Offshore Installation Operations
(VMO Standard Part 2-4)

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FOREWORD

DNV is a global provider of knowledge for managing risk. Today, safe and responsible business conduct is both a license to operate and a competitive advantage. Our core competence is to identify, assess, and advise on risk management. From our leading position in certification, classification, verification, and training, we develop and apply standards and best practices. This helps our customers safely and responsibly improve their business performance. DNV is an independent organisation with dedicated risk professionals in more than 100 countries, with the purpose of safeguarding life, property and the environment.

DNV service documents consist of among others the following types of documents:

— Service Specifications. Procedural requirements.
— Standards. Technical requirements.

The Standards and Recommended Practices are offered within the following areas:

A) Qualification, Quality and Safety Methodology
B) Materials Technology
C) Structures
D) Systems
E) Special Facilities
F) Pipelines and Risers
G) Asset Operation
H) Marine Operations
J) Cleaner Energy
O) Subsea Systems
U) Unconventional Oil & Gas
CHANGES – CURRENT

This is a new document.

General

This is a new document in a series of documents replacing “DNV Rules for Planning and Execution of Marine Operations” (1996/2000). This Standard replaces Pt.2 Ch.4 in the referred Rules. Nearly all parts of the text have been updated with the following main changes:

— The old Sec.2 “Loads” has been expanded with new title “General requirements” reflecting this.
— The old Sec.6 “Piling and Grouting” has been expanded with new title “Foundation installation” reflecting this.
— Requirements to self-upending jackets, docking onto an installed substructure and buoyancy tank removal have been included.
— The stability and reserve buoyancy requirements have been modified.
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SECTION 1 INTRODUCTION

1 Application

1.1 General

1.1.1 This standard, DNV-OS-H204, provides specific requirements and recommendations mainly applicable for jacket installation operations.

1.1.2 The principles and requirements given in this standard may be adopted for the installation operations of other types of objects, whenever applicable and for any relevant installation phases.

Guidance note:
The standard gives requirements to four main installations phases:
— launching
— upending
— positioning and setting down
— connection to foundation, i.e. by suction, piling and/or grouting. Connection of TLP to tendons is also briefly covered.

1.2 Complementary standards

1.2.1 DNV offshore standards covering marine operations, i.e. DNV-OS-H101, DNV-OS-H102 and DNV-OS-H201 through DNV-OS-H206, are collectively referred to as the VMO Standard.

Guidance note:
The “VMO Standard” supersedes and replaces “DNV - Rules for Planning and Execution of Marine Operations”. See also Table 1-1.

1.2.2 General recommendations for planning, relevant loads and design of marine operations are given in DNV-OS-H101 and DNV-OS-H102.

1.2.3 For offshore installation operations involving lifting, the requirements in DNV-OS-H205 are applicable and should be used to supplement the requirements in this standard.

Guidance note:
Guidance regarding offshore marine operations not covered in this standard may be found in:
— offshore installation of decks (topsides) by float-over - DNV-OS-H201
— sea transport of jackets – DNV-OS-H202
— hook-up of floating platforms to pre-laid mooring systems – DNV-OS-H203
— offshore installation of subsea objects - DNV-OS-H206.

1.3 Objectives and conditions

1.3.1 The objectives of this Standard are stated in DNV-OS-H101, Sec.1 A.

1.3.2 The general conditions for use of this Standard are stated in DNV-OS-H101, Sec.1 B200.

2 References

2.1 Numbering and cross references

2.1.1 Table 1-1 defines the numbering system used throughout this standard, in comparison with that adopted in the DNV-H series of offshore standards, published to date. See Table 1-1.

2.1.2 The text in this standard includes references to the documents listed in Table 1-2. If indicated where the reference is given, the referenced text shall be considered as part of this standard.
2.1.3 Requirements herein are based on the document revisions listed in Table 1-2, however the latest revision shall normally be applicable, 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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2.1.4 The documents listed in Table 1-3 include information that through references in this text, clarify and indicate acceptable methods of fulfilling the requirements given in this standard.

2.1.5 The latest revision of the informative references should normally be used.

3 Definitions

3.1 Verbal forms

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

3.1.2 Shall: verbal form used to indicate requirements strictly to be followed in order to conform to the document.

3.1.3 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.

3.1.4 May: verbal form used to indicate a course of action permissible within the limits of the document.
3.2 Terminology

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

**Docking:** The activities necessary to accurately position a self-floating object on supports prepared at the seabed.

**Free-flooding:** A “free-flooding” tank is open to the sea and ventilated so it is filled naturally when submerged.

**Grouting:** The activities associated with cementing void spaces between pile and pile sleeve after pile-driving, or underpinning an object placed on the sea bottom, by injecting cement under the base structure.

**Jacket:** A sub-structure, positioned on the seabed, generally of tubular steel construction and secured by piles, designed to support topsides facilities.

**Launching:** Activities comprising of the cutting of seafastening of an object resting on a specially equipped launch barge, skidding of the object along skidways and lowering into the water until the object is free floating.

**Lifting:** The activities necessary to lift or assist an object by crane.

**Object:** An offshore structure or parts thereof subjected to one or several of the offshore installation operations covered in this Standard.

**Piling:** The activities necessary to secure an object to the sea bottom by driving piles into the sea bottom.

**Positioning:** The activities necessary to position an object over a predetermined location.

**Safe condition:** A condition where the object is considered exposed to normal risk for damage or loss. See also DNV-OS-H101.

**Setting:** The activities necessary to set-down an object on the seabed after positioning, including levelling, soil penetration and suction (if applicable).

**Swaging:** A method that is using hydraulic force to form immediate structural connections between pile sleeves and foundation piles.

**Upending:** The activities necessary to upend (rotate) a floating object.

3.3 Abbreviations and symbols

3.3.1 The list below defines the abbreviations and symbols used in this standard.

- **CoB:** Centre of Buoyancy
- **CoG:** Centre of Gravity
- **GBS:** Gravity Base Structure
- **GM:** Initial metacentric height
- **PNR:** Point of No Return
- **ROV:** Subsea Remotely Operated Vehicle
- **TLP:** Tension Leg Platform
- **T_{POP}:** Planned operation period, see DNV-OS-H101
- **T_{R}:** Operation reference period, see DNV-OS-H101
- **WNE:** Not to exceed weight
- **μ_{dyn}:** Dynamic friction coefficient
- **μ_{s}:** Static friction coefficient
SECTION 2 GENERAL REQUIREMENTS

1 Design phase

1.1 Planning and design

1.1.1 General requirements for planning and design are given in DNV-OS-H101, Sec.2 A.

1.1.2 The required operation reference period, $T_R$, defined in DNV-OS-H101, Sec.4 A, shall be evaluated and documented thoroughly; this should be done at the earliest possible opportunity.

1.1.3 The start and end points of all offshore installation operations (and where necessary sub-operations) shall coincide with clearly defined “safe conditions”.

1.1.4 An offshore installation operation may consist of several consecutive and/or overlapping sub-operations; each stage shall be thoroughly considered in the overall planning of the operation.

1.1.5 All possible environmental conditions, see DNV-OS-H101, Sec.3, shall be evaluated and considered during planning and design.

Guidance note:
Appropriate consideration should be given to environmental limitations for safe transfer of personnel. See also [4.6.3].

1.1.6 Site surveys, see [4.3], schedules shall be adequate to provide the seabed topography and bathymetry information required for the planning and design phase.

1.2 Risk management

1.2.1 Operational risk shall be evaluated and handled in a systematic way. See DNV-OS-H101, Sec.2 C.

2 Loads

2.1 General

2.1.1 Loads and load effects are generally defined in DNV-OS-H102. Any loads and load effects not described in DNV-OS-H102 shall be identified and considered accordingly.

2.1.2 The loads described in [2.2] through [2.5] should be considered relevant for the installation phases covered in the standard.

2.1.3 The design principles and methods described in DNV-OS-H102 shall be adhered to.

2.1.4 Sensitivity studies should be carried out according to DNV-OS-H102 Sec.4 A200, whenever relevant.

2.2 Hydrostatic loads

2.2.1 Hydrostatic pressure loads associated with external water pressure on submerged structures or internal water pressure in water filled or pre-pressurized compartments shall be considered.

2.2.2 The characteristic value of the hydrostatic pressure loads shall be determined for the most severe hydrostatic head occurring during installation of the object.

2.3 Dynamic loads

2.3.1 Hydrodynamic loads related to translation and rotation of the object during launching, upending, positioning and setting shall be considered.

2.3.2 Possible loads due to vortex shedding of e.g. free standing piles, should be considered.

2.3.3 The characteristic dynamic loads during positioning and setting shall be determined considering the largest positioning velocities and accelerations. Possible impact loads should be included.

