



RECOMMENDED PRACTICE

DNV-RP-H201

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# Lifting appliances used in subsea operations

NOVEMBER 2014

*The electronic pdf version of this document found through <http://www.dnv.com> is the officially binding version*

## 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.

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- *Recommended Practices*. Guidance.

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

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## **CHANGES – CURRENT**

### **General**

This is a new document.

Det Norske Veritas AS, company registration number 945 748 931, has on 27<sup>th</sup> November 2013 changed its name to DNV GL AS. For further information, see [www.dnvgl.com](http://www.dnvgl.com). Any reference in this document to “Det Norske Veritas AS” or “DNV” shall therefore also be a reference to “DNV GL AS”.

### *Acknowledgment*

The RP is based on contributions from hearing parties in the industry.

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# 1 General

## 1.1 Introduction

This document is the result of a joint industry project, established to develop a Recommended Practice (RP) covering design, manufacturing, maintenance and operational aspects associated with lifting appliances intended for subsea lifting operations.

Present rules, regulations and standards for offshore lifting appliances are based mainly on risks associated with cranes of moderate capacity and lifting operations to/from supply vessels. Subsea lifting is complex - it involves technology, working procedures, weather evaluations, competence, organisations and management. Challenges related to modern subsea lifting operations, involving for example higher lifting capacities, greater water depths and incorporating motion compensation systems, are covered to a lesser degree in the present codes.

It is therefore the ambition that this document shall increase the overall awareness of risks from subsea lifting activities and how to best manage these risks.

## 1.2 Objective

The objective of this RP is to provide recommendations and guidance on important aspects relating to operational parameters, risk management, related technical challenges, engineering solutions, maintenance and inspection, ensuring the safe execution of subsea lifting operations.

### 1.2.1 Contents of the RP

- Section 1 - general information and introduction with overview, definitions, references and provisions relevant for the following sections.
- Section 2 - structure and dynamics.
- Section 3 - control and power systems.
- Section 4 - fabrication, inspection, certification and maintenance.
- Section 5 - operational recommendations for planning and performing subsea lifting.
- Appendices.

## 1.3 Application

### 1.3.1 General

*1.3.1.1* This RP is applicable to lifting appliances used in subsea lifting operations. In the context of this RP a subsea lifting operation means installation or removal of objects underwater. An object will normally be lifted through the splash zone, lowered to and landed on the seabed, or vice versa, see section [1.9.3].

**Guidance note:**

Lifting operations in air are covered by DNV-OS-H205.

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*1.3.1.2* This RP addresses all lifting appliances used in subsea lifting operations. In practice this generally means an offshore/subsea crane, A-frame with winch or other types of winch systems.

*1.3.1.3* This RP can be used to evaluate if existing lifting appliances are suitable for subsea operations and in the design of new lifting appliances.

**Guidance note:**

It is not the intention of this document to disqualify a certified lifting appliance from use unless the results of a risk assessment for a particular operation do so.

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*1.3.1.4* The recommendations and guidelines herein can be used as a basis for gap analyses, risk assessments and the identification of any mitigating actions considered necessary to qualify a lifting appliance for subsea operations.

**Guidance note:**

Gap analysis and risk assessment should be carried out according to recognised methods.

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### 1.3.2 Personnel lifting and diving

*1.3.2.1* This RP covers lifting of unmanned objects. Lifting of personnel, i.e. handling of diving systems is covered by available standards and should only be carried out if the lifting appliance is certified for handling of such systems according to DNV-OS-E402 *Diving Systems*, Section 7, or an equivalent standard.

## 1.4 Main principles

### 1.4.1 Subsea operations

1.4.1.1 Lifting appliances intended for subsea operations shall be suitably designed or shall be proven suitable for such use.

**Guidance note:**

Requirements for subsea lifting appliances can be found in for instance NORSOK R-002 Annex G.12.4 and DNV Standard for Certification No. 2.22 *Lifting Appliances* - Ch.2 Sec.7.

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1.4.1.2 Lifting appliances used for subsea operations shall be designed and certified in accordance with recognised standards/codes that include requirements for subsea cranes. Alternatively recognised standards/codes for offshore cranes / lifting appliances may be adopted - the lifting appliance shall be proven suitable for subsea lifting.

1.4.1.3 In order to ensure that a new lifting appliance is optimised for its intended use, the owner and the designer should agree on the design specifications at an early stage.

1.4.1.4 In case of the following circumstances:

- lifting appliances, structural parts, systems and/or equipment are not covered by available recognised standards/codes,
- existing standards/codes are not deemed satisfactory for the purpose of subsea lifting,
- where the planned operations are not covered by the existing certification, the use of the equipment shall be based on acceptance criteria, qualified in accordance with recognised methods.

**Guidance note:**

For this purpose, procedures and principles as stipulated in DNV-RP-A203 *Technology Qualification* should be applied. Also the method specified in DNV-OS-E407 *Underwater deployment and recovery systems* may be applied.

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1.4.1.5 Experience and recommendations from the original manufacturer of the lifting appliance should be considered, particularly during the risk assessment; this may include for example special handling characteristics, limitations or features concerning the operability imposed by the equipment.

1.4.1.6 Installation, operation and maintenance manuals shall be available for all subsea lifting appliances.

1.4.1.7 A formal hazard identification (HAZID) and risk analysis should be undertaken in relation to the design and/or the intended operation, to eliminate or minimise risks as far as practically possible. Mitigating measures shall be implemented to manage any significant risks that cannot be eliminated. If an acceptable level of risk cannot be demonstrated, the proposed operation, procedure and/or lifting appliance should be abandoned or replaced with a suitable alternative solution.

1.4.1.8 Environmental conditions leading to operational challenges should be part of the assessment of the lifting appliance. A risk assessment or a Technology Qualification (TQ) process may be applied to assess the suitability for such operations.

1.4.1.9 The equipment should be fit for the intended operation, taking into account sea states, current, vessel motions etc. Also requirements for vessel movement, heading - and positioning capability should be stated.

### 1.4.2 Loads and loads effect

1.4.2.1 All loads and load effects shall be analysed and considered in planning and preparation of the lifting operation. The analysis shall take into account environmental actions and shall be carried out according to recognised methods. See [2.4].

**Guidance note:**

For this purpose, DNV-RP-H103 *Modelling and analysis of marine operations* can be applied. The RP provides guidance for modelling and analysis of marine operations including lifting through splash zone, lowering in deep water and landing on seabed.

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### 1.4.3 Statutory regulations

1.4.3.1 Satisfying the recommendations in this RP does not automatically guarantee compliance with local national (statutory), or international regulations, rules, etc. – where necessary, these should be considered separately.



## 1.5 References

Documents listed in [Table 1-1](#) and [Table 1-2](#) include information, which through references in the RP indicate acceptable methods of fulfilling the recommendations given.

<i>Reference</i>	<i>Title</i>
DNV-OS-C301	<i>Stability and Watertight Integrity</i>
DNV-OS-E101	<i>Drilling Plant</i>
DNV-OS-E303	<i>Offshore Fibre Ropes</i>
DNV-OS-E407	<i>Underwater Deployment and Recovery Systems</i>
DNV-OS-H101 <sup>1)</sup>	<i>Marine Operations, General</i>
DNV-OS-H102 <sup>1)</sup>	<i>Marine Operations, Design and Fabrication</i>
DNV-OS-H204 <sup>1)</sup>	<i>Offshore Installation Operations (VMO Standard Part 2-4)</i>
DNV-OS-H205 <sup>1)</sup>	<i>Lifting Operations (VMO Standard - Part 2-5)</i>
DNV-OS-H206 <sup>1)</sup>	<i>Loadout, transport and installation of subsea objects (VMO Standard - Part 2-6)</i>
DNV-RP-A203	<i>Technology Qualification</i>
DNV-RP-C204	<i>Design Against Accidental Loads</i>
DNV-RP-C205	<i>Environmental Conditions and Environmental Loads</i>
DNV-RP-D102	<i>Failure Mode and Effect Analysis (FMEA) of Redundant Systems</i>
DNV-RP-E301	<i>Design and Installation of Fluke Anchors in Clay</i>
DNV-RP-E302	<i>Design and Installation of Plate Anchors in Clay</i>
DNV-RP-E304	<i>Damage Assessment of Fibre Ropes for Offshore Mooring</i>
DNV-RP-H101	<i>Risk Management in Marine- and Subsea Operations</i>
DNV-RP-H102	<i>Marine Operations during Removal of Offshore Installations</i>
DNV-RP-H103	<i>Modelling and Analysis of Marine Operations</i>
DNV Ship Rules	<i>Rules for Classification of Ships</i>
DNV Standard for Certification No. 2.22 (DNV STC 2.22)	<i>Lifting Appliances</i>

<sup>1)</sup> The DNV offshore standards covering marine operations, i.e. DNV-OS-H101, H102, H204, H205, H206, replace the DNV Rules for planning and execution of marine operations.

### Guidance note:

The DNV service documents are available at <http://www.dnvgl.com/rules-standards/default.aspx>.

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<i>Reference</i>	<i>Title</i>
API 2C	<i>Specification for Offshore Pedestal-mounted Cranes</i>
AS 1418.2-1997 Part 2:	<i>Serial hoists and winches</i>
ASME B30-7-2001	<i>Base mounted drum hoists</i>
CI 2001-04	<i>Fibre Rope Inspection and Retirement Criteria - Cordage Institute - International Guideline</i>
EN 13135-2	<i>Cranes – Equipment – Part 2: Non-electrotechnical equipment</i>
EN 13557: 2008	<i>Cranes - Controls and control stations</i>
EN 13852-1	<i>Cranes - Offshore cranes - Part 1: General - purpose offshore cranes</i>
EN 13852-2	<i>Cranes - Offshore cranes - Part 2: Floating cranes</i>
EN 14492-1	<i>Cranes - power driven cranes and hoists</i>
EN ISO 13849-1	<i>Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design</i>

