<i>Selection criteria for structural category</i>		<i>Examples for typical structures involved in marine operations</i>	<i>Recommended structural category</i>		<i>Insp. Cat., DNV</i>
<i>Failure consequence</i>	<i>Structural part</i>		<i>DNV-OS-C101</i>	<i>Guidance Note⁴⁾ NORSOK N-004</i>	
Substantial, the structure possesses limited residual ²⁾ strength	Complex ¹⁾ joints	— Padeyes and other lifting points — Seafastening elements without redundancy — Spreader bars	Special	DC1 – SQL1	I
	Simple joints and members		Primary (Special) ³⁾	DC2 – SQL2 (SQL1) ³⁾	I ⁵⁾
Not substantial, the structure possesses residual ²⁾ strength	Complex ¹⁾ joints	— Structures for connection of mooring and towing lines — Grillages — Redundant ²⁾ seafastening elements	Primary (Special) ³⁾	DC3 – SQL2 (SQL1) ³⁾	II
	Simple joints and members		Primary (Special) ³⁾	DC4 – SQL3 (SQL1) ³⁾	II
Un-substantial, as local failure will be without substantial consequences	Any structural part	— Bumpers and guides — Fender structures — Redundant ²⁾ (parts of) grillages	Secondary	DC5 – SQL4	III

1) Complex joints mean joints where the geometry of connected elements and weld type leads to high restraint and to tri-axial stress pattern.
 2) Residual strength (redundant) means that the structure meets requirements corresponding to the damaged condition in the check for ALS, with failure in the actual joint or component as the defined damage.
 3) Selection where the joint strength is based on transference of tensile stresses in the through thickness direction of the plate.
 4) The indicated NORSOK design classes and corresponding material selection according to NORSOK M-120 should be considered as guidance only.
 5) Extent of inspection according to NORSOK M-101 inspection category B is normally acceptable.

302 All steel materials shall be suitable for the intended service conditions and shall have adequate properties of strength, ductility, toughness, weldability, and corrosion resistance.

303 Material types and qualities should comply with requirements in DNV-OS-B101.

304 The non-structural steels shall have adequate mechanical properties and weldability for the intended application.

A 400 Tolerances

401 As-built deviations shall not exceed fabrication tolerances assumed in applied structural codes and standards, or in the design analysis, unless specially considered on a case to case basis.

402 Acceptance of any as-built deviations exceeding specified tolerances shall be confirmed (as applicable by e.g. Company, designer or installation contractor) in writing.

403 DNV-OS-C401, Ch.2 Sec.2 E indicates the normally acceptable fabrication tolerances.

404 Some marine operations procedures may be difficult (impossible) to execute if standard tolerances are applied. In these cases it should be duly considered to define and document the consequences of using less strict tolerances than indicated in DNV-OS-C401.

B. Fabrication

B 100 Workmanship

101 Workmanship during fabrication shall be of good standard and according to accepted practice. See also DNV-OS-C401, Sec.1 and Sec.2 B, C, D and E.

102 Guidelines regarding assembly and welding may be found in DNV-OS-C401, Ch.2 Sec.2 F.

B 200 Marine work

201 Environmental conditions during marine work could be unfavourable and the time available is often limited. Also accurate fit-up could be difficult to obtain e.g. due to a dented barge deck. Such issues regarding marine work shall be duly considered in the planning of the work. See also Sec.5 B405.

Guidance note:

Due to the special conditions during marine work the following precautions are recommended:

- a) Welding procedure specifications should be qualified by welding procedure tests carried out under conditions representative of the actual working environment; see DNV-OS-C401, Ch.2 Sec.1 B500.
- b) Thorough inspections of fit-up and welding should be planned for.
- c) Weather conditions and forecast to indicate acceptable conditions for welding considering the welding method and available shelter at the welding locations.
- d) Use of increased weld size in order to compensate for inaccurate (i.e. too big gaps) fit-up to be considered.
- e) Robust- and well proven welding methods and procedures to be applied.
- f) Use of material with improved weldability; see DNV-OS-C101, Sec.4 D200, to be considered.

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B 300 Weld inspection

301 All NDT (non-destructive testing) of structures and structural components shall be carried out by qualified personnel and covered by written specifications and procedures.

302 Personnel evaluating results from NDT shall possess thorough knowledge and experience with NDT.

303 The NDT method selected shall be suitable for detection of the type of defects considered detrimental to the safety and integrity of the structures.

304 The extent of NDT shall be based upon the importance of the connection in question. Aspects which shall be considered in specifying the extent of NDT are:

- stress level and stress direction
- cyclic loading
- material toughness
- redundancy of the member
- overall integrity of the structure
- accessibility for examination.

305 If allowed, plates experiencing stress in through thickness direction without proven through thickness properties should be checked for lamination by UT after welding.

306 Requirements to non-destructive testing (NDT) of welds may be found in DNV-OS-C401, Ch.2 Sec.3 C.

307 Minimum extent of inspection should be as shown in DNV-OS-C401, Ch.2 Sec.3 Table C1 with “Inspection Category” as defined in Table 6-1. See also Table 6-2 for a summary and especially note 4) to the table.

308 Normally final inspection and NDT of welds shall not be carried out before 48 hours after completion. However, for materials with yield strength of 355 MPa or less this could be reduced to 24 hours. See NORSOK M-101, Sec.9.1 and DNV-OS-C401, Ch.2 Sec.3 C100 for further details.

Guidance note:

For marine operations with weld inspection on critical path, minimum waiting time should be selected according to Table 6-2.

<i>Inspection Category</i>	<i>Minimum extent of NDT</i>		<i>Minimum waiting time before NDT</i>	
	Visual	Other ¹⁾	SMYS ²⁾ ≤ 355MPa	SMYS > 355MPa
I	100%	100%	24 hours ⁵⁾	48 hours ⁵⁾
II	100%	20% ⁴⁾	Cold weld ³⁾	24 hours ⁵⁾
III	100%	5% ⁴⁾	Cold weld ³⁾	24 hours ⁵⁾

1) Test method to be selected according to the type of connection, see DNV-OS-C401, Ch.2 Sec.3, Table C1.
 2) SMYS to be defined according to the specification for the actual material used and not according to the minimum required design value.
 3) The NDT could start when the weld is cold, but it is recommended to wait as long as practicable.
 4) An increased % rate shall be evaluated if defects are found and/or weld conditions and precautions, see B200, are not fully satisfactory.
 5) The use of PWHT (post weld heat treatment) may reduce the required waiting time.

309 Note that decreased waiting time according to Table 6-2 may only be used if the precautions listed in B200 are fulfilled.