Guidance note:
The velocities and accelerations during positioning and set-down of the object may be determined by model tests and/or theoretical calculations.
2.4 Soil interaction loads

2.4.1 The loads associated with soil interaction include foundation reactions on mudmats, slabs, skirts, etc. during the soil penetration phase, see also [2.5].

2.4.2 Loads from the soil include friction forces or bearing pressure. The characteristic value of loads from the soil shall be determined considering the following:

a) type of soil and belonging soil parameters
b) seabed topography
c) penetration depth.

2.5 Other loads

2.5.1 When relevant, consideration shall be given to special loads such as:

— slamming loads
— loads due to pressure differences in independent skirt compartments and bucket foundations during the soil penetration phase
— loads in the object due to transfer of ballast
— loads from pile installation and driving
— loads due to installation tolerances
— loads due to levelling of the object
— loads due to removal of auxiliary buoyancy
— crane loads during crane assisted upending/positioning.

2.5.2 Characteristic values of the above loads may be determined considering the following operational aspects:

a) limitations related to the strength of the object and the soil penetration rate
b) capacity of the skirt water evacuation system
c) whether “suction” is used or not
d) ballasting arrangement and rate
e) object on bottom stability design conditions/limitations.

3 Documentation

3.1 General

3.1.1 General requirements to documentation are given in DNV-OS-H101, Sec.2 B.

3.2 Design documentation

3.2.1 The following design documentation covering all applicable operational phases, are normally required:

— structural strength analysis and stability calculations for the object
— analyses/calculations/certificates/statements adequately documenting the necessary strength and capacity of all involved equipment and structures
— documentation of soil characteristics
— vessel (barge) data, stability and strength verifications
— ballast calculations covering the planned operation as well as contingency situations.

3.2.2 Calculations and evaluations of expected monitoring results should be made. Acceptable tolerances should be stated and documented.

3.3 Equipment, fabrication and vessels

3.3.1 The integrity and suitability of equipment, structures and vessels shall be demonstrated by adequate documentation e.g. by valid certificates and inspection/test/survey reports.

3.3.2 Testing and calibration of survey equipment once mounted on site should be performed according to equipment operation manuals.

3.3.3 Calibration certificates/reports should be available for monitoring equipment.

3.4 Operation manual

3.4.1 A dedicated operations manual shall be prepared, see DNV-OS-H101, Sec.4 E.
3.4.2 The items listed below will normally be crucial for the successful execution of offshore installation operations and should be emphasized in the manual:

a) Definition of design/operational limitations and requirements for weather forecasts as well as wind, wave and current monitoring.

b) Detailed operation schedule, relating to any specific weather window/s and the identification of all “safe conditions” as necessary.

c) Checklists ensuring that all required preparations have been carried out.

d) Correct positioning of the object and vessels.

e) Monitoring procedures describing equipment set-up, testing, recording, expected readings including acceptable deviations and reporting routines during the operation.

f) Detailed ballast procedures.

g) Relevant contingency procedures.

3.5 Log

3.5.1 A detailed log shall be maintained throughout the operation and kept thereafter, see DNV-OS-H101 Sec.2 B500. The following should be recorded:

— environmental conditions
— the sequence of events
— all monitoring results.

3.5.2 All data logged and used to control / manage the operations shall be readily available.

4 Operational aspects

4.1 General

4.1.1 The general operational requirements in DNV-OS-H101 Sec.4 apply.

Guidance note:
The following paragraphs include some additional requirements and/or emphasise requirements considered especially important for offshore installation operations.

4.2 Preparation

4.2.1 The environmental conditions (monitored/observed and forecast) shall be such that proposed operations can be completed in a well-controlled manner, in accordance with the design assumptions and operational limitations associated with the objects involved.

Guidance note:
Safe working conditions for personnel both on board and during transfers to barge and object (if applicable) should be ensured. See [4.6.3].

4.2.2 All structures and equipment necessary for the operation shall be correctly rigged and ready for use.

4.2.3 Adequate lighting shall be provided in all involved areas throughout the operation. Possible delays beyond daylight hours should be considered.

4.3 Installation site surveys

4.3.1 An early bathymetric survey of the installation site should be performed, with sufficient accuracy for the design of the intended operations.

4.3.2 The soil parameters at the target area for installation should be determined based on geotechnical site investigations. Such data are normally determined as basis for the design for the in-place condition.

4.3.3 The type and extent of site surveys should be determined in relation to type, size, design tolerances and importance of the object to be installed and the uniformity of the seabed. Obstacles both on and in soil strata should be revealed.
4.3.4 In selecting the size of each area to be investigated, sufficient tolerances should be included to account for:
- positioning errors during site investigation
- errors in navigation equipment used for installation
- realistic operational tolerances.

4.3.5 The required measurement accuracy for differential elevation measurements should be considered.

4.3.6 Level and profile changes of the seabed, between initial surveys and installation, should be considered and investigated as relevant.

Guidance note:
Level differences could be caused by sand waves, drilling operations, scouring, strong currents, etc.

4.3.7 Consideration should be given to the effects of local depressions such as pockmarks or jack-up footing imprints.

4.3.8 Seabed survey(s) should be carried out to identify and prevent obstacles such as boulders, anchors and other miscellaneous debris from jeopardising installation of the object.

4.3.9 If levelling, e.g. by rock dumping, of the area for the final object position are required (see Sec.5 [6.1.2]), the survey procedure should adequately reflect this.

4.3.10 An ROV visual and side scan debris survey should be performed immediately prior to installation, confirming no obstructions on site. Visual survey may suffice for small areas with good visibility.

4.4 Monitoring

4.4.1 Monitoring methods employed should be commensurate with the accuracy required (i.e. acceptable monitoring tolerances).

4.4.2 Target values and maximum deviations from target values, i.e. tolerances for monitoring should be clearly defined.

4.4.3 Monitoring of environmental conditions shall be carried out according to DNV-OS-H101, Sec.4 D.

4.5 Weather forecast

4.5.1 The operation manual shall clearly define weather limitations and requirements for weather forecasting, see DNV-OS-H101, Sec.4 C.

4.5.2 Swell could be of significant importance for offshore installation operations and shall be duly considered.

4.6 Organisation and personnel

4.6.1 General requirements for the organisation, personnel qualifications and communication during offshore installation operations are given in DNV-OS-H101, Sec.4 E.

4.6.2 Operators shall have the necessary training and experience in operating equipment. Where necessary, operators should be able to demonstrate/document their competencies.

4.6.3 Adequate facilities for transferring personnel safely in the limiting weather conditions, to/from vessel(s) and if applicable to/from installation structures shall be provided.
SECTION 3 LAUNCHING

1 Introduction

1.1 Application

1.1.1 Sec.3 applies to longitudinal and transverse launching of objects from single transportation barges. Launching from multi-barge systems necessitates special considerations and requirements in addition to those given in this section.

1.1.2 Launching of objects with asymmetrical launch frames will require special considerations with respect to possible yaw motions.

1.1.3 Transverse launching operations should be considered in a similar manner to longitudinal operations. Special considerations shall be given to the behaviour of the launch barge during launch.

1.2 Design considerations

1.2.1 See Sec.2 [1] for general considerations.

1.2.2 The following parameters shall be considered in relation to operational feasibility and structural limitations of the launched object and of the barge:

a) barge main particulars including stability data  
b) object design including buoyancy requirements  
c) position of the object on the barge  
d) barge draught and trim at pre-launch condition  
e) barge bending moment and shear force  
f) barge (stern) allowable submergence  
g) barge ballasting plan and procedures  
h) limiting environmental conditions  
i) rocker arm arrangement and rotational limitations  
j) allowable rocker arm and skidway reactions  
k) friction coefficient  
l) minimum water depth in launch/upending area  
m) adequate sea room for manoeuvring.

1.2.3 The launch shall be initiated in a controlled manner by removing the anti self-launch devices and/or by pushing/pulling the launched object to overcome the static friction forces.

1.2.4 Tugs should not be used to initiate the launch.

1.3 Documentation

1.3.1 See Sec.2 [3] for general documentation requirements.

1.3.2 The launch analysis, see [2.2], shall be properly documented by design report(s). If model tests have been carried out, these should also be documented by test report(s).

1.3.3 For vessels that will be ballasted/de-ballasted during operations, the minimum following documentation shall be presented:

a) general arrangement drawing/s, including ballasting system details  
b) hull structural drawings, including any internal reinforcement  
c) tank plan  
d) limitations for maximum submerging  
e) load limitations on rocker arms  
f) longitudinal hull beam strength limitations  
g) deck load capacity plan  
h) equipment data and drawings  
i) hydrostatic data including curves/tables
j) guidelines for air pressurised barge tanks, if used  
k) details of skidway rails and skidding surface.