<b>Table 1-2 Other references (Continued)</b>	
<i>Reference</i>	<i>Title</i>
EN ISO 13849-2	<i>Safety of machinery - Safety-related parts of control systems - Part 2: Validation</i>
FEM 1.001:10.1998	<i>Rules for design of hoisting appliances</i>
IACS RecNo.47	<i>Shipbuilding and repair quality standard</i>
IACS UI SC249	<i>Implementation of SOLAS II-1, Regulation 3-5 and MSC.1/Circ. 1379</i>
ICLL 1966	<i>International Convention on Load Lines</i>
IEC 60204-32:2008	<i>Safety of machinery - Electrical equipment of machines - Part 32: Requirements for hoisting machines</i>
IEC 60331	<i>Tests for electric cables under fire conditions</i>
IEC 60529	<i>Degrees of protection provided by enclosures (IP Code)</i>
IEC 60812	<i>Analysis techniques for system reliability - Procedure for Failure Mode and Effects Analysis</i>
IEC 61508	<i>Functional safety of electrical/electronic/programmable electronic safety-related systems</i>
IEC 62061	<i>Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems</i>
IMCA M 197 <sup>1)</sup>	<i>Guidance on Non-destructive examination (NDE) by means of magnetic rope testing</i>
IMCA M 194 <sup>1)</sup>	<i>Guidance on Wire Rope Integrity Management for Vessels in the Offshore Industry</i>
IMCA M 203	<i>Guidance on Simultaneous operations (SIMOPS)</i>
IMO - Intact Stability Code	<i>The International Code on Intact Stability, 2008, as adopted with Res. MSC.267(85) on 4 December 2008</i>
ISO 4309	<i>Crane Wire ropes Care maintenance, Inspection and Discard</i>
ISO 12100	<i>Safety of machinery - General principles for design - Risk assessment and risk reduction</i>
ISO 12480-1	<i>Cranes - Safe use - Part 1: General</i>
ISO 12482	<i>Cranes - Monitoring for crane design working period</i>
ISO 13850	<i>Safety of machinery - Emergency stop - Principles for design</i>
ISO 17894	<i>Ships and marine technology -- Computer applications -- General principles for the development and use of programmable electronic systems in marine applications</i>
ISO 19901-6	<i>Petroleum and natural gas industries - Specific requirements for offshore structures - Part 6: Marine operations</i>
ISO 4413:2010	<i>Hydraulic fluid power - General rules and safety requirements for systems and their components</i>
ISO 6336	<i>Calculation of load capacity of spur and helical gears</i>
ISO 9554: 2010	<i>Fibre ropes - General specifications</i>
ISO 9927-1	<i>Cranes - Inspections - Part 1: General</i>
ISO/TR 14121-2: 2012	<i>Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods</i>
NORSOK D-010	<i>Well Integrity in drilling and well operation</i>
NORSOK N-003	<i>Actions and Action Effects</i>
NORSOK R-002	<i>Lifting Equipment</i>
NORSOK U-102	<i>Remotely operated vehicle (ROV) services</i>
SOLAS 1974/88 as amended	<i>International Convention for Safety of Life at Sea</i>

<sup>1)</sup> International Marine Contractors Association

## 1.6 Definitions

### 1.6.1 Verbal forms

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

### 1.6.1.1 Shall

Indicates requirements strictly to be followed in order to conform to this RP, and from which deviation is not recommended, unless accepted by all involved parties.

### 1.6.1.2 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.

**Guidance note:**

The term “should” means that other solutions can be chosen. It shall be documented that the alternative solution provides an equivalent level of safety and reliability.

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### 1.6.1.3 May

Indicates a course of action permissible within the limits of this RP.

## 1.6.2 Terminology

Terms of special importance are defined as indicated below.

### *3<sup>rd</sup> party verification*

Verification done by a competent independent person/body.

### *Actual hook load*

The total load on the hook, including (but not limited to) the static weight of the lifted object, in addition to any loose gear (e.g. slings, lifting beams, etc.), load effects from tugger lines, guides, environmental, hydrodynamic and hydrostatic loads.

### *Automatic overload protection system (AOPS)*

A system designed to safeguard and protect the crane from damage against excessive load / moment during operation, by allowing automatic release of the hook, e.g. by limiting the retaining force of the winch.

**Guidance note:**

Guidance on activation characteristics and retaining force can be found in EN 13852-1 Cranes - General Purpose offshore cranes and DNV Standard for Certification No. 2.22 Lifting Appliances

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### *Characteristic load*

The reference value of a load to be used in the determination of load effects.

### *Closed loop control*

Type of control with a feedback from controlled parameter

### *Competent Person/Body*

Person or body possessing knowledge and experience required to perform/witness thorough examination and test of lifting appliances and loose gear, and who is acceptable to the relevant authority.

### *Deep water*

Water depths regarded as being particularly challenging, in terms of placing high demands on equipment and operational aspects; depth is not quantified, since it will depend on the operation and equipment used.

### *De-rating*

Reduction of rated capacity, when lifting under circumstances or in conditions exceeding the design criteria of the lifting appliance. See [2.4.3].

**Guidance note:**

Forces on the lifted object from hydrodynamic effects and specific operational loads, (e.g. tugger loads) are not considered for de-rating. The sum of all forces and loads shall be less than the de-rated capacity of the lifting appliance at the specified significant wave height, or weather limitation.

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**Guidance note:**

De-rated capacity > Static hook load + hydrodynamic effects + weight of deployed wire rope.

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### *De-rating chart*

Modified load-chart defining the reduced rated capacity, as a result of de-rating. This is normally presented in de-rating tables, charts or similar. - see also Load chart.

### *Design dynamic factor - DDF*

This factor is normally specified by the designer and applied in the design of the lifting appliance. DDF is not the same as DAF, which is defined separately and applicable to a specific operation.

$DDF = \text{Design load} / \text{SWL}$ .

#### **Guidance note:**

For an offshore or subsea lifting appliance the DDF is normally defined for  $H_s = 0\text{m}$ . DDF may however be defined with reference to a specified significant wave height.

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#### **Guidance note:**

When DDF is specified for a significant wave height, the limiting parameters or conditions shall be specified, for instance, restricting vessel heading relative to the waves.

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### *Design load*

Load used for the purposes of design, derived by combining relevant characteristic load(s) (both static and dynamic) with appropriate load factor(s). The design load represents all foreseeable loads and combinations thereof (including all directions) that the lifting appliance will be subject to. Design load shall not be confused with SWL.

### *Design criteria*

Criteria applied for verification of systems, equipment, structures etc.

### *Design temperature*

Reference temperature used as a criterion for the selection of material grades.

### *Dynamic amplification factor - DAF*

A factor accounting for the global dynamic effects normally experienced during lifting. In this RP the term DAF denotes the dynamic effects for a specific operation. DAF should not be confused with the term Design Dynamic Factor DDF, which is used to define the design capacity of the lifting appliance.

$DAF = \text{Dynamic load} / \text{Characteristic load}$

### *Dynamic load*

The static load subject to a dynamic factor.

### *Engineered lift*

Lift planned and designed by qualified and competent engineers considering the capacity, functions and performance of the lifting appliance, rigging, support structure, weather, sea and loading conditions. The lift is specially prepared and documented by operational procedures, pertinent calculations and documentation of the equipment.

### *Equivalent standard*

Standard or code addressing the same aspects, providing equivalent requirements and an equal level of safety. When using other / equivalent standards, a gap analysis may be considered appropriate, to confirm equivalency. The equivalent standard should be accepted by all parties involved.

### *Gap analysis*

In the context of this RP, an assessment used for the purposes of comparing two standards, or to compare/identify the requirements for and the capabilities of a given lifting appliance.

#### *Guidance note:*

Additional information providing advice, examples, statements etc. Reference to standards and codes is given to guide the user of the RP and to provide additional information; guidance notes are not mandatory.

### *HAZID*

A formal hazard identification study is the process of identifying hazards in order to plan for, avoid, or mitigate their impacts. Hazard identification is an important step in risk assessment and risk management. HAZID is used to identify and evaluate hazards when the operational procedures have been developed and may be a useful technique to reveal weaknesses in the design and the detailed marine operations procedures.

### *HAZOP*

A hazard and operability study is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation.

### *Heave compensation:*

Heave compensation is a system that compensates for the unwanted vertical motion of the rope exit point - REP

due to vessel motion. Heave compensation systems are normally divided into 2 different types. Active heave compensation – (AHC) and Passive heave compensation (PHC). Heave compensation systems are normally used to control the position of the lifted object or to better control the load on the lifting appliance. See [App.C](#).

#### *Active heave compensation - AHC*

The system normally controls the rope/load position, based on a reading of the REP relative to the seabed, acting on continuous input from a control unit. AHC can be based on external power supply alone or also on the release of stored energy.

#### *Passive heave compensation - PHC*

System used to reduce fluctuations in position of the lifted object and/or the load in the hoisting wire; based on stored energy that responds to the external actions.

#### *Heel*

Inclination of the vessel about its longitudinal axis, also referred to as list.

#### *Job Safety Analysis or Safe Job Analysis - SJA*

Tool which can be used to define and control the hazards associated with a certain process, operation, job or procedure.

#### *Lifted Object:*

The structure handled during the lifting operation.

#### *Lifting accessories*

As for *lifting gear*, see below.

#### *Lifting appliance*

Machine or appliance used for the purpose of lifting and/or lowering objects.

#### *Lifting gear*

Load carrying accessories used in combination with a lifting appliance, not necessarily part of the permanent lifting configuration/ - examples include:

- attachment rings, links, shackles, swivels, slings, etc.
- sheaves, hook-blocks, hooks, load cells
- loose gear.

#### **Guidance note:**

Lifting gear, considered as separate components, shall be designed and tested in accordance with the provisions for loose gear, e.g. DNV Standard for Certification No. 2.22 Lifting Appliances.

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#### *Load chart*

Diagram or table showing rated capacity depending on radius or boom angle, environmental conditions, out of plane influences and type of operation. See *De-rating chart*

#### *Load curve*

A line or curve in the load chart, specifying the rated capacity at all lifting radii for a specified condition.

#### **Guidance note:**

The rated capacity is normally related to the wave height, but acceleration at the *REP* may be used.

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#### *Load factor*

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

#### *Loose gear*

Equipment used to attach the lifted object to the hook, e.g. slings, nets, baskets, chains, links, rings, shackles, lifting beams and frames, spreaders, grabs, loading pallets, skids, etc., but which do not form a part of the load. Loose gear is not normally attached to the hook on a permanent basis and may be stored separately from the crane. See *Lifting gear*.

#### *Manual overload protection system (MOPS)*

System, activated by the crane operator, protecting the crane against overload and over-moment by reducing the load-carrying capacity and allowing release of the hook. Sufficient retaining force should be provided to avoid “backlash” of the wire rope or over speed of the drum.

#### *Offlead*

Horizontal load at the boom tip caused by radial displacement of the hook and/or radial acceleration of the

boom tip.

**Guidance note:**

Loads from tugger winches, guides etc. shall be checked against the allowable sidelead and offlead as basis for the de-rating chart of the crane.

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*Offshore crane*

Lifting appliance mounted on a vessel or offshore installation, intended for handling cargo at sea, outside the vessel deck area.

*Overload*

Load exceeding the allowable rated capacity or safe working load.

*Pitch*

Vessel angular motion about transverse vessel axis. To be included in the de-rating as in addition to the static inclination angle, trim and accelerations.

*Point of no return:*

Defined point/stage/location during the operation where it is no longer possible to stop or reverse the operation, or recover the lifted object. This point should be defined prior to and should be clearly recognised during lifting operations. Safe conditions after passing point of no return shall be defined and considered in the planning.

*Rated capacity*

In the context of this document, rated capacity is defined as actual static hook load that the lifting appliance is designed to lift for a given operating condition (e.g. boom configuration, reeving arrangement, off lead/side lead, heel/trim, radius, wave height and period etc.) plus the weight of the hook and deployed wire rope. Rated capacity is applied at the REP.