2 Loads and analyses

2.1 General

2.1.1 See Sec.2 [2] for general requirements for loads.  

Guidance note:  
It is recommended and normal practice to apply WNE for the purposes of structural jacket launch analysis.  

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2.2 Launch analyses

2.2.1 Launching operations can be represented by a series of different load cases, from initiation to the stage where the barge and object float separately. The entire launching sequence should be considered step-by-step, whilst the most critical load case for each specific member of the launched object is identified and assessed.

2.2.2 The trajectory of the launched object should normally be computed by dynamic analyses. In general, three dimensional analyses are recommended.  

Guidance note 1:  
The barge size should be suitable for the launched object. Normally it is advisable to select the smallest barge that is meeting the requirements of accessibility, redundant and reserve buoyancy, free board, overhangs, etc. At least the launch velocity should be sufficient to ensure adequate clearances between barge and object after their separation. It is recommended that the relative launch velocity of object versus barge is $\geq 1$ m/s when the jacket tilts.  

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Guidance note 2:  
The need for validation (by model testing) of computed values should be considered on a case by case basis and conducted as required.  

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2.2.3 The analyses should include assessment of the barge motions.

2.2.4 All significant forces influencing the behaviour of the barge and launched object shall be considered.

2.2.5 Particular attention should be given to the behaviour of the barge and the resulting forces from the rocker arm on the launched object.

2.2.6 Launch analyses shall include sensitivity analyses, with consideration given to the following variables and their min-max design envelopes:  

— object weight and CoG  
— barge pre-launch condition/ jacket start position  
— dynamic friction between launch runners and skidways.

Guidance note 1:  
In marginal cases it is recommended to also include hydrodynamic properties of barge and object in the sensitivity analysis.  

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Guidance note 2:  
The buoyancy and CoB uncertainties are normally included whilst assessing the required weight contingency and CoG envelope.  

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2.3 Loadcases and load effects

2.3.1 The definition of critical load cases should be based on the launch analyses, see [2.2] and analysed quasi-statically. Self-weight, buoyancy forces, drag, barge support forces, etc. should be distributed appropriately to the structural members of the launched object and barge.
Guidance note:
All stages of the launching should be analysed. Normally this implies the assessment of all hard truss points on jacket above rocker arm pin. In addition the jacket (object) should be analysed for some carefully selected cases following the barge/jacket separation.

---end---of---Guidance---note---

2.3.2 Loading effects from wind, motions due to waves and the launch operation itself shall be considered. The resulting increase in hydrodynamic forces due to wind and waves may be accounted for by using a dynamic amplification factor on the static forces.

Guidance note:
A DAF = 1.1 is normally considered sufficient to account for the effect of wind and wave motions, however see [6.1.2].

---end---of---Guidance---note---

2.3.3 Loads derived from [2.3.1] and [2.3.2] shall be applied to the launched object and to the launch barge.

2.3.4 Members exposed to slamming loads during launch such as risers, jacket legs, buoyancy tanks, flood valves and other specific equipment should be checked for the largest relative velocity at the actual member; relative velocities should be determined from the launch analysis, see [2.2].

2.3.5 Calculations of ULS characteristic loads on buoyant compartments and buoyancy tanks shall consider the largest submergence draft during launch with intact structure.

2.3.6 ALS characteristic loads on buoyant compartments and buoyancy tanks shall be calculated for the free floating condition draft, assuming accidental flooding of any one buoyant compartment.

Guidance note:
ALS loads do not need to be calculated for other stages of the launch.

---end---of---Guidance---note---

3 Launched object

3.1 General

3.1.1 Launched object refers to the main object and all attached items and appurtenances e.g. buoyancy tanks, control capsules, risers and j-tubes.

3.2 Buoyancy, clearances and stability

3.2.1 The buoyancy and stability of the launched object shall be such that it satisfies the requirements in [3.2.2] and [3.2.3] below, considering “worst case” results from any sensitivity analyses.

3.2.2 The seabed clearance to the lowest protruding member of the launched object during launch should not be less than the greater of 5 metres and 10% of the water depth at lowest astronomical tide.

3.2.3 Upon completion of the launching operation, the object should remain afloat in stable equilibrium, with sufficient freeboard to allow commencement of the upending operation. Accidental flooding of any one compartment shall be considered.

Guidance note 1:
In intact condition the minimum freeboard of rigging/control platform may be taken as the significant wave height for installation plus 1.0 meters, however minimum freeboard should not be less than 2.5 meters. The freeboard should be sufficient to commence upending without problems from damage condition affecting one compartment.

---end---of---Guidance---note---

Guidance note 2:
See Sec.4 [3.2.2] and Sec.4 [3.2.3] for spare buoyancy and stability requirements.

---end---of---Guidance---note---

3.3 Structural strength

3.3.1 The launched object shall have sufficient strength to withstand the loads acting on the object as described in [2.3].

3.3.2 Special attention shall be paid to local support loads acting on the launch frames. Fabrication tolerances of the launch runner, including variations in timber material properties shall be considered.
3.4 Buoyancy compartments

3.4.1 Buoyancy tanks (auxiliary or permanent) and other buoyant structures, including watertight diaphragms shall be designed with due consideration to their criticality; i.e. increased design factors may be considered appropriate in some cases.

3.4.2 Connections between the buoyancy tank/s and the launched object shall be designed to withstand all hydrodynamic and buoyancy loads acting on them during launch. A consequence factor of 1.3 should be applied to the primary steel attachments both in ULS and ALS design cases.

Guidance note 1:
The consequence factor may be reduced, with due consideration of the attachment system and consequence of an attachment failure.

Guidance note 2:
Other installation phases than launching may be important for the design of buoyancy tanks and their connections. See e.g. Sec.4 [2.3.3], [2.3.4], [3.3.2], Sec.5 [2.3.4], [3.4.3] and Sec.5 [6.2].

3.5 Launch devices

3.5.1 Anti self-launch devices shall have sufficient structural strength to secure the jacket against sliding, allowing for both planned maximum initial barge trim (heel if sideways launch) and barge motions. Friction may be considered, assuming the lowest design friction (see [5.4.5]) is used, together with a conservative value for barge trim and motions.

Guidance note:
The barge motions should be calculated/assessed based on the maximum allowable launch sea state. Normally it will be adequate to consider the motions by adding 50% to the forces due to barge trim.

3.5.2 Launch lugs and similar structures shall have sufficient structural strength to withstand the maximum static friction forces. A skew load factor of 1.5 should be applied and pre-trim may be taken into account.

3.6 Rubber diaphragms

3.6.1 Rubber diaphragms shall have sufficient strength to withstand internal and external water head or air pressure, including loads due to temperature changes after assembly.

3.6.2 A test and inspection programme including short term and long term tests (see [5.6.2]) shall be carried out to ensure adequate strength and integrity of the diaphragms.

3.6.3 After the rubber diaphragms have been mounted on the object special attention shall be given to protect the rubber from the surrounding environment.

3.6.4 It shall be ensured that the rubber diaphragms cannot jeopardize pile installation and/or grout quality.

Guidance note:
The inclusion of the rubber diaphragm systems in pile sleeves to increase object buoyancy shall be removable such that they will not interfere with the monitoring or quality of the grout level in the pile sleeve.

4 Launch barge

4.1 General

4.1.1 Barge equipment and systems shall meet the requirements of sub-section [5] with respect to capacity, arrangement, inspection, and testing.

4.1.2 General requirements to barges (vessels) are given in DNV-OS-H101, Sec.6 D.

4.2 Stability during launching

4.2.1 The barge shall have sufficient positive intact stability, ensuring sufficient heel within acceptable tolerances throughout all stages of the launching operation.

Guidance note:
The general barge intact and damage stability requirements in DNV-OS-H101, Sec.5 B do not need to be adhered to during launching. It is assumed that strict weather limitations are imposed in this phase however and that the barge
will be ballasted back to the transport condition, if weather conditions deteriorate. Alternatively, the following could be used as guidance:

Prior to the initiation of jacket sliding, the stability of the jacket/barge combination should comply with the following:

a) Minimum range of static stability shall be not less than \((15 + 10/GM)\) degrees.

b) Dynamic stability as given in DNV-OS-H101, Sec.5 B, Figure 1. The wind velocity to be used in the calculations could reflect the specified weather limitations, but an adequate safety margin should be applied. Normally the wind velocity should be a minimum of 25 meters/second, or the design wind speed for the towage to location.

After initiation of jacket sliding, until the jacket starts to rotate relative to the barge, the stability of the jacket/barge combination shall comply with the following:

a) Metacentric height of the jacket/barge combination should be positive. Normally the contribution to the water plane area of the jacket should not be considered. Reduced “effective” weight due to buoyancy of submerged jacket members should be considered.

b) Angle of heel caused by 1.5 times the limiting launch wind speed should be shown to be acceptable.

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4.2.2 Relevant contingencies should be included in the stability calculations, see [2.2].

4.3 Structural strength

4.3.1 Loads on the barge should be assessed in accordance with Sub-section [2].

4.3.2 The loads on the launch barge should be demonstrated and verified to be within the operational limitations of the barge and assessed by the Classification Society associated with it. This verification normally includes evaluation of:

— bending, shear and torsion of the barge hull
— rocker arm and skidway reactions considering barge local strength
— barge submersion
— barge hydrostatic stability
— special requirements from the Classification Society.

Guidance note 1:
Any reinforcement required should normally be subject to acceptance by the Classification Society associated with the barge.

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Guidance note 2:
The allowable loads given from the Classification Society are based on general assumptions regarding the operation and design factors according to the Classification Society Rules. These assumptions and design factors should be thoroughly assessed considering the specific procedure and applied/allowable design factors for the actual operation.

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4.3.3 Structural components on the barge not assessed by the barge's own Classification Society should be verified to have sufficient structural strength to withstand all loads during the launching operation.

Guidance note:
Typically, such components can include skidway, brackets for attachment of positioning lines, supports for winches, hydraulic jacks and sheave blocks, etc.

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5 Systems and equipment

5.1 General

5.1.1 Systems and equipment should comply with the requirements given in DNV-OS-H101, Sec.6 A.

5.2 Ballasting system

5.2.1 The barge ballasting system shall have sufficient capacity to achieve the predetermined barge launch parameters within the planned time for this activity.

Guidance note:
The planned operation period should include a period for ballasting the barge. The period length must reflect potential inefficiencies in the pumping system and the impact of possible failure.

Normally it is recommended that the planned time for pre-ballasting does not exceed 25% of the planned operation period \((T_{POP})\) and that the barge ballast capacity fulfil the following requirements:
5.2.2 The barge tank volume should have sufficient spare capacity such that the required trim, heel and draft can be maintained in the event of accidental flooding of any one compartment.

5.2.3 Hatch covers over barge tanks should be closed prior to and during launch.

Guidance note:
This precludes the use of portable submersible pumps during the ballasting operation.

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5.3 Power supply and flame cutting facilities

5.3.1 The power supply on the barge shall have sufficient capacity for all demands placed upon it, including any contingencies.

5.3.2 Flame cutting facilities, should be located appropriately and have documented capacity for cutting of the seafastening members within the planned time for this activity.

Guidance note:
It is recommended that the planned time period for cutting does not exceed 25% of the planned operation period (T_{POP}).

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5.4 Launch pull systems

5.4.1 The object to be launched shall be secured to the barge with anti-self-launch devices, preventing an uncontrolled or premature launch after cutting of the seafastening members. See [3.5.1] for strength requirements.

5.4.2 Launch lugs, if applicable, should be designed to provide self-release of pulling wires after the launching has started - see [3.5.2] for strength requirements.

5.4.3 The launch initiating push/pull system shall have sufficient capacity to overcome the static friction forces and shall be capable of applying the force required over a sufficient distance to ensure initiation of the launch.

Guidance note:
The system should normally fulfil the following requirements:
— 130% capacity with intact system.
— 100% capacity with any one component failed or repair documented to be feasible within a time period accounted for in the T_{POP}.

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5.4.4 The sliding surfaces on the launch frames and on the launch barge skidways should have a finish and capacity that assures a sufficiently low friction coefficient.

5.4.5 For design and planning of the launch operation minimum and maximum design friction coefficients should be established.

Guidance note 1:
The characteristic friction coefficients should normally be documented by:
— manufacturer specifications
— experiences from similar operations and/or
— results from applicable friction tests.

The design friction coefficients should be based on characteristic friction coefficients and appropriate material factors, see DNV-OS-H102.

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Guidance note 2:
If reliable values are unavailable, the maximum (upper bound) design friction coefficients given in DNV-OS-H201, table 3-2 may be used. Minimum characteristic dynamic design friction coefficient should not be taken greater than 0.03 without documentation.

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5.4.6 The dynamic friction coefficient shall, if possible, be verified through monitoring of required pull/push force during loadout.

**Guidance note 1:**
The friction coefficient calculated based on the loadout monitoring should be within the applied upper and lower bound characteristic friction coefficients. Otherwise, additional launch analysis may be required.

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**Guidance note 2:**
The initial launch condition (draft and trim) for the barge should be adjusted to take into account the final best estimate for the friction coefficient, if considered necessary.

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5.5 Equipment arrangement

5.5.1 Equipment on the barge to be used prior to and during launch shall be fit for the intended purpose and arranged to ensure appropriate start-up time. All equipment shall be arranged to avoid damage to the object during launch.

5.5.2 The guide-rails on the skidways and rocker arms shall have sufficient strength and be designed to ensure a smooth launching.

**Guidance note:**
The strength assessment should consider transverse force due to maximum barge heel/roll and object due to transverse asymmetries (including weight & buoyancy) in the launched object and uneven friction on the launch/skidways.

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5.6 Inspection and tests

5.6.1 All equipment and systems to be used during the launch operation both on the object and barge shall be inspected and/or function tested prior to departure from shore. Associated documentation shall confirm that all equipment and systems are in good working order and fit for purpose.

**Guidance note:**
The tests/inspections of the barge permanent systems and equipment should confirm compliance with Classification Society requirements.

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5.6.2 Rubber diaphragms shall be thoroughly tested for short and long term operation.

**Guidance note:**
The tests should be performed as close to sail away as possible and include the following:

— Each individual diaphragm should be tested to 1.25 times the maximum working pressure with a minimum duration of 10 minutes.
— One diaphragm of each type should be tested at 1.1 times the maximum working pressure with a minimum duration of 48 hours.

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5.6.3 Integrity of the rubber diaphragms must be established before commencing launching operation. This can be easily done by visually confirming all diaphragms to be in inflated position before commencing launch position.

5.6.4 Prior to departure from shore, the barge shall be inspected and compliance confirmed in accordance with Classification Society requirements.

5.6.5 A survey of the skidways and rocker arms shall be performed to verify that alignment and level reflects the criteria defined as part of structural verification of the barge and the launched object.

5.6.6 All buoyant tanks e.g. buoyant legs, buoyancy tanks, should have a minimum 5 PSI (0.35 BAR) internal overpressure at departure from the shore.

**Guidance note:**
Permanently buoyant members as jacket braces are not considered tanks in this item.

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5.6.7 A monitoring system should be arranged such that the pressure in the tanks can be readily determined; pressure should be confirmed prior to launch to verify the integrity of the tanks.
Guidance note:
The pressurizing should normally be done and monitored minimum 3 days prior to loadout and through to sail away of the object.

5.6.8 In the event of any leakage detected during tow, adequate measures should be performed to identify the extent of the leakage - any consequences should be evaluated prior to launching.

6 Operational aspects

6.1 General

6.1.1 The requirements in Sec.2 [4] apply.

6.1.2 Prevailing environmental conditions shall be evaluated and compared with the operational limitations assumed as part of the simplified analysis, see [2.3.2].

Guidance note:
Barge roll motions have not normally been considered as part of the launch analysis. A situation with significant swell on the barge beam, combined with heading the barge, as recommended, into the wind, see [6.3.3], would hence not be covered by the launch analysis. Such launch conditions are accordingly normally unacceptable.

6.2 Preparations for launching

6.2.1 The following conditions should be complied with prior to cutting seafastening and/or ballasting the launch barge:

a) It should be ensured that all necessary acceptances and preparations for the weather restricted part of the offshore installation operation are granted.

b) Site bottom condition as shown by ROV or diver surveys accepted by all involved parties.

c) The launch position and orientation has been found acceptable.

d) Obstacles which may unduly delay the operation have been removed.

e) There are no other simultaneous vessel operations at the site that could jeopardize the installation.

f) All structures and equipment necessary for the operation are correctly rigged, ready to be used, and in acceptable condition after sea transport.

Guidance note:
It is recommended that all critical equipment is re-inspected following sea transport (see also [5.6.6]).

6.2.2 The release of seafastening members and barge ballasting shall be performed in accordance with a predetermined step-wise procedure.

6.2.3 Seafastening cut-lines should be indicated by painting.

6.2.4 If present, wind vortex-shedding prohibiting devices (e.g. wire ropes) shall not be removed until such time that wind conditions forecast during the period prior to launch, dictate that it is safe to do so.

6.2.5 Weather conditions and forecasts shall be evaluated continuously, as shall any critical wave, wind, and current data. The point of no return shall be identified in the procedure. A weather check shall always be made before a point of no return (PNR) is crossed.