**Guidance note:**

Rated capacity  $R_0$  = maximum load, normally defined as SWL, at  $H_s = 0$  m

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**Guidance note:**

$R_n$  reflects the rated static capacity for a specific wave height  $n$ .

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*Recognised standard*

A standard recognised by the majority of professional people and institutions engaged in the relevant offshore industry.

**Guidance note:**

A certain safety level can be achieved by following other standards or codes than referred to in this RP. However the basis for and methodology applied can be different in different standards, the combination of different standards and codes should be avoided.

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*Relevant standard*

Standard used to comprehensively address a given subject whilst defining necessary requirements and ultimately ensuring satisfactory levels of safety.

*Resonance*

Tendency of a system to oscillate with excessive amplitude at certain frequency ranges. Resonance amplification may be experienced if the REP oscillation period or the wave period is close to the natural period of the lifting system.

*Response amplitude operators - RAO*

Transfer functions used to determine the effect a wave with certain periods will have upon the motion of a vessel. The RAO gives the vessel response per unit wave amplitude as a function of wave period.

*Risk*

Risk is often characterized by reference to potential events and consequences of an event, or a combination of these.

**Guidance note:**

See ISO 31000 Item 2.1 for detailed definition.

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Risk management

Identification, assessment, and prioritization of risks followed by coordinated application of resources to minimize, monitor, and control the probability and/or impact of undesirable events.

#### *Roll*

Vessel angular motion about longitudinal vessel axis. To be included in the de-rating as an increase of the inclination angle, in addition to heel and accelerations.

#### *Rope exit point - REP*

Location on the lifting appliance where the hoist rope is suspended - typically found at the outer sheave in the crane boom tip.

#### *Safe Working Load - SWL*

SWL is defined as the actual static hook load permitted for a given operating condition (e.g. configuration, position of load). In the context of this RP, SWL shall be applied for the load at the REP.

##### **Guidance note:**

The term SWL is commonly used to denote the certified lifting capacity for lifting appliances according to ILO conventions and thus deemed necessary to use in the RP.

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##### **Guidance note:**

Maximum static capacity = SWL

Maximum dynamic capacity = SWL × DDF

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#### *Safe state:*

Condition during which lifting appliance, carried load, environment and people present in working area are considered safe, i.e. no further action is required to actively manage the situation. In some cases STOP function is considered a safe state, however a number of situations exist (e.g. in the splash zone, landing phase, hook close to the supply boat etc.) where STOP function cannot be considered a safe state. Safe states should be defined on a case by case basis, for each lifting appliance and mode of operation by formal risk assessment.

#### *Side-lead:*

Horizontal load at the boom tip caused by the lateral displacement of the hook and/or the lateral acceleration of the boom tip.

##### **Guidance note:**

Loads from tugger winches, guides etc. have to be checked against the allowable horizontal loads as basis for the de-rating chart of the crane.

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#### *Significant wave height - H<sub>s</sub>:*

Four times the standard deviation of the surface elevation in a short-term wave condition. (close to the average height of the one third highest waves in a short-term constant sea state, typically 3 hours)

#### *SIMOPS*

Refers to two or more potentially clashing operations e.g. occurring at the same location at same time.

#### *Splash zone*

The area where the variation of the level of sea surface affects the lifted object.

#### *Step*

A stop point/ check point or point in operation where something is changed.

#### *Subsea crane*

Crane intended for lowering and retrieval of objects, through the air/water interface, water-column and the seabed.

#### *Subsea lifting appliance*

Lifting appliance intended for handling of objects (lowering and retrieval) to and from below sea level.

#### *Technology qualification*

Technology qualification is the process of providing a sufficient evidence base on which to confirm that a technology will function within specified operational limits, with an acceptable level of confidence. The TQ process can be used to qualify new technology or existing technologies when circumstances are not covered by or are outside the validity of available standards.

#### *Trim*

Static inclination of a vessel about the transverse axis.

### *Tugger Winch*

Tugger winches can be used to assist the lifting operations, for instance control horizontal movements and rotation. Use of tugger winches should be thoroughly examined as part of total risk assessment.

### *Vessel*

A common term for ships, crafts, offshore units and floating offshore installations. It could be barge, ship, tug, mobile offshore unit, crane vessel or other type of vessel.

### *Working load - W*

In the context of this document working load is defined as the weight of the lifted object including environmental effects, special loads and the weight of the deployed wire rope and lifting gear. The working load acts at the REP. See [2.5.1.1]

#### **Guidance note:**

The working load shall be less than the rated capacity.  $W_n < R_n$

$W_n$  reflects the working load for a specific wave height  $n$ .

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## **1.7 Abbreviations and acronyms**

<i>AHC</i>	Active heave compensation
<i>AI</i>	Analogue input
<i>AO</i>	Analogue output
<i>AOPS</i>	Automatic overload protection system
<i>CILP</i>	Change-in-length performance
<i>CoB</i>	Centre of buoyancy
<i>CoG</i>	Centre of gravity
<i>CPU</i>	Central processing unit
<i>CT</i>	Constant tension
<i>d</i>	Diameter of hoisting rope
<i>DAF</i>	Dynamic amplification factor
<i>DDF</i>	Design dynamic factor
<i>DI</i>	Digital input
<i>DO</i>	Digital output
<i>DP</i>	Dynamic positioning
$D_p$	Pitch diameter of sheave
<i>FAT</i>	Factory acceptance test
<i>FMEA</i>	Failure mode and effect analysis
<i>FMECA</i>	Failure mode effects and criticality analysis
<i>GW</i>	Guide wire
<i>HAT</i>	Harbour acceptance test
<i>HAZID</i>	Hazard identification analysis
<i>HAZOP</i>	Hazard and operability study
<i>HIL</i>	Hardware in loop
<i>HIPAP</i>	High precision acoustic positioning
<i>Hmax</i>	Maximum expected wave height for a given $H_s$
<i>HMPE</i>	High-modulus polyethylene
<i>HP</i>	High pressure
<i>HPU</i>	Hydraulic power unit
<i>IEC</i>	International Electrotechnical Commission
<i>ILO</i>	International labour organisation
<i>I/O</i>	Input/Output
<i>JSA</i>	Job safety analysis
<i>LP</i>	Low pressure
<i>MBL</i>	Minimum breaking load
<i>MOPS</i>	Manual overload protection system
<i>MOU</i>	Mobile offshore unit
<i>MRU</i>	Motion reference unit
<i>MSB</i>	Main switchboard



<i>NDE</i>	Non-destructive examination
<i>OPLIM</i>	Operational environmental limiting criteria
<i>OS</i>	Offshore standard
<i>PHC</i>	Passive heave compensation
<i>PL</i>	Performance Level
<i>PLr</i>	Required Performance Level
<i>PLC</i>	Programmable Logic Controller
<i>PMS</i>	Power management system
<i>PNR</i>	Point of no return
<i>R</i>	Rated capacity
<i>RAO</i>	Response amplitude operators
<i>REP</i>	Rope exit point
<i>ROV</i>	Remote operated vehicle
<i>RP</i>	Recommended practice
<i>SIMOPS</i>	Simultaneous operations
<i>SJA</i>	Safe job analysis
<i>SRP/CS</i>	Safety related parts of the control system (ref. EN ISO 13849-1)
<i>SWL</i>	Safe working load
<i>SOW</i>	Scope of work
<i>THD</i>	Total Harmonic Distortion
<i>TQ</i>	Technology qualification
<i>UHF</i>	Ultra high frequency (~300 to ~3000 MHz)
<i>UPS</i>	Uninterruptible power supply
<i>VHF</i>	Very high frequency (~30 to ~300 MHz)
<i>W</i>	Working load
<i>WPQ</i>	Welding procedure qualification
<i>WPS</i>	Welding procedure specification

## 1.8 Symbols

$H_s$	Significant wave height
$W_0$	Working load at zero sea state or flat sea
$R_0$	Rated capacity at zero sea state or flat sea
$W_{2.0}$	Working load at significant wave height $H_s = 2$ m
$R_{2.0}$	Rated capacity at significant wave height $H_s = 2$ m
$T_R$	Operational reference period

## 1.9 Types of lifts/operations

### 1.9.1 Introduction

1.9.1.1 Subsea lifting is divided into the following 3 different types of operations and phases.

### 1.9.2 Type of operation

- Deployment.
- Recovery.
- Transfer/Relocation.

**Guidance note:**

In air lifting operations typically involve lifts from a barge to another vessel or fixed installation, or transfers from one lifting appliance to another - in air lifting is covered in for example DNV-OS-H205 and not specifically considered here.

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**Guidance note:**

In air phases are included because they are part of a subsea lifting operation.

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### 1.9.3 Lifting phases

1.9.3.1 The phases are described below - specific recommendations related to each are given in relevant

sections of this document.

### 1.9.3.2 Deployment

<i>Pre lift:</i>	Last stage before lifting the object. Vessel is typically in its final location, the next step being commencement of the operations.
<i>Lift off:</i>	Lift off from deck.
<i>Overboard:</i>	Move the object outboard, over the sea.
<i>Splash zone:</i>	Lower the object through the air-water interface, down to where the effects from the waves on the object are insignificant, normally approximately 50 m below surface.
<i>Lowering:</i>	Lowering the object through the water column down and close to its landing location
<i>Move:</i>	Moving vessel from one location to another.
<i>Landing:</i>	Landing the object on seabed, other structure etc.

### 1.9.3.3 Recovery

<i>Pre lift:</i>	Last stage before lifting the object.
<i>Subsea lift off:</i>	Lifting from subsea location.
<i>Move:</i>	Moving vessel from one location to another.
<i>Recovery:</i>	Lifting the object from subsea location closer to but below air-water interface, normally approximately 50 m below surface.
<i>Splash zone:</i>	Lifting the object through the wave influenced part of water column and into the air.
<i>In-boarding:</i>	Moving the object from over the sea to inboard
<i>Landing:</i>	Landing on deck.

### 1.9.3.4 Relocate

<i>Pre lift:</i>	Last stage before lifting the object.
<i>Subsea lift off:</i>	Lifting from subsea location.
<i>Move:</i>	Moving vessel from one location to new location.
<i>Transfer:</i>	Shift the load from one lifting appliance to another.
<i>Landing:</i>	Landing the object on seabed, other structure etc.

## 1.9.4 Steps

1.9.4.1 Every subsea lifting operation should be broken down into discrete, well defined steps. A step can be a characteristic/significant point in the operation, e.g. change of condition, checkpoint etc. A PNR will typically represent an important step, where necessary checks and confirmation from competent and appropriate personnel are necessary, before progressing to the next step. Phases listed in section [1.9.3] will normally be divided into several sub-steps, depending on the specific operation.

## 2 Structure and dynamics

### 2.1 Introduction

This chapter covers recommendations related to structure and dynamics for lifting appliances intended to be used in subsea lifting operations.

### 2.2 Main principles

#### 2.2.1 General

2.2.1.1 An appropriate risk analysis should be carried out to ensure that the design is qualified for subsea lifting.

**Guidance note:**

Principles for risk assessment are given in ISO 12100 and ISO/TR 14121-2.