Guidance note:
Normally the point of no return for launching will be when seafastening that cannot be reinstated within a reasonable timescale, is cut.

6.2.6 Seafastening members that have been cut shall be removed and fastened securely to the barge, in a location that will not cause interference with the object during launch.

6.2.7 Rigging equipment should be connected to attachment points (padeyes, trunnions, bollards, etc.) specially designed for the corresponding loads. Other attachment points should not be used.

6.2.8 Cutting of anti-self-launch devices (shear plates) shall be thoroughly coordinated.
6.3 Positioning of barge and object

6.3.1 The launch barge should be positioned by lines attached to tugs. The object to be launched should also be connected to positioning and hold-back vessels, by lines with sufficient slack to allow free movement during the launch.

Guidance note:
If may be found adequate to position the barge by anchor lines instead of tugs. In this case acceptable dynamic behaviour of the barge and anchor lines throughout the launch need to be documented.

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6.3.2 The barge should be positioned relative to a set of predetermined co-ordinates within an area that has been subjected to surveys. The launch location should be well clear of any structures, pipelines, etc. positioned on or near the seabed.

6.3.3 The barge heading for launch should, where possible, be into the prevailing wind and wave direction.

6.4 Monitoring of launching operations

6.4.1 The following parameters should be monitored before (preparation phase), during and after launch as applicable:

a) barge trim and draught
b) barge position and orientation
c) barge motions
d) barge ballast and stability parameters
e) draught, heel, and trim of the object after launch.
SECTION 4 UPENDING

1 Introduction

1.1 Application

1.1.1 This section applies to upending operations of objects carried out by controlled ballasting, flooding and/or de-ballasting of buoyant compartments.

1.1.2 The upending operation may or may not be assisted by crane(s), the lifting aspects of which are covered by DNV-OS-H205/VMO Rules Part 2-5 - Lifting Operations.

1.2 Design considerations

1.2.1 See Sec.2 [1] for general considerations.

1.2.2 The following parameters should be considered in relation to operational feasibility and structural limitations of the object:

a) hydrostatic stability
b) ballasting/de-ballasting system capacity and redundancy
c) limiting environmental conditions
d) water depth
e) crane lifting capacity.

1.3 Documentation

1.3.1 See Sec.2 [3] for general documentation requirements.

1.3.2 The upending analysis, see [2.2], shall be properly documented by design report(s). If model tests have been carried out these should be documented by a test report.

2 Loads and analyses

2.1 General

2.1.1 See Sec.2 [2] for general requirements.

2.2 Upending analysis

2.2.1 In principle the entire upending sequence should be considered continuously from the initial self-floating condition to the final self-floating condition and installation. However, the upending operation may be represented by a step-by-step sequence of different loadcases.

Guidance note:
Model tests may be used to verify the objects behaviour during upending.

2.2.2 An adequate number of steps shall be analysed to ensure that the critical loadcase/s for all members are identified.

Guidance note:
For some stages of upending operations, consideration of only a few degrees between each step may be necessary; a maximum of 15 degrees between each step should normally be adopted.

2.2.3 Upending analysis should include any one (critical) compartment accidentally flooded.

2.2.4 Upending analyses should include sensitivity analyses considering maximum possible variations in weight and CoG.

Guidance note:
It is recommended to carry out sensitivity analysis including the most onerous compartment accidentally flooded. However, reduced variations in weight and CoG may be considered in this case.
2.3 Loadcases and load effects

2.3.1 The basic load cases described in [2.2] should be analysed by static analyses considering the buoyancy, self-weight and any applied loads.

**Guidance note:**
Global structural analysis may be waived for upending operations, if it can be demonstrated that similar analysis have been undertaken, including more onerous loading conditions during transportation, installation or the in-place phases.

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2.3.2 For crane assisted upending dynamic loads in the rigging due to relative movements between object and crane vessel shall be included in the analyses.

**Guidance note:**
For non-crane assisted upending a DAF of 1.1 for dynamic effects is recommended.

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2.3.3 ULS characteristic loads on buoyant compartments and buoyancy tanks should be calculated for the largest submergence draft with intact structure.

2.3.4 ALS characteristic loads on buoyant compartments and buoyancy tanks should be calculated for the largest submergence draft assuming accidental flooding of any one buoyant compartment.

2.4 Self-upending jackets

2.4.1 A self-upending jacket has no intermediate stages for checks and control and is inherently irreversible. Therefore the calculations for launch and upending must cover all reasonable variations of jacket weight, CoG, and damage conditions.

**Guidance note:**
A self-upending jacket is one that after launch rotates to a near-vertical attitude without an intermediate horizontal phase. This may be achieved by distribution of buoyancy and/or free-flooding compartments.

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2.4.2 A rapid assessment of jacket weight and status after the upending shall be planned for.

**Guidance note:**
The integrity of the jacket after launch can be assessed by jacket draught readings, once the stable near-upright condition is achieved. Calculations should be carried out and a suitable tabular and/or diagrammatic presentation should be included in the Installation Manual, so that the assessment can be made from the post-upending draught readings.

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2.4.3 Provision for contingency air de-ballast of critical compartments may be required to ensure adequate emplacement behaviour under all circumstances, but should not normally be relied on for the “base case” undamaged operation.

2.4.4 The launching ULS and the upending ULS and ALS requirements to reserve buoyancy and bottom clearance apply.

3 Upended object

3.1 General

3.1.1 Upended object refers to the object to be upended including any attached components e.g. buoyancy tanks, risers, positioning brackets, clamping devices.

3.2 Buoyancy, clearances and stability

3.2.1 It shall be shown that the object will behave in a stable manner during the upending operation.

**Guidance note:**
Model tests may be used to verify the objects behaviour during upending.

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3.2.2 The initial metacentric height (GM), corrected for free surface effect, should normally not be less than 0.5m in the intact condition and 0.2 m in the one compartment damage condition, for any defined step during the operation. See also [3.2.4].
Guidance note 1:
It is assumed that CoB and CoG have been calculated based on “worst case” sensitivity, see Sec.3 [3.2.1]. Normally only variations in CoG are considered in order to cover the uncertainties in both CoG and CoB.

---end---of---Guidance---note---

Guidance note 2:
A limited period during upending when the jacket is metastable or unstable longitudinally (i.e. in the upending direction) may be acceptable, provided the behaviour has been investigated and all interested parties are aware of it. Practical problems which may be encountered with attending vessels, or rigging and handling lines should be resolved.

---end---of---Guidance---note---

3.2.3 Positive restoring moments up to an angle ensuring a stable behaviour of the object both in intact and damage condition should be documented as applicable.

3.2.4 Effect on the stability of force re-distribution in the rigging due to heel (trim) of the object should be considered for crane assisted upending operations.

Guidance note:
The requirements in [3.2.2] above may be reduced, subject to a documented positive effect of rigging force re-distribution.

---end---of---Guidance---note---

3.2.5 The buoyancy contingency calculated for upending by ballasting only (any stage) shall not be less than:
— in ULS (i.e. no object damage) - 10% of the object total buoyancy
— in ALS (i.e. object damaged condition) - 5% of the object total buoyancy.

3.2.6 For crane assisted upending operations the requirement for buoyancy contingency should be determined in each case.

Guidance note:
The combined spare buoyancy and spare crane capacity should normally not be less than the following for any stage:
— In ULS, i.e. no object damage: 20% of the combined object total buoyancy and crane capacity.
— In ALS, i.e. object damaged condition: 10% of the combined object total buoyancy and crane capacity.

---end---of---Guidance---note---

3.2.7 The design clearances between mudline and the lowest protruding member considering the lowest astronomical tide, shall not be less than:
— in ULS (i.e. no object damage) - 5 meters
— in ALS (i.e. object damaged condition) - 2 meters.

Guidance note:
The above stated clearances include allowance for motions normally imposed by environmental conditions. However, it should be considered in each case if the indicated clearances need to be increased due to possible excessive environmental caused motions.

---end---of---Guidance---note---

3.2.8 Upending should not be performed above any subsea structures (e.g. preinstalled template, pipe well heads, pipelines, etc.).

Guidance note:
If upending above subsea structures is not avoidable this could be acceptable if additional risk reducing precautions as increased bottom clearances, more buoyancy redundancy and additional monitoring are applied.

---end---of---Guidance---note---

3.2.9 Upon completion of the upending operation, the object should remain afloat in stable equilibrium and with sufficient freeboard to allow commencement of the positioning and setting operations.

Guidance note:
The effect of one compartment damage should be considered.

---end---of---Guidance---note---

3.3 Structural strength

3.3.1 Objects shall have sufficient strength to withstand the loads described in [2].
3.3.2 The buoyancy tank connections shall have sufficient structural strength to withstand buoyancy loads and loads due to the transfer of ballast water.

3.3.3 For rubber diaphragms, the requirements in Sec.3 [3.6.1] apply.

3.3.4 Brackets on the object used for positioning purposes only shall be designed to resist towline pull from any likely direction.

**Guidance note:**
See DNV-OS-H101, Sec.6 B700 for applicable design requirements. If characteristic loads for the positioning brackets are not accurately (conservatively) calculated, including dynamic effects, it is recommended to design the brackets as towline connections. See DNV-OS-H202/ VMO Rules Part 2-2 - Sea Transport for guidance.

3.3.5 Clamping lines and similar devices may be used to secure articulated structures in a predetermined orientation during upending operations. Clamping devices shall have sufficient strength to withstand loads due to for example environmental conditions, buoyancy, gravity and transfer of ballast water, etc.

4 Systems and equipment

4.1 General

4.1.1 Systems and equipment shall comply with the requirements given in DNV-OS-H101, Sec.6 A.

4.1.2 Due attention should be given to the availability and functionality of systems and equipment in all object positions during the upending.

4.2 Ballasting and de-ballasting systems

4.2.1 The ballasting system shall have sufficient capacity to achieve upending, within the planned timescale for this activity.

**Guidance note:**
Ballasting capacity should normally fulfil the following minimum requirements:

— 130% capacity with intact system.
— 100% capacity with any one pump system failed.

4.2.2 The ballast system, if applicable, including the buoyancy tanks connected to the ballast system should be designed such that the upending operation may be reversed at any stage.

**Guidance note:**
Where it is not practicable to have a reversible upending ballast system, the upending/installation procedure should clearly identify the point of no return.

4.2.3 The ballast system shall be designed so that the object will remain in stable equilibrium in case of failure. See also [3.2.2].

4.2.4 For articulated structures ballasting/de-ballasting systems including the buoyant compartments shall have sufficient capacity to avoid overloading of the universal joint and to avoid exceeding rotational limitations for the universal joint for normal and for reversed upending operations.

4.2.5 Two separate methods should be available for starting or stopping flooding of any one independent compartment. Where requirement in item [4.2.6] is satisfied, a back-up method of discontinuing the flooding may be omitted.

4.2.6 The ballast compartments should be designed, where possible, such that closing of the ballast valve is not critical, i.e. 100% flooding of compartments once they are being utilised, should be the planned procedure.

4.2.7 The design and layout should seek to hinder damages.

**Guidance note:**
Any part of the ballasting system should be routed as much as possible towards the inside of the object structure in order to minimise risk of damage.
5 Operational aspects

5.1 General

5.1.1 The requirements in Sec.2 [4] apply.

5.2 Positioning

5.2.1 The final upending location shall be selected with due consideration to the assumptions made, see [3.2].

5.2.2 The object to be upended should be positioned and maintained at the predetermined location during the upending operation by means of positioning lines. The positioning lines should be attached and operated without influencing the hydrostatic stability, bottom clearance, etc.

5.3 Monitoring of upending operations

5.3.1 Where applicable, the following parameters should be monitored:

   a) draught, trim and heel
   b) seabed clearance
   c) environmental conditions
   d) amount of water in the ballasting compartments
   e) open/close mode for valves
   f) air pressure
   g) ballasting rate
   h) crane hook load.

5.3.2 The position and orientation of the object should be monitored by surface and/or underwater positioning systems.

   Guidance note:
   The applied monitoring method/system may/should reflect the accuracy required for positioning and orientation of the object during all phases of the upending.

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SECTION 5 POSITIONING AND SETTING

1 Introduction

1.1 Application

1.1.1 This section applies to positioning and setting (including docking, see Sub-section [5], if applicable) operations of objects where the vertical motion of the object is (partly) achieved by controlled ballasting, flooding or de-ballasting of buoyant compartments.

1.1.2 The positioning and setting operation may or may not be assisted by crane(s). Lifting aspects of crane-assisted operations are covered by DNV-OS-H205/VMO Rules Part 2-5 - Lifting Operations.

1.2 Design considerations

1.2.1 See Sec.2 [1] for general considerations.

1.2.2 The following parameters should be considered in relation to the operational feasibility and structural limitations of the object:

a) hydrostatic stability
b) ballasting system capacity
c) limiting environmental conditions
d) positioning and verticality tolerances
e) soil characteristics
f) on-bottom stability.

1.3 Documentation

1.3.1 See Sec.2 [3] for general requirements to documentation.

2 Loads and analyses

2.1 General

2.1.1 See Sec.2 [2] for general requirements to loads.

2.2 Positioning and setting analyses

2.2.1 The positioning and setting operations represent a sequence of loadcases during the horizontal and vertical translation of the object. In principle, the entire positioning and setting sequence should be considered step-by-step and the most critical loadcase for each specific member of the object shall be identified.

2.3 Loadcases and load effects

2.3.1 The basic load cases described in [2.2] should be analysed by a static analysis considering the buoyancy, self-weight, soil reaction, positioning loads, etc.

Guidance note:
The structural analysis verifying the global integrity of the object may be omitted, providing that a similar structural analysis considering a more onerous loading condition for another phase has been documented.

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2.3.2 For crane assisted positioning, dynamic loads in the rigging due to relative movements between object and crane vessel shall be included in the analyses.

2.3.3 Positioning line loads should be assessed considering relevant design environmental conditions.

2.3.4 ULS loads on buoyant compartments and buoyancy tanks should be calculated for the maximum submergence draft, i.e. normally for the final on-bottom position.

2.3.5 Local loads on mudmats, slabs, skirts, dowels, bumpers, and guiding structures, etc., should be considered during the setting, levelling, and soil penetration phase.
Guidance note:
It should be thoroughly evaluated if such loads could be relevant also for elements (e.g. lower horizontal jacket braces) that are not a part of the foundation or guiding structures.

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3 Object

3.1 General

3.1.1 Object refers to the object to be positioned and set including any attached components e.g. buoyancy tanks, positioning brackets for positioning lines, bumpers, guiding structures (attached to the object or the seabed), clamping lines, mudmats, skirts and dowels.

3.2 Stability afloat

3.2.1 It shall be verified that the object will behave in a stable manner during the positioning and setting operation also when considering horizontal loads from positioning lines.

Guidance note:
It is recommended that the initial metacentric height (GM) corrected for free surface is at least 1.0m.

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3.3 On-bottom stability

3.3.1 The object shall have sufficient on-bottom stability against overturning and sliding, considering relevant environmental design loads and prior to the permanent support configuration being installed. Normally on-bottom stability should be verified for ULS; it may also be relevant however to verify on-bottom stability for ALS.

Guidance note:
It may be found adequate to calculate on-bottom stability for a restricted weather condition. However, un-piled condition may last for longer than 72 hours and at least intermittent phases prior to final pile installation would normally last longer. Hence, normally on-bottom stability needs to be checked, at least for some installation stages, for unrestricted weather conditions. Relevant environmental design loads for ULS should be based on the estimated maximum period (TPOP), from PNR (normally launch, see Sec.3 [6.2.5]) to and including the considered on-bottom stability condition.

The possibility for situations where the structure must be left for a longer period without permanent supports due to unplanned or unforeseen events should be thoroughly evaluated. In this case relevant environmental design loads should be based on an estimate for this longer period. However, this case may be designed and verified as an ALS.

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3.3.2 The on-bottom stability of the object in the ULS condition should normally fulfil the following criteria:
— No uplift of the periphery.
— A minimum safety factor of 1.5 against overturning.
— Utilisation less than 1.0 of horizontal (sliding) and vertical soil capacity, considering relevant soil material factors.
— Object structural utilisation less than 1.0.

Guidance note:
It may be relevant to calculate the stability for several combinations of environmental loads and number of piles stabbed (and self-penetrated).

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3.3.3 Limited uplift of the periphery of the object may be accepted in ALS, provided adequate safety against overturning, soil/object overloading and/or sliding can be assured.

Guidance note:
Safety and material factors equal to ULS factors divided by 1.15 are normally acceptable in ALS. See DNV-OS-H102. Any additional or modified load conditions due to the uplift should be considered.

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3.4 Structural strength

3.4.1 The object shall have sufficient structural strength to withstand the loads described in Sub-section [2].
3.4.2 Buoyant compartments shall have sufficient structural strength to withstand the loads described in [2.3.4]. See also Guidance Note to [2.3.5].

3.4.3 Auxiliary buoyancy tanks including their attachments to the object shall be designed to withstand vibration loads due to pile driving, if the buoyancy tanks are to remain in-place during pile driving.