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2.2.1.2 Valid certificates based on ILO Form 2, specifying the design standard applied, SWL, design dynamic factor, test load, crane group/class and design temperature shall be provided with the lifting appliance.

#### 2.2.2 Technology qualification

2.2.2.1 Technology qualification (TQ) should be applied for lifting appliances, structural parts and equipment to be used under circumstances outwith the validity of available standards, see [1.4.1.4].

#### 2.2.3 Environmental conditions

2.2.3.1 Lifting appliances including lifting accessories, systems and mechanisms are designed for specified environmental limitations therefore it shall be confirmed that the operational conditions are within these limits.

2.2.3.2 When an installation vessel is subjected to motions and accelerations, the lifting capacity of the lifting appliance should normally be reduced accordingly. The lifting capacity shall be selected according to a load chart covering the actual conditions. see section [2.3.1] and [2.4.3].

2.2.3.3 Loads and load effects on the lifted object due to relevant environmental conditions shall be calculated - see section [5.7].

2.2.3.4 The effects on the lifting appliance and components due to longer operations and cyclic loading compared to conventional deck to deck lifts need to be taken into account in the design and maintenance of the lifting appliances.

2.2.3.5 The design temperature should be defined either by project specific / operational requirements or by the applicable recognised standard.

2.2.3.6 For subsea operations in particularly cold (e.g. arctic) environments, very low ambient temperatures may cause operational and technical challenges, e.g. brittle failure of steel components if unsuitable materials are specified.

2.2.3.7 Snow and ice accretion due to sea spray may lead to additional environmental loads and operational challenges.

2.2.3.8 The pH of the water (e.g. in volcanic areas) can be acidic and may lead to accelerated corrosion.

### 2.3 Lifting capacity

#### 2.3.1 General

2.3.1.1 The certified lifting capacity is specified by means of SWL and a corresponding DDF, where SWL reflects the maximum allowable static load, and SWL multiplied with the DDF reflects the maximum allowable dynamic load, normally for  $H_s = 0$  m. In this RP, the rated capacity reflects the allowable load at the REP. The rated capacity is normally subjected to de-rating associated with vessel motions when operating in  $H_s > 0$  m.

2.3.1.2 Lifting appliances will be subject to additional forces associated with vessel motions, leading to reduced capacity, if lifting in sea states exceeding flat seas conditions. De-rating shall be carried out for higher sea conditions accordingly. Sea conditions are normally presented in terms of  $H_s$ , including limitations on wave period, wave spectrum, wave heading, etc.

2.3.1.3 Loads on a lifting appliance, see [2.5.1.1] shall not exceed the specified rated capacity for a given  $H_s$ . The static load shall not exceed the static rated capacity, and the dynamic loads, see [5.7.1] shall not exceed the dynamic capacity. See Figure 2-1.

2.3.1.4 The designer shall present tables, graphs, plots or other means to document the operational limits for the lifting appliance due to environmental conditions, environmental loads, vessel heading and vessel motions/accelerations for the relevant environmental conditions. In order to incorporate all parameters and develop suitable de-rating documentation, effective communication at an early stage of the design of the lifting appliance, between the manufacturer/designer and the owner is important.

2.3.1.5 It is the responsibility of the operator of the lifting appliance not to exceed the rated capacity specified by designer. The rated capacity should be presented in a clear and unambiguous manner.

2.3.1.6 Further, the maximum offlead/sidelead operating angles defined in the certified basis of design shall be verified against the intended operations, design standard and engineered lift.

## 2.4 Subsea lifting capacity

### 2.4.1 Non-engineered lift

2.4.1.1 Non-engineered lifts or “routine” lifts are considered “everyday” lifts, without specific supporting documentation. For non-engineered lifts, a simplified approach by applying a conservative dynamic factor to compensate the lack of detailed engineering may be sufficient.

#### Guidance note:

DNV’s Standard for Certification No. 2.22 Lifting Appliances June 2013 Sec.7 applies a minimum design dynamic factor of 1.7 for significant wave heights up to  $H_s = 2.0$  m. It shall, however, be noted that for objects with a large horizontal surface, large volume compared to the weight etc. this factor may be insufficient, and an engineered lift approach shall be applied.

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### 2.4.2 Engineered lift

2.4.2.1 Engineered lifts are particularly planned and prepared operations. For lifting appliances subjected to engineered lifts, de-rating of the lifting capacity shall normally be provided and the actual static and dynamic loads shall not exceed the de-rated capacity for the specific sea condition.

### 2.4.3 De-rating

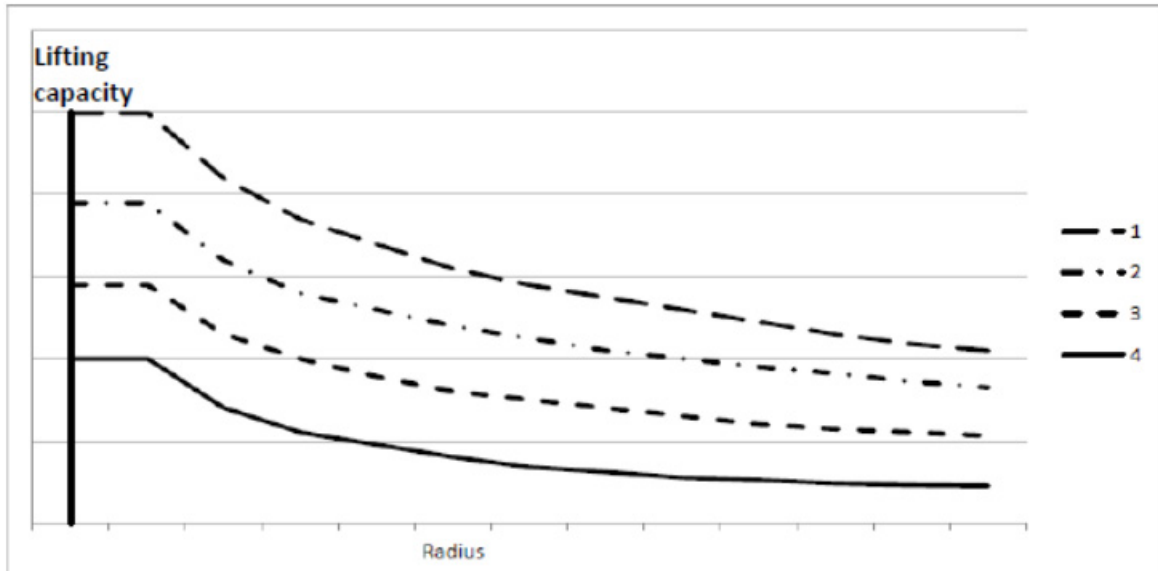
2.4.3.1 De-rating concerns the capacity of the lifting appliance with respect to structural strength. De-rating does not consider the forces and hydrodynamic effects from the lifted object. The Working load -  $W_n$  shall be less than the de-rated capacity -  $R_n$  of the lifting appliance, at the  $H_s$  in question. See [Figure 2-2](#).

2.4.3.2 De-rating shall be presented in terms of the maximum allowable static capacity  $R_0$  and dynamic capacity  $R_n \times DDF$ . The de-rating can be presented for different sea conditions, or for the accelerations related to different sea conditions. See [Figure 2-1](#).

2.4.3.3 De-rating is normally presented by means of De-rating charts or Load charts. These charts can be presented in different ways. An example of a de-rating chart with operational limits is given in [Figure 2-1](#).

## Operational limitations

- Design Dynamic factor:  $DDF = 1.3$ .
- Heel / Trim inclination:  $5 / 2$  deg.
- Offlead / sidelead: 9%.
- Maximum operating wind speed: 24 m/s.
- Based on RAO-data the load chart is valid for a  $H_s = 2$  m, wave period  $T = 10$  s, and vessel is heading maximum  $\pm 15$  deg from head seas.



- 1) Dynamic design capacity at  $H_s = 0$ m:  $SWL \times DDF$ .
- 2) Static design capacity at  $H_s = 0$ m:  $SWL$ .
- 3) Dynamic de-rated capacity at  $H_s = 2$ m:  $R_{2,0} \times DDF$ .
- 4) Static de-rated capacity at  $H_s = 2$ m:  $R_{2,0}$ .

**Figure 2-1**  
**Example - De-rating chart**

2.4.3.4 To establish the load charts, the reduced lifting capacity due to the vessel motions shall be calculated. This shall normally be carried out by the designer of the lifting appliance.

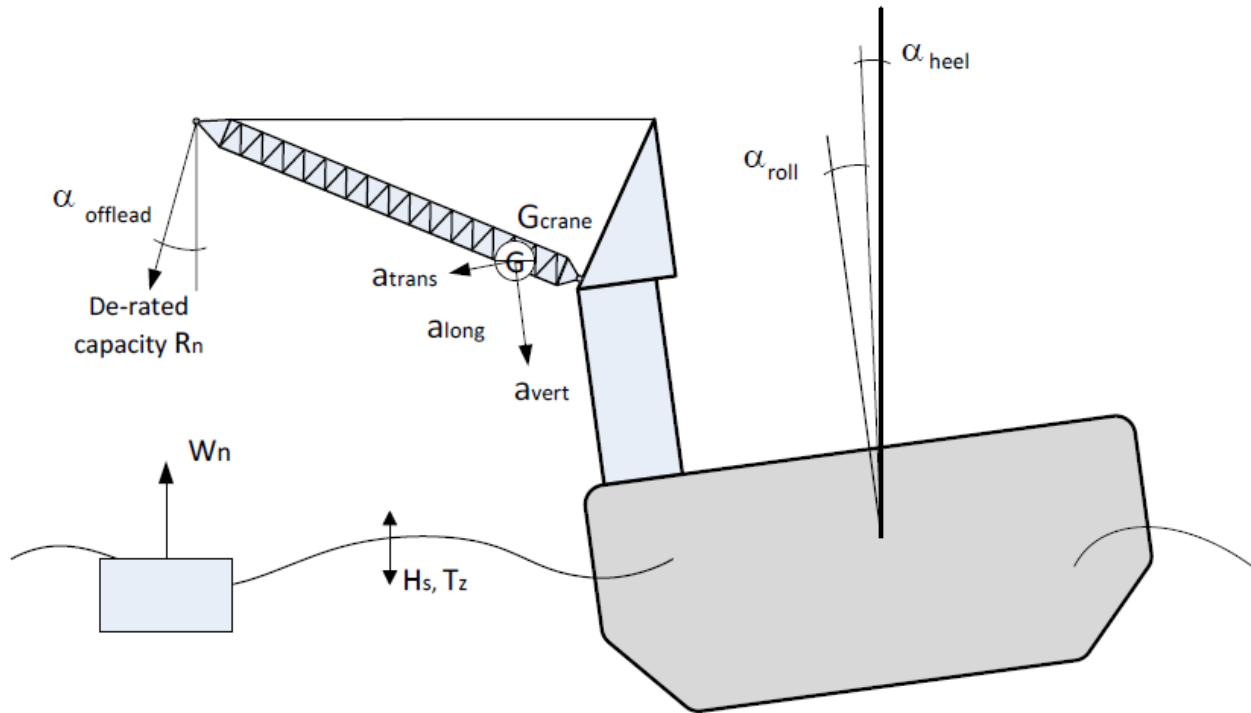
**Guidance note:**

It is recommended that the owner provides the designer with the relevant input parameters (max  $H_s$ , wave periods, wave heading, vessel motions, offlead/sidelead, etc.)

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2.4.3.5 De-rating shall consider the following influences on the structural integrity of the lifting appliance:

- Vessel motions (dynamic angles and accelerations).
- Heel/trim.
- Offlead/sidelead.
- Wind.



**Figure 2-2**  
**De-rating of crane**

**Guidance note:**

The figure shows static and dynamic inclination and accelerations in the transverse direction of the vessel.

Relevant inclinations and accelerations in the longitudinal direction of the vessel shall be included in the de-rating.

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2.4.3.6 Vessel's motion characteristics are necessary to carry out these calculations. Response amplitude operators (RAOs) for the actual vessel are the preferable basis. However, a simplified approach based on general equations for the vessel type, or empirical data may be applied in lieu of detailed analysis.

2.4.3.7 Vessel motions shall be calculated on the basis of the specified  $H_s$ , wave period and wave spectrum, as described above. The vessel motion amplitude shall be based on statistical values with 95% probability of non-exceedance for a time period of 3 hours. Limitations due to vessel heading and vessel stabilizers should be considered. To ensure accuracy, it is recommended that dynamic loads on the lifting appliance be derived on the basis of vessel specific RAO data.

**Guidance note:**

See DNV-OS-H102 Marine Operations, Design and Fabrication, (Sec. 4 B Motion analysis and C Load cases) for guidance on motion analysis and establishing relevant load cases. See also DNV-RP-C205 Sec.7.

API 2C provides proposed/estimates for accelerations for cranes on board certain types of vessels.

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2.4.3.8 Inclination of the vessel due to vessel motions shall be applied by means of relevant accelerations and angles for the  $H_s$ , wave period and wave spectrum in question, see [Figure 2-2](#).

2.4.3.9 Heel and trim angles for still water shall be included. Limitations due to vessel characteristics and/or stabilizers may be applied. The applied heel and trim angles shall be specified in the load chart.

**Guidance note:**

Heel and trim angles are specified in DNV's Standard for Certification No.2.22 Lifting Appliances or in other recognised codes or standards.

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2.4.3.10 Offlead/sidelead angles as agreed with the owner shall be included. If not specifically agreed, 9%, according to DNV Standard for Certification No. 2.22, Lifting Appliances is recommended. The applied

offlead/sidelead angles shall be specified in the load chart, see [Figure 2-1](#).

2.4.3.11 Operational wind speeds shall be specified and forces calculated in accordance with DNV's Standard for Certification No. 2.22, Lifting Appliances, or other recognised standard/codes. Wind forces shall be considered to act on both the lifted load and the structure of the lifting appliance.

2.4.3.12 The capacity of pedestal / foundation, often separately delivered by the yard, shall also be included in the de-rating.

2.4.3.13 Load charts for subsea handling shall not be confused with load charts for ship-to-ship handling.

## 2.4.4 Load case

2.4.4.1 Load actions from the above conditions shall be applied as design loads for Load Case II (LC II), as specified in DNV Standard for Certification No. 2.22 Lifting Appliances. However, the heel and trim angles shall be as specified for Load case I (LC I).

2.4.4.2 When dynamic load curves are calculated in accordance with above, static load curves,  $R_n$  shall be established by dividing the dynamic load curves by the DDF (normally 1.3), where  $R_n$  reflects the static load that can be lifted by the lifting appliance. Both static and the dynamic load curves shall be presented in the load chart.

2.4.4.3 When loads charts are presented as a function of accelerations, a MRU measuring the accelerations and deck inclination shall be used to ensure that movements and accelerations remain valid, i.e. within the limits of the applicable load curves. Accelerations shall be based on the same statistical value of 95% probability of not being exceeded for a time period of 3 hours, as specified for vessel motion amplitude.

## 2.5 Lifted loads

### 2.5.1 Description of loads

2.5.1.1 Forces and environmental effects on the lifted object shall be assessed and derived in accordance with recognised methods. Forces and hydrodynamic effects on an object lifted subsea will depend on many factors and shall be evaluated for each lift. Such effects depend on the characteristics of the object, the installation vessel, the lifting appliance itself and the operational and environmental conditions experienced - see section [\[5.7\]](#).

#### Guidance note:

Calculation of hydrodynamic forces can be done according to DNV RP-H103 *Modelling and analysis of marine operations*.

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## 2.6 Winches and winch drums

### 2.6.1 General

2.6.1.1 Winch types intended for subsea operations are normally of "single drum" or "traction and storage" type. Single drum winches are normally fitted with a large drum, designed to accommodate long lengths of rope arranged in several overlapping layers, utilised to provide adequate traction/tensioning and storage of the rope. Traction and storage winches incorporate normally one or several drums providing tension/traction and one drum with low wire tension for storage, operating a single rope layer on the traction drums.

2.6.1.2 Loading and therefore stresses on winch drums and flanges depend on variables such as but not limited to rope length / number of layers, rope configuration, characteristics, stiffness, age and use of the rope, drum design, nature of operations (e.g. amount of line tension "locked" into the first few layers), load characteristics, spooling arrangements, etc.

2.6.1.3 The number of rope layers on a single drum winch can lead to significantly higher loading and resultant stresses in comparison with the traction drum arrangement. Specifically, for single drums, high tension retrieval operation starting at first rope layer, will result in high drum loading and in turn high compressive hoop stresses.

2.6.1.4 Suitable corrosion protection is necessary to protect the drum from the effects of salt water carried by the wire.

2.6.1.5 The designer shall ensure adequate design of the winch drum. The intended use and operating conditions should be provided by the owner.

#### Guidance note:

Verification of the design by means of testing as specified in DNV Standard for certification No.2.22 Lifting



Appliances may be carried out as part of the certification.

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2.6.1.6 The provision of calculations adequately demonstrating structural integrity of the drum can be challenging - a TQ process and/or a well-documented testing programme may therefore be applied in lieu of detailed calculations.

## 2.6.2 Calculation methods

2.6.2.1 DNV Standard for Certification No. 2.22 Lifting Appliances, indicating a simplified method for hoop stress calculations, by applying a C-factor, may be applied for the drum. A C-factor of 3.0 is normally considered acceptable for subsea handling, both for the use of steel wire and fibre rope. Methods for the calculation of drum stresses can also be found in ASME B30-7-2001: Base-Mounted Drum Hoists.

2.6.2.2 Operating the winch in a manner that does not utilise the first rope layer on the drum for lifting purposes (with a pre-stress of 10 - 20% of line pull) may provide “protection” of the drum from subsequent layers, in effect by reducing hoop stress. A reduced C-factor of 1.75 may normally be applied, however, for wire ropes with high transverse stiffness, the C-factor may exceed above values.

2.6.2.3 Other calculation methods may be employed, for instance the method developed by Dietz/Mupende. Their method takes into account the transverse stiffness of the wire rope. This information can be provided by the wire rope manufacturer or by additional testing the rope. The above methods do not consider the effects from longitudinal or ring stiffeners, where provided inside the drum.

2.6.2.4 Deflection of the drum and the effects that this can have on drum mounting points, when multi-layer drums and “stiff” wire ropes are used, should be evaluated.

2.6.2.5 Testing may be restricted to limited depths if deemed sufficient for planned operations. However, this depth shall be stated explicitly as an operational limitation on the Certificate for the lifting appliance. Onshore testing using winch to winch or other representative methods can be accepted.

## 2.6.3 Spooling

2.6.3.1 Inadequate spooling may lead to damage of the rope and/or the drum; the need for a separate spooling device / level winder should be evaluated.

2.6.3.2 Significant deformation of drum flanges may result in the rope “cutting” into underlying layers, causing increased flange stress, damage to the rope and operational difficulties. Flange deformation may also lead to skewed distribution of loads in the drum’s gear transmission. It is therefore necessary that flange deformation is kept to a minimum. The design of drum flanges should be such that these effects are avoided.

2.6.3.3 Loose spooling of the rope may cause the knifing effect. Retrieval of empty hook, followed by high tension lowering is known to cause this problem. This is especially relevant for lightweight fibre ropes. Rope tensioning when spooling in empty hook should therefore be applied, i.e. clump weights or other back tensioning device. Spooling and unspooling at constant tension; such as storage drum on a traction winch, may also be applied.

2.6.3.4 Crushing of underlying rope on multi-layered drum may also require special consideration, see [2.7].

## 2.6.4 Gear transmissions

Gear transmissions and brakes shall be evaluated with respect to the specific loads and load spectrum for proposed subsea operations. Due consideration shall be made to AHC operations and expected load cycles/spectrum. For more accurate information, load cycle monitoring systems may be utilised.

### Guidance note:

Relevant standards/codes may be applied, such as FEM 1.001, DNV’s Ship Rules Pt.4 Ch.4 Sec.2 “Gear transmissions”, ISO 6336, EN 13135-2, etc.

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2.6.4.1 For gear transmissions that are prone to overheating, additional coolers may be necessary, whereby special attention should be paid to gearboxes used for AHC.

2.6.4.2 Gears and brakes shall be designed to ensure that all movements are started and stopped smoothly.

2.6.4.3 Flange deformations in the winch drum may lead to skewed distribution of loads in the drum’s gear transmission, especially for multiple gear designs with pinions and gear mounted far out on the drum flange. The flange deformation shall therefore be kept to a minimum, and specifically evaluated with respect to the applied gears.



## 2.7 Steel wire ropes

### 2.7.1 General

2.7.1.1 Steel wire ropes shall be evaluated with due consideration to their certification, design, strength and safety factor, design duty/life and fatigue and appropriate criteria relating to their condition and discard.

2.7.1.2 Steel wire ropes for subsea operations shall be delivered with ILO Form 4 “Certificate of test and thorough examination of wire rope” or similar. End terminations shall be in accordance with recognised standards/codes and shall normally be included in the certificate.

2.7.1.3 Steel wire ropes shall normally be galvanized. End terminations shall be of suitable type to avoid galvanic corrosion.

2.7.1.4 For single fall configurations the rope shall be rotation resistant.

2.7.1.5 For multi-fall reeving configurations operational measures e.g. anti-twist systems, and type of rope should be evaluated to prevent twisting.

2.7.1.6 Safety factors shall be in accordance with recognised standards/codes, or specially approved.

2.7.1.7 The required minimum safety factor shall be based on the static or dynamic lifting capacity, whichever provides the higher safety level.

#### Guidance note:

According to DNV Standard for Certification No. 2.22, Lifting Appliances, the safety factor is calculated based on either the SWL or the DDF, whichever provide the greater safety factor to be used.