3.4.4 For positioning brackets the requirements of Sec.4 [3.3.4] apply.

3.4.5 Guides and bumpers attached to the object or to the seabed, shall have sufficient strength and ductility to resist impact and guiding loads during positioning without causing operational (e.g. position tolerance) problems and without overloading members of the object.

Guidance note:

Design and material factors should be as generally defined in the VMO Standard. Actual characteristic loads will be subject to method, current, etc. and need to be calculated/assessed in for each case. See DNV-OS-H101 Sec.6 C and DNV-OS-H102 for further guidance.

3.4.6 After positioning, the guides and bumpers shall be able to resist loads due to object motions caused by the design sea state.

3.4.7 Anchoring and mooring systems should have sufficient strength to withstand loads due to positioning occurring during horizontal translation of the object and all foreseeable environmental loads.

3.4.8 Clamping lines and similar devices attached to articulated structures should withstand the loads occurring during the positioning and setting operation.

3.4.9 Footing structures such as mudmats, slabs, skirt, etc. shall have sufficient strength to withstand installation loads occurring during setting, levelling, and soil penetration/piling, see also [2.3.5].

3.4.10 Footing structures shall withstand forces associated with environmental loads, before permanent attachment to the seabed is obtained. Unacceptable settlement of the object before permanent attachment to the seabed is obtained should be avoided by sizing the footing structures to ensure an acceptable soil pressure. Loads due to the on bottom stability requirements, see [3.3], should be considered.

4 Systems and equipment

4.1 General

4.1.1 Systems and equipment shall comply with the requirements given in DNV-OS-H101, Sec.6 A.

4.2 Ballasting and de-ballasting system

4.2.1 The requirements given in Sec.4 [4.1] shall apply for the positioning and setting operation.

4.2.2 The ballasting/de-ballasting systems on gravity structures should be capable of levelling the object by eccentric ballasting in order to counter uneven settlement. The soil parameters and the seabed bathymetry, see Sec.2 [4.3], should be considered for the evaluation of above condition.

4.3 Mooring and towing system

4.3.1 The mooring and towing system to be used during positioning and setting (installation) of the object should be according to DNV-OS-H101, Sec.6 C and DNV-OS-H202, Sec.4./VMO Rules Part 2-2 - Sea Transport.

4.4 Positioning systems and clearances

4.4.1 Jacket positioning systems shall have sufficient accuracy to be able to verify the specified tolerances on position and orientation. The reliability of positioning should be determined, with regard to previous surveys.

4.4.2 Two independent positioning systems shall be provided; one of them shall be independent of visibility.

4.4.3 Clearances between the structure and any installed subsea assets (pipelines, templates) shall be a minimum of 5.0 m; otherwise docking piles shall be used to facilitate positioning.
5 Docking

5.1 Application

5.1.1 This sub-section is applicable for setting operations, where accurate positioning is obtained by docking.

Guidance note:
Docking is commonly used for accurate positioning of platform substructures over a pre-installed template with pre-drilled wells, but may also be used in other cases when there is a need for accurate positioning of a platform substructure. A special case is docking onto an installed substructure (see [5.5]).

5.1.2 The requirements to inshore docking, see DNV-OS-H201, Sec.7 C, should be considered and applied as found relevant.

5.2 Positioning, tolerances, clearances and monitoring

5.2.1 When the jacket is to be docked over a template, wellhead docking piles or similar, a docking analysis shall be carried out to determine:
— the jacket behaviour during docking
— the loads and stresses on docking piles and jacket members
— the limiting seastate and current speed for installation, taking into account the crane vessel behaviour.

5.2.2 It shall be documented that the docking positioning means, normally piles, are in an accurate position relative to the target point.

5.2.3 Installation tolerances for docking should correspond to the design of the docking system and pile.

5.2.4 Positive clearances shall be ensured during the docking operation between the structure and any installed subsea assets (pipelines, templates). All movements, tolerances and deformations shall be considered in the least favourable direction.

5.2.5 Adequate positioning and monitoring systems shall be used during the operation.

5.3 Accidental conditions

5.3.1 Relevant accidental conditions shall be considered, i.e. the docking system should be able to resist:
— relevant accidental impact load considering the design environmental condition, mass of structure and added mass from water, and the method to be used
— failure of one arbitrary positioning line
— accidental flooding of any one buoyant compartment of the object.

5.4 Docking method

5.4.1 The main docking method, vertical or horizontal movement in the final positioning phase, shall be carefully selected based on operational feasibility and safety.

Guidance note:
Vertical docking is the method where it is easiest to ensure sufficient clearances throughout the operation. Two methods are normally adopted, namely a passive or an active system. A passive system does not require outside intervention e.g. people on the jacket, hydraulics. The active system normally lowers the docking sleeves down from the object over the docking piles, in a predetermined sequence.

A passive docking system should be designed with a primary and a secondary docking pile, i.e. engaging one docking pile at a time.

In active docking systems, some rotation and translation of the object should be possible after having lowered down the docking sleeves. Lowering of the docking sleeves should be performed by a suitable system e.g. by a winch system.

A suitable bumper system should normally be installed on the object, to act against the docking piles during horizontal docking.

5.4.2 Particular attention should be paid to the accidental load conditions as given in [5.3.1] and their corresponding consequences.

5.5 Docking onto an installed substructure

5.5.1 The requirements in this section are applicable for docking of one part of a platform substructure with another part, already installed at the bottom.
5.5.2 Installation tolerances for the pre-installed and the other part(s) should be unambiguously defined.

Guidance note:
This item is valid for both as installed tolerances and tolerances during the docking operation.

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5.5.3 Monitoring and levelling (if applicable) systems ensuring that the installation tolerances will be met should be installed and tested.

Guidance note:
Adequate marking for easy identification of completed docking should be installed.

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5.5.4 Ballasting capabilities for adequately adjusting the part to be docked within the required tolerances during docking should be documented.

5.5.5 The systems and equipment needed for connecting the parts together should be robust and incorporate adequate backup.

Guidance note:
This item is valid also for any pre-installed risers and J-tubes that shall be connected together.

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5.5.6 If required impact absorbing system(s) shall be used in order to ensure no structural overloading during the docking. See also Sec.2 [2.3].

6 Operational aspects

6.1 General

6.1.1 The requirements in Sec.2 [4] apply for positioning and setting operations.

6.1.2 If the soils survey or bathymetry suggests that the object verticality tolerances may not be achieved then consideration should be given to levelling the seabed. Alternatively there should be contingency plans for levelling the object. For jacket or topsides e.g. use of levelling tools and grippers.

6.1.3 A final survey of the seabed including final testing and calibration of the underwater position/orientation monitoring systems should be carried out prior to commencement of the positioning and setting operation, see also Sec.2 [4.3.8].

6.1.4 Clamping lines should be easy to release after completion of the installation operation. Normally, clamping lines should be released from a position above the water surface.

6.1.5 The guiding structures shall be designed to ensure accurate positioning within the given tolerances for the project.

6.1.6 The object shall be kept within the tolerances during the docking in order to ensure that correct final position is obtained.

Guidance note:
Normally observation ROVs should be used at sufficient number of guiding locations to ensure that the guiding system is engaged properly.

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6.1.7 Completed docking, i.e. correct final position, shall be confirmed before any de-rigging of equipment commences.

Guidance note:
Normally paint marks should be made in order to facilitate the visual confirmation with ROV of final position.

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6.2 Buoyancy tank removal

6.2.1 Connections between auxiliary buoyancy tanks and the object should be designed to ensure the rapid and safe release of the devices.

Guidance note 1:
Removal of buoyancy tanks should be scheduled into the installation sequence so that jacket safety is optimized. Early removal may delay pile installation. Late removal may mean increased wave forces on the jacket. Ballasted buoyancy
tanks will assist resistance against overturning, but may overload the soil under the mudmats and change jacket verticality.

The method of removal will depend on the design of the buoyancy tanks, their attachments and the equipment available. Removal is generally by lifting or floating.

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Guidance note 2:
Release system to have at least two independent methods of release.

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6.2.2 Separation from the jacket shall be in a controlled manner. In general, where disconnection is by means of remotely pulling connecting pins or burning, the tank should be in a neutrally buoyant state at the instant of disconnection. Where remotely operated pins are used a back-up method or system should be available.

6.2.3 Where adjustment of buoyancy by means of ballast or compressed air is needed, a backup method or system should be available.

   Guidance note:
   It is normally recommended that buoyancy tank compartments are flooded by valves and de-watered via rubber diaphragms.

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6.2.4 Removal by lifting should be in accordance with DNV-OS-H205/VMO Rules Part 2-5 - Lifting Operations, taking account of crane vessel dynamics and maximum of in-water or lift in air loads.