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2.7.1.8 Fatigue damage and lifetime of the wire rope have to be evaluated against manufacturer specification, complemented by thorough examination and inspection. Expected lifetime will vary significantly depending on the duty factor and wire routing, e.g. the distance between sheaves and presence of reverse bending, etc. Application of AHC leads to accelerated damage due to more frequent bending cycles and increased temperature in the wire rope. It is important to identify the sections of the wire rope which will be utilised most from cyclic bending and loading (these sections will experience higher rates of deterioration than other sections). A wire rope monitoring system may be installed to provide more accurate information. Load, heat, bending cycles per unit length, etc. should be monitored. Altering length of rope deployed at suitable intervals is recommended, in order to distribute the bending cycles on different parts of the rope. The length of the intervals will depend on the characteristics of the system and operation and should be evaluated case by case. See [4.4] for recommendations regarding condition monitoring of wire rope.

#### Guidance note:

Large diameter wire ropes will experience more heat generation than smaller ones, during AHC.

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2.7.1.9 A risk analysis, involving the wire rope manufacturer, a wire rope competent person and a representative from the end user, may be carried out to ensure appropriate wire rope design and strength.

2.7.1.10 Resonance problems may develop if the REP oscillation period or the wave period is close to the natural resonance period of the hoisting system. This can be managed by changing the natural frequency of the system i.e. using stretchers or passive heave compensation, see [C.3.1] and [C.4.1]. It is recommended to carry out pertinent analyses to identify potential critical depths.

#### Guidance note:

For this purpose, DNV-RP-H103 *Modelling and analysis of marine operations* can be applied.

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## 2.8 Fibre ropes

### 2.8.1 General

2.8.1.1 Fibre ropes for lifting operations are normally made from polyamide, aramids, HMPE, etc.

2.8.1.2 The use of fibre ropes will tend to reduce the overall load on the lifting appliance, compared with steel wire ropes, due to buoyancy and significant lower weight/strength ratios - significant benefits can be achieved, particular for heavy lifts at increasing depths.

2.8.1.3 Present fibre rope standards/codes do not address subsea handling adequately. However, DNV-OS-E303 *Offshore Fibre Ropes* and DNV-OS-E407 *Underwater Deployment and Recovery Systems*, Appendix C, address fibre ropes in general and are recommended as guidance. See also section [4.5].

## 2.8.2 Acceptance criteria

2.8.2.1 A risk analysis or TQ process in accordance with DNV-RP-A203 is generally recommended for assessment of fibre rope application, with due consideration given to the following:

- a) Type of certification.
- b) Elongation/elasticity.
- c) Strength/safety factors.
- d) Shape change.
- e) Sheave profile.
- f) Bending over sheaves.
- g) Heating/increased temperature.
- h) Abrasion.
- i) Weight per unit of length.
- j) Number of cycles and service life.
- k) Terminations/splicing.
- l) Damping.
- m) Discard criteria.
- n) Drum spooling.

## 2.8.3 Documentation

2.8.3.1 Fibre ropes for subsea operations shall normally be delivered with certificates, see [4.5]. Testing shall be based on both dry and wet fibre rope for some types of fibres, polyamide / nylon, as the presence of water can effectively reduce the MBL. For such fibre ropes, both dry and wet MBL shall be specified in the certificate. End terminations shall normally be included in the certificate; however, the end termination may be covered by a separate certificate.

## 2.8.4 Change-in-length performance characteristics

2.8.4.1 Extension and elongation properties vary significantly from steel wire ropes. For fibre ropes, these characteristics are referred to as the change-in-length performance (CILP). Fibre ropes tend to have a much higher “constructional” elongation, which is an important consideration in terms of the final length of the rope. Constructional elongation is permanent/non-recoverable and is often referred to as “bedding-in”. This manifests itself more so at low loads, i.e. up to 5% (approx.) of MBL. Above this load, most high performance fibre ropes demonstrate more linear elasticity prior to complete rupture; there is no yielding. Elastic stiffness of fibre ropes is less than the elastic stiffness of an equivalent strength steel wire rope.

2.8.4.2 For HMPE ropes, attention should be paid to creep, especially if exposed to high temperature.

## 2.8.5 Performance margins

2.8.5.1 A fibre rope generally has a larger diameter than a wire rope of the same capacity.

2.8.5.2 Performance margins for fibre ropes shall be assessed with respect to both static and dynamic loads. A risk assessment may be adopted as a basis for evaluating appropriate safety margins, taking into account effects such as:

- type of operation
- type of fibres (nylon fibre ropes normally require a higher margin than other fibre ropes)
- type of lifting (lifting by friction leads to a different fracture mechanism than lifting by pulling, necessitating a different assessment of appropriate safety margins).

## 2.8.6 Shape change

2.8.6.1 Fibre ropes are subject to shape changes as a result of load and/or contact surfaces. In most cases, natural shape change will not negatively affect the performance of the rope. However, forced shape changes, i.e. use in a V-shaped groove of a sheave will affect performance.

2.8.6.2 Level wind mechanisms may require adjustments due to the changes in cross section while under load.

2.8.6.3 After the bedding process, most ropes do not experience significant change of cross section. However, the ability to change shape may increase the possibility of the rope to cut into underlying layers on a winch drum.

2.8.6.4 Flattening of the rope is common when in contact with flat surfaces; such flattening may not affect performance, however should be clarified with the rope manufacturer.

## 2.8.7 Sheave profile

2.8.7.1 The desired groove shape is either a “U” or flat groove. The width should be at least 10% larger than the rope diameter. If spliced repairs need to pass through a sheave, larger sheave grooves (above 10%) should be used to accommodate the spliced repairs. “V” grooves should be avoided if the rope is subjected to repetitive bending.

2.8.7.2 In general, pitching of the rope should be avoided.

## 2.8.8 Bending

2.8.8.1 All ropes are sensitive to repeated bending; greater number of cycles will reduce service life, due to increased internal temperature and abrasion. Characteristics of fibre ropes change with increased temperature, measures to control this should be adopted.

### Guidance note:

A cooling system or special coating may be used to reduce the increase of temperature in the rope. The system adopted will depend on the nature and diameter of the rope being used.

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## 2.8.9 Failure mechanism

2.8.9.1 The primary failure mechanism for fibre ropes is associated with abrasion between the strands, caused by “scissoring” motion of the strands as the rope is bent and straightened. As a result of friction between the strands, internal heat is generated.

2.8.9.2 In less severe applications i.e. low loads, large  $D_p/d$  ratios and low frequencies, abrasion itself will be the primary failure mechanism.

2.8.9.3 In more severe applications i.e. high loads, small  $D_p/d$  ratios and high frequencies, the main failure mechanism is heat in some fibres, with extreme abrasion in others.

2.8.9.4 When using HMPE, heat will cause the fibres to creep, manifesting in a rapid increase in length, greatly reducing the life of the rope. For other fibres (e.g. aramids), excess abrasion and heat will result in breakdown of the fibres. See Guidance note above.

2.8.9.5 Active heave compensation systems lead to accelerated wear, due to increased bending cycles. Assessment of service life/fatigue of fibre ropes is complex, due to the multidimensional nature of the possible failure mechanism. A fibre rope heat and load monitoring system may be installed to provide more accurate information.

2.8.9.6 When specifying fibre ropes, bending fatigue properties shall be evaluated, with due consideration given to proposed operations. The manufacturer should confirm an appropriate  $D_p/d$  ratio, based on the specific application.

## 2.8.10 Fibre rope terminations

2.8.10.1 Fibre ropes are generally terminated using splices, the diameter of which can be 50% greater than the rope diameter itself. This can lead to operational difficulties which may result in rejection. Splice length and diameter should therefore be considered during equipment design, for both end and in-line terminations used for maintenance and repairs.

2.8.10.2 Socket terminations / potted fittings can be used and generally accommodate less space than splices, but are challenging to fit and their efficiency is generally less than for splices.

2.8.10.3 Termination hardware should conform to latest edition of DNV-OS-E303.

## 2.8.11 Fibre rope repairs

2.8.11.1 All repair methods shall be qualified and the integrity of protective sheathing reinstated in accordance with Manufacturer instructions.

2.8.11.2 Repairs shall be performed by personnel authorised by the fibre-rope manufacturer.

### Guidance note:

Information concerning fibre rope damage assessment and repair can be found in DNV-RP-E304, API RP 2I, ISO 18692 and CI 2001-04.

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2.8.11.3 If a rope section has been spliced, that section shall not be used over a sheave or in bending when used in an activated AHC system.

## 2.8.12 Damping

2.8.12.1 Fibre ropes experience more hysteresis than steel wire ropes, i.e. better damping. Furthermore, synthetic fibres are viscoelastic and thus the level of damping is dependent on the strain rate.

## 2.8.13 Drum spooling

2.8.13.1 The spooling performance of fibre ropes will improve after the rope has bedded in.

2.8.13.2 When installing a new rope, the highest possible back tension should be applied.

2.8.13.3 The primary issue with fibre ropes used on a drum is “cutting” into underlying layers. This will tend to occur if spooling on under low tension is followed by spooling off under higher tension.

### Guidance note:

It is recommended that sufficient tension is maintained whilst spooling rope onto a drum, especially when retrieving rope only – a supplementary traction winch or controlled storage system may be considered.

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## 2.9 Lifting gear and components

### 2.9.1 General

2.9.1.1 Lifting gear and components typically include chains, slings, hooks, hook blocks, rings, shackles, swivels, spreader beams etc.

### Guidance note:

For general requirements, reference is made to DNV Standard for Certification No. 2.22 *Lifting Appliances*, DNV-OS-H205 *Lifting Operations* Sec.4.3 or equivalent standard/code.

For design requirements of temporary structures, reference is made to DNV-OS-H102 *Marine Operations Design and Fabrication*.

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2.9.1.2 All lifting gear and components shall be suitable for subsea operations and facilitate safe lifting operations.

2.9.1.3 Where possible, lifting gear and components shall be designed/shown to be free-flooding and draining, alternatively closed spaces shall be designed to withstand the external water pressure anticipated.

2.9.1.4 Loose gear shall be resistant to and/or protected against the corrosive effects of sea-water (and/or acidic water in volcanic areas). Ease of access for inspection should be incorporated, in particular concealed “rust traps” should be avoided. Loose gear for single use may be specially considered.

2.9.1.5 Sheaves used in heave compensation systems shall have a minimum  $D_p/d = 20$ .

2.9.1.6 Material properties suitable for proposed design temperatures and environmental conditions shall be specified. See [4.8.3] Certification of component, loose gear and rigging equipment.

## 2.10 Tugger winches

### 2.10.1 General

2.10.1.1 This chapter applies to both permanent and temporary tugger winches. Use of tugger winches will depend on vessel capability and project requirements. The use of tugger winches should be specially considered during project risk evaluation.

2.10.1.2 Tugger winches not supporting the weight of the lifted object are not subjected to certification requirements.

2.10.1.3 Tugger winches used to assist the primary lifting appliance in supporting a proportion of the weight of the lifted object, certification requirements apply.

2.10.1.4 Tugger winches shall not exert forces on the lifted object in excess of the established off-lead and side-lead.

2.10.1.5 Tugger winches should not generate sudden loads or release of loads, therefore constant tension mode which pays out rope with a significant retaining force if the winch capacity is exceeded, is recommended. Tugger winches shall have an appropriate response time.

*2.10.1.6* Requirements to tugger winches can be found in standard EN 14492-1:2006+A1:2009. Requirements to winch foundation can be found in DNV Rules for Classification of Ships Part 3 Chapter 3 Section 5 B.

*2.10.1.7* Tugger winches should be designed with a DDF of 1.1 if they are equipped with a constant tension system, otherwise the DDF should be 1.3.

*2.10.1.8* Tugger winches can be controlled by either the crane driver or a dedicated winch operator. Pedal controls should be avoided. A suitable means of communication shall be arranged between the crane driver and the operator of the tugger winch.

*2.10.1.9* Nylon/polypropylene forerunners may be used to absorb shock loads in steel wire ropes when a tugger winch is controlled manually.

## 3 Control / power systems

### 3.1 Introduction

This chapter applies to control and power systems installed on lifting appliances intended for subsea operations as indicated in [1.9].

#### 3.1.1 Main principles

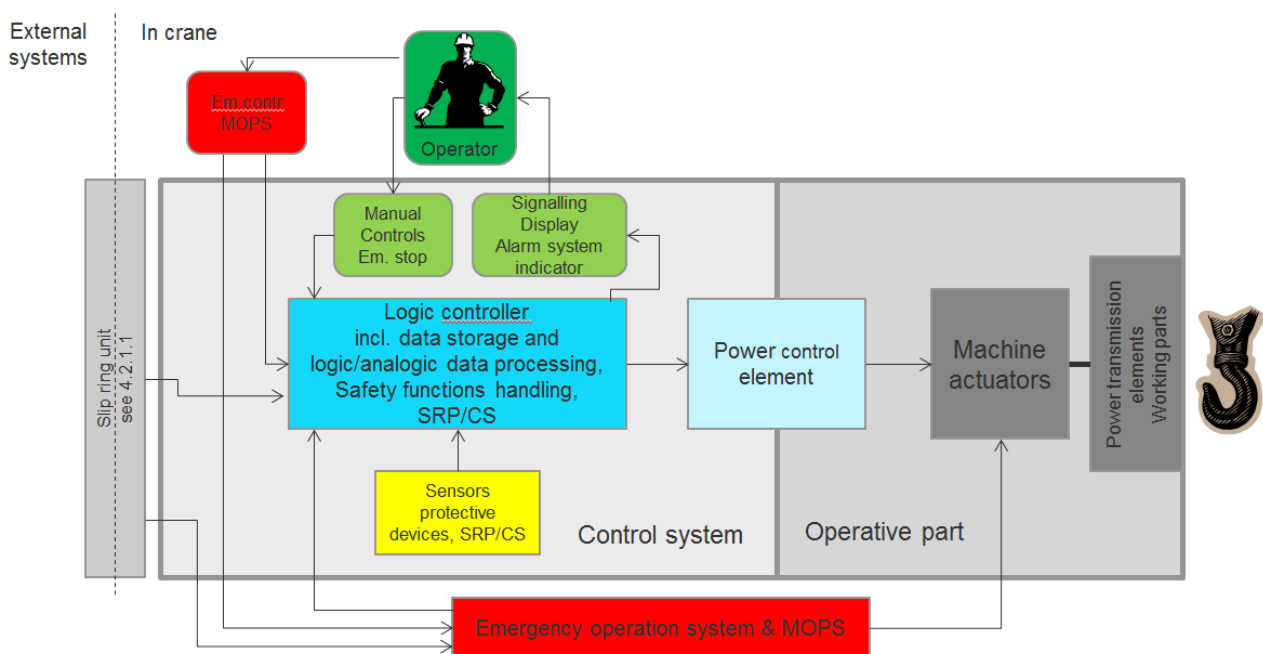
3.1.1.1 In general all recommendations in this chapter are applicable to new control and power systems, installed on new lifting appliances, intended for subsea operations.

3.1.1.2 A risk assessment shall be carried out on existing lifting appliances intended for subsea operations displaying insufficient safety levels, increased frequency of failures or that have caused a serious incident.

3.1.1.3 If a safety assessment indicates a need to upgrade existing power / control systems, relevant parts of this RP may be used as basis to improve the safety level.

#### 3.1.2 Schematic representation of the lifting appliance, intended for subsea operations

3.1.2.1 Information flow in the control system and associated elements are identified as indicated in the following generic schematic.



**Figure 3-1**  
 Schematic representation of the lifting appliance

**Note:**

1. Diagram does not incorporate details described in section [3.4], including for example redundancy
2. Figure presents a description of information flow on a generic lifting appliance.

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### 3.2 Electrical installations

#### 3.2.1 General

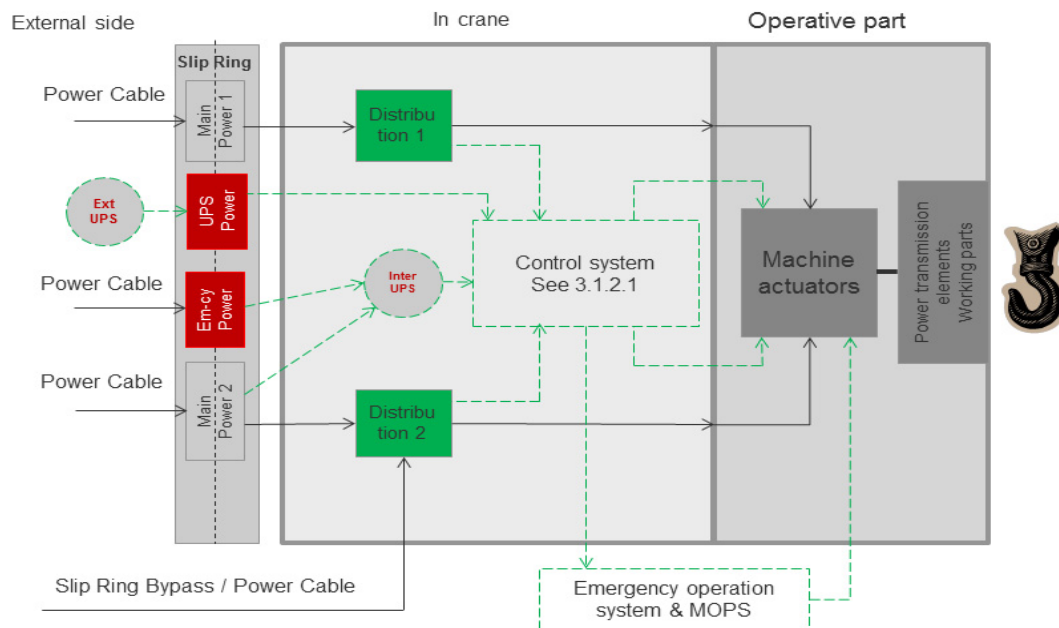
3.2.1.1 Electrical installations should comply with relevant and recognised codes and standards pertinent to the area of use of the lifting appliance and as a minimum to the latest revisions of the following standards:

- DNV Standard for Certification No. 2.22 *Lifting Appliances*
- DNV Rules for Ships Pt.4 Ch.8 *Newbuildings machinery and systems - Main class - Electrical Installations*
- EN/IEC 60204-32:2008 *Electrical equipment of machines, Requirements for hoisting machines*
- EN 13557: 2008 *Controls and control stations*.

3.2.1.2 Other standards may be considered relevant, however should be evaluated on a case by case basis.

### 3.2.2 Power systems

3.2.2.1 Schematic representation with respect to power flow in a lifting appliance intended for subsea operations is illustrated below.



**Figure 3-2**  
**Generic representation of the power system**

**Note:**

- Figure 3-2 represents possible componentry and information flow, which may be installed on a subsea lifting appliance. Some of the elements may not be present on equipment other than subsea cranes e.g. winches do not have a slip ring unit. The figure does not include all components recommended on every lifting appliance.
- Arrangement of the MSB is generic to illustrate that the use of two power feeders from two separate sections of MSB is recommended.
- Due to MSB topology, User/Operator should observe Class requirements, due to possible conflicts with DP requirements and DNV-RP-D102 Appendix D.4 *Separated power systems simultaneous supplying equipment placed in a non-separated area.*

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3.2.2.2 Means of well-tried safety principles should be provided in the slip-ring unit for emergency and UPS power (e.g. separate chambers, over dimensioning, extra fire protection). A list of well-tried safety principles can be found in EN ISO 13849-2 Annex D Table D2.

3.2.2.3 Precautions taken to improve safety of the slip ring according to [3.2.2.2] should be documented and subjected to 3rd party verification.

3.2.2.4 Phase monitoring should be provided as per IEC 60204-32 p 7.8

3.2.2.5 An Earth fault monitor should be installed and an alarm should be presented on the main control station of the lifting appliance. For lifting appliances not equipped with displays, this function might be included in a red “common alarm” indication.

3.2.2.6 There should be at least two separate independent main power feeders for a subsea crane. These should follow MSB structure, each from a separate section. Complete blackout in the power/control system of the crane, while one section of the MSB is failing should be avoided. See [3.2.2] block diagram “Main Power 1” and “Main Power 2”.

3.2.2.7 Lifting appliances other than subsea cranes should fulfil recommendations described in [3.2.2.6], if complete blackout in the power/control system can result in significant hazards. This should be evaluated by a Risk Assessment or FMECA.



3.2.2.8 Power supply to essential consumers should be monitored by the lifting appliance control system. Essential consumers are listed in [Table 3-1](#).

<b>Table 3-1 Essential consumers</b>	
<i>No</i>	<i>Title</i>
1	Main Logic Unit
2	Main power units (main switchboards, main control cabinets, main motor starters)
3	Any emergency arrangement (emergency lowering)
4	Cooling system
5	Internal UPS
6	Emergency operation system
7	Emergency lighting/escape routes lighting/aircraft landing lights/lighting of emergency operation stands
Note: Some of the components may not be installed on every lifting appliance. However if present, it is recommended that it is considered an essential consumer.	

3.2.2.9 When a new lifting appliance is to be installed on a vessel in operation, the manufacturer shall consider existing power supply configuration, capacity and bus-tie-breaker in order to provide safe solution for main power supply availability

### 3.2.3 Emergency power

3.2.3.1 Consumers as indicated in [Table 3-2](#), if installed, should as a minimum be connected to the emergency source of power.

<b>Table 3-2 Emergency power consumers</b>	
<i>No</i>	<i>Title</i>
1	Main Logic Unit
2	Emergency operation equipment shall be considered if provided level of main power redundancy is not sufficient. To be documented in FMECA document.
3	Emergency lighting
4	Internal UPS
Note: Some of the components may not be installed on every lifting appliance. However if the component is present, power supplied via an emergency source is recommended. The numbering does not indicate priority.	