   Guidance note:
   Note that it may be necessary to consider the tanks flooded or partly flooded for this lift.

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6.2.5 Where the tanks are floated up and towed clear, sufficient control must exist to avoid impact with the jacket. The tank must have adequate intact stability at all stages.

6.3 Monitoring

6.3.1 The position and orientation of the object should be monitored by surface and/or underwater positioning systems.

6.3.2 Monitoring of clearances to guiding structures positioned on the seabed to achieve strict positioning tolerances should be considered.
SECTION 6 FOUNDATION INSTALLATION

1 Introduction

1.1 Application

1.1.1 This section applies to:
— the execution of piling and pile grouting operations for piled offshore structures such as jackets
— under-base grouting of jackets with plated foundations and gravity base structures
— installation of foundation by suction
— hook-up to tendon system.

1.1.2 For underwater connection of objects (e.g. jackets) installed in two or more parts the requirements in this section should be considered as relevant.

1.1.3 Other methods, as e.g. swaging, not specifically mentioned in this Section should be documented according to the general principles in the VMO Standard. See also Sec.1 [1.1.2].

1.2 Documentation

1.2.1 See Sec.2 [3] for general requirements to documentation.

1.2.2 The pile driveability analysis shall be documented by design report(s), taking into account the considerations mentioned in [2.3].

1.2.3 Bucket suction foundation installations shall be documented by design report(s), taking into account the considerations mentioned in [2.5].

2 Design considerations

2.1 General

2.1.1 See Sec.2 [1] for general design phase considerations.

Guidance note:
For requirements to the design of foundations see DNV-OS-C101, Sec.11.

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2.1.2 Calculations and analyses covering all strength aspects in [2.3] through [2.6] shall be carried out.

2.2 Systems and equipment

2.2.1 Systems and equipment should generally comply with the requirements given in DNV-OS-H101, Sec.6 A.

2.3 Piling

2.3.1 Pile driveability analyses shall document that the intended pile driving is feasible, considering:
— soil formation characteristics
— pile dimensions including followers as relevant
— type of hammer with relevant characteristics including mass, stiffness and damping of its components, rated energy and efficiency
— pile driving procedure, e.g. whether set-up due to halts must be considered
— inclination of piles, which may influence the hammer efficiency

2.3.2 Special attention shall be given to pile and pile guide design when the pile and/or hammer protrude through or are close to the splash zone.

2.3.3 The natural frequencies of the pile (free-standing) and pile/hammer system should be established. The possibility for current induced vortex shedding or other dynamic effects should be investigated.

2.3.4 The pile and pile guides/sleeve should be verified for design combinations including:
— pile stick-up length
— pile inclination including effect of maximum out of verticality of object
— sea state including a range of wave periods
— current
2.3.5 When the pile or pile guide/sleeve design are affected by wave loading during pile driving, the limiting sea state for pile driving should be stated.

2.3.6 Fatigue (FLS) analysis of structural parts (appurtenances) due to loads caused by friction between pile and sleeve shall be carried out, if relevant.

2.3.7 A pile handling procedure shall be established in due time before the operation, describing:

- lifting equipment for hammers and piles
- lifting/upending procedure for piles
- operational and accidental impact loads from dropped objects or vessels
- back-up equipment
- all relevant operational aspects, see [3.2].

2.4 Grouting systems

2.4.1 Grout packer, seals and packer inflation lines, if applicable, should be designed to withstand accelerations and vibrations from pile driving.

2.4.2 Adequate back-up in order to ensure completion of the grouting operation shall be provided.

Guidance note:
E.g. normally the grouting system design should provide three systems with independent lines. One of the lines may be a grouting stinger from top of the sleeve or leg.

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2.4.3 Grouting systems should be pressure tested.

Guidance note:
The test pressure and procedure should be documented. Normally 600 PSI (40 BAR) could be considered as a suitable test pressure.

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2.5 Bucket suction foundations

2.5.1 The guidelines given in DNV-RP-E303 to suction anchors in clay should be considered as found relevant.

2.5.2 Adequate venting during set down of the buckets shall be ensured.

2.5.3 The bucket structural strength shall be acceptable considering maximum out-of-roundness tolerance.

2.5.4 Feasibility of reaching required penetration shall be properly documented. Due consideration should be made to:

a) expected (and maximum and minimum) soil friction
b) expected (and maximum) suction versus penetration depth
c) soil sealing differential pressure versus penetration depth
d) capacity of suction pumps
e) maximum allowable suction related to possible soil plug heave
f) maximum allowable suction related to buckling of the bucket.

2.6 Tension leg platforms

2.6.1 The design conditions for installation given in DNV-OS-C105 Sec.3 B500 shall be considered.

2.6.2 The tendons should normally be preinstalled and the following design conditions for installation, pre-connection phase and connection (hook-up) should be addressed:

a) maximum bending stresses and accumulated strain
b) compression loads and buckling
c) fatigue contribution
d) vortex shedding induced vibrations.
2.6.3 The following design conditions should be addressed for the connection phase:

a) hull position and station keeping tolerances  
b) hull motion tolerances  
c) tendon connection method/procedure  
d) characteristics of involved equipment (e.g. for jacking and ballasting).

2.6.4 The minimum number (and lay-out) of connected tendons to secure the hull (platform) in a “safe condition” shall be defined.

3 Operational aspects

3.1 General

3.1.1 The requirements in Sec.2 [4] apply generally.

3.2 Pile installation

3.2.1 The piles shall be installed in a sequence providing adequate stability to the object in all phases of the installation.

Guidance note:
Adequate stability for the recommended installation sequence should be documented by design calculations/analysis. If alternative sequences may be chosen calculations for these should also be available.

3.2.2 Particular attention should be paid to operational procedures when large self-penetration and/or “runaway” during driving of piles may be expected.

3.2.3 The pile lifting and upending sequence should be carefully considered. Eccentric- and out-of-plane loads should be thoroughly accounted for in the design. See also DNV-OS-H205/VMO Rules Part 2-5 - Lifting Operations for general aspects to be considered during lifting.

3.2.4 The piles and piling equipment should be lowered and retrieved, where possible, well away from the object and any other seabed structure, e.g. pipeline.

3.2.5 A suitable arrangement for locating and guiding the piles into the pile sleeves should be provided.

3.2.6 Pile driving records should be taken, including for each pile: type of hammer, a continuous log of blow counts, hammer performance, a time log including any stops and restarts and the reason therefore.

3.3 Clearances

3.3.1 The calculated minimum horizontal clearance between pile, hammer or follower and primary structural elements should not be less than 3.0 m during stabbing and retrieval.

3.3.2 Nominal vertical clearances between hammer and primary structure during driving should not be less than 0.5 m.

3.4 Followers

3.4.1 Use of follower(s) should be considered in order to avoid pile stick-up at final penetration. The length of follower(s) should be adequate to obtain required horizontal clearances during driving and necessary vertical clearance between hammer and sleeve funnel.

3.4.2 Followers shall be subject to periodical inspections by suitable NDE; a maintenance record shall be kept.

3.5 Grouting

3.5.1 For GBS, due consideration should be given to under base grouting, in terms of selecting systems, equipment and vessels to ensure sound and feasible operations.

Guidance note:
The positioning systems and manoeuvrability of the vessels should be planned in order to minimize the possibility of unacceptable impact loads to the installed object from the vessels, see also DNV-OS-H102 Sec.3 F. Appropriate fender structures could be incorporated to reduce possible impact loads.
3.5.2 The limiting environmental criteria should be established for grouting operations, considering vessel station keeping capabilities, grout system design, ROV operability, etc.

3.5.3 No piling should be performed after commencement of the pile grouting operation.

3.5.4 Possible movements that can deteriorate the grouted connection shall be considered.

Guidance note:
E.g. problems during grouting of wind turbine foundations have been experienced due to wave induced movements.

3.5.5 Prior to transferring any heavy items, e.g. topside module, onto the object the required grout strength (curing time) should be documented. The grout should be tested to verify that required strength has been achieved.

3.6 Bucket suction foundations

3.6.1 The suction equipment shall be tested. Requirements to minimum pumping pressure and flow rate should be established before the testing.

3.6.2 All relevant parameters shall be controlled, monitored and recorded during the installation. This shall include:
   a) differential pressure (suction)
   b) penetration
   c) flow rate
   d) heel and trim.

3.6.3 Back-up equipment and contingency procedures shall be defined.

3.7 Tension leg platforms

3.7.1 It shall be ensured by monitoring that the tendons are kept within their design conditions.

3.7.2 Pre-installed tendons should be subject to continuous surveillance until platform hook-up in order to avoid interference with other tendons or vessels and to ensure that proper tension is maintained.

3.7.3 Protection of the unconnected tendons should normally be considered.