3.2.3.2 Final list of emergency power consumers should be identified and documented by Risk Assessment/FMECA.

3.2.3.3 Cables providing emergency power and functions should be fire resistant.

**Guidance note:**

Requirements for fire resistant cables can be found in IEC 60331.

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### 3.2.4 Uninterruptable power supply - UPS

3.2.4.1 Functions listed in [Table 3-3](#) should be powered by uninterruptable power supply (UPS) with capacity sufficient to terminate lifting operation in a safe manner or going to the safe state, where recommended time is minimum 30 min.

Main purpose of this recommendation is to have possibility to monitor the situation, have the total overview of the crane functions and failures. Other consumers should be considered for supply from the internal UPS based on conclusions of the risk assessment and FMECA, taking into account limitations of the internal UPS capacity.

<b>Table 3-3 List of recommended UPS consumers</b>	
<i>No</i>	<i>Title</i>
1	Main logic unit – with its I/O
2	Main screen
3	Alarm system with buzzer



4	Manual Overload Protection
5	Movement monitoring system
6	Lighting of the emergency control stand
Note: Some of the components may not be installed on every lifting appliance. However if the component is present it is recommended that it is supplied from uninterruptable power supply. The numbering does not indicate priority.	

3.2.4.2 Functions listed in [Table 3-3](#), if installed, should have independent and dedicated UPS.

See. [\[3.2.2\]](#) block diagram – Internal UPS.

3.2.4.3 UPS should be supplied from one main and one emergency line. See [\[3.2.2\]](#) block diagram.

### 3.2.5 Electric motors

3.2.5.1 For all motors exceeding 100 kW the starting current of the electric motor should be limited upwards to 250% of the rated current of the motor.

3.2.5.2 Electric motors over 0.5 kW should have independent and dedicated short circuit and overload protection in the dedicated distribution board, typically installed on the lifting appliance. Overcurrent protection may be omitted for the motors fitted with winding temperature detectors.

3.2.5.3 Selectivity with circuit breakers in MSB, or other higher level feeders, shall be documented.

3.2.5.4 Electric motors which are placed in other compartments than their starters should be equipped with dedicated local stop buttons with lock. Emergency stop designation should not be used for that purpose. Restarting an electric motor should not be possible until the lock is released.

3.2.5.5 Main electric motors providing power to the hoisting system installed on subsea lifting appliances should have IEC S1 duty cycle designation.

### 3.2.6 Power distribution

3.2.6.1 It is recommended that main electric power distribution cabinets fitted on the lifting appliance and connected to the different sections of the external main switchboard should be physically separated from each other and as far as practicable placed in opposite sides of the compartment or in different compartments. See [\[3.2.2\]](#) block diagram “Distribution 1” and “Distribution 2”.

3.2.6.2 It is recommended that cables routed to different parts of the system as defined in [\[3.2.2.6\]](#) and [\[3.2.3.3\]](#) should be as far as practicable physically separated by means of routing on separate cable trays on opposite sides of the compartments or in different compartments.

3.2.6.3 Cables for emergency operation and cables for main power defined in [\[3.2.6.2\]](#) and [\[3.2.3.3\]](#) should be placed in separate chambers of the slip ring. Separate chambers mean special safety precaution in case of major overheating or other failures which may spread in the slip ring causing total failure. In the slip ring, failure of one set of cables should not disable power flow in the other part. Technical data and current limits, including limits for starting current, shall be specified by the manufacturer.

3.2.6.4 In case of slip ring failure, bypass facilities, e.g. flexible cable, shall be available on the lifting appliance, to be able to operate the lifting appliance to the safe position, see [\[3.2.2.1\]](#), [Figure 3-2](#) “Slip Ring Bypass / Power Cable”.

However bypass facilities shall not be understood as substitute for the slip ring emergency power.

3.2.6.5 Ingress protection according to IEC 60529, should as a minimum be as indicated in [Table 3-4](#) for electrical components.

<i>Type of the compartment</i>	<i>Recommended IP</i>
Cabin	23
Engine Room / Technical rooms	44
Weather deck areas	56

3.2.6.6 See [3.2.2.1] - block diagram - losing one main power feeder, “Main Power 1” or “Main Power 2”, should not result in losing any of the essential functions as indicated in Table 3-5.

<b>Table 3-5 Essential functions</b>	
<i>No</i>	<i>Title</i>
1	Alarm and monitoring system
2	Measurements
3	Movement monitoring
4	Power supply monitoring as stated in 4.2.1.2
5	Communication system (VHF, UHF)
6	Operating the lifting appliance with limited speed/capacity (hoisting/lowering, slewing, luffing, folding)
7	Overload protection systems
Note: Applicable to any lifting appliance. The numbering does not indicate priority.	

### 3.2.7 Power quality

3.2.7.1 Total voltage harmonic distortion measured on the main power connection terminals of the lifting appliance should not exceed 5%. THD should be tested when a lifting appliance is installed in its final location. Worst case scenario should be considered for the tests.

## 3.3 Hydraulic installations

### 3.3.1 General

3.3.1.1 Hydraulic installations should comply with relevant and recognised standards pertinent to the area of use of the lifting appliance and as a minimum to the standards as stated below:

- DNV Standard for Certification No. 2.22 *Lifting Appliances*.
- DNV Rules for Ships Pressure testing references Pt.4 Ch.6 Sec.5 and Sec.7, and Pt.4 Ch.7.
- ISO 4413.

3.3.1.2 Other standards may be considered relevant, but should be evaluated on a case by case basis.

3.3.1.3 Hydraulically powered lifting appliances intended for subsea lifting operations typically employ a number of primary hydraulic pumps in parallel. They also tend to require a substantial number of hydraulic motors to drive the winch system.

3.3.1.4 Appropriate measures (e.g. completing a FMECA) shall be taken to prevent single points of failure in the common hydraulic system.

Failure of some of the components, e.g. pumps, motors, may result in failure or shutdown of the entire lifting appliance creating a major hazard for the subsea lifting operation.

3.3.1.5 Early detection and warning mechanisms indicating deterioration in one of these pumps or motors is of utmost importance, to provide sufficient time to terminate a critical operation and to prevent massive damage and spread of contamination in the hydraulic system.

### 3.3.2 Power quality

3.3.2.1 The lifting appliance should operate safely as long as possible, with low probability of total failure due to contamination. In the event of hydraulic failure, contamination from oil and its escalation should be avoided and contained safely; further distribution of contaminated oil should be avoided.

3.3.2.2 Incipient deterioration of hydraulic pumps / motors is typically associated with fluid contamination, e.g. metallic particles in the drain oil and often increased flow.

3.3.2.3 Measures should be in place to avoid component failure due to contamination, of which there are two main mechanisms; i.e. environmentally borne contamination and contamination associated with internal wear. Measures shall be installed to capture contaminants. Where appropriate, filters should be incorporated and/or sensors used to detect contamination in the hydraulic oil should be used.

3.3.2.4 Airborne contamination is mainly introduced via tanks and cylinder rod seals. Tanks shall be sealed to prevent water or dust ingress. Tank air pass shall be filtered to capture moisture and solid particles. Cylinder rods shall be replaced as soon as leaks are detected. Possible mitigation of contaminant generated by components due to normal wear may include filtration on pressure and return lines.

3.3.2.5 The hydraulic tank shall be designed to allow solid particles to drop to the bottom of the tank before

reaching the outlet or suction pump.

3.3.2.6 Oil temperature and condition shall be monitored. Condition monitoring may include checks for solid particles and water content in the oil. Oil chemical analysis may be used to check oil viscosity and other additives. The supplier shall install a tank connection to connect a temporary offline filtration unit and water separator.

3.3.2.7 To implement early detection, individual metal particle sensors in the drain line from each pump and motor may be deployed to alert the operator, providing sufficient time to terminate a critical operation.

3.3.2.8 Early detection of imminent failure incorporates the possibility of taking necessary actions, e.g. stopping, isolating or controlling a defective pump, to ensure the continuation of operations in a safe manner, if an alarm occurs during a critical lifting operation.

3.3.2.9 To collect relevant information about the system and implement appropriate barriers against failures in the hydraulic system, the supplier of the lifting appliance shall perform relevant investigations, based on for example risk analysis, FMECA - see [3.4.2.7] to [3.4.2.8].

3.3.2.10 The quality of hydraulic fluid at certain locations (e.g. in way of the most sensitive / critical components) in the system should be equivalent to or better than that specified in the manufacturer's datasheet.

3.3.2.11 A dossier of hydraulic components and their parameters (in terms of fluid quality) should be provided by the manufacturer and documented in the User Manual.

3.3.2.12 The manufacturer / designer of the hydraulic system should perform an analysis, e.g. FMECA, see [3.4.2.7] to [3.4.2.8], of sensitive components and their location / criticality in that system. Results should be documented and be provided for review by a 3<sup>rd</sup> party.

## 3.4 Safety evaluation of the design of control / power systems

### 3.4.1 General

3.4.1.1 The safety of a lifting appliance should be evaluated and documented by performing a risk assessment. EN ISO 12100 is recommended as a guiding standard. An equivalent standard may be used for that purpose, providing it is referred to in IEC 61508/62061 or ISO 13849.

3.4.1.2 Risks listed in [App.A Table A-1](#) shall be considered as a minimum requirement.

3.4.1.3 A hierarchal/barrier approach to the management of possible hazards shall be adopted; i.e. the manufacturer shall incorporate all possible inherently safe design measures before considering protective measures. Similarly, possible protective measures shall be adopted, before relying on warnings, instructions to operators and maintenance procedures, as per common engineering practices.

#### Guidance note:

IEC 61508/62061 and ISO 13849 or equivalent standard can be used as guidance in this process.

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3.4.1.4 Design and construction of the control system in order to ensure safe and reliable functioning of the lifting appliance are key factors in ensuring the safety of the lifting appliance as a whole.

3.4.1.5 Control systems shall be designed and constructed so that, if faults or errors occur, they do not lead to hazardous situations. Hazardous functions of the machinery can be brought under control, for example, by stopping the function, removing power from the function or preventing the hazardous action of the function. If the relevant functions of the machinery are able to continue despite the occurrence of a fault or a failure, e.g. by means of redundant architecture, there shall be means of detecting the fault or failure so that the necessary action can be taken to achieve or maintain a safe state.

3.4.1.6 The means to be used to fulfil requirement [3.4.1.5] depend on the type of control system, on the part of the control system concerned and on the risks that could arise in case of its failure.

3.4.1.7 The level of performance required for a given safety related part of the control system is to be determined on the basis of the manufacturer's risk assessment.

#### Guidance note:

Specifications for the design of safety related parts of control systems are given in EN ISO 13849-1 or IEC 61508/62061.

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3.4.1.8 The control system must be able to withstand intended operating stresses and external influences, taking into account foreseeable abnormal situations and reasonably foreseeable misuse as per IEC 61508/

62061 and ISO 13849-1 standards.

3.4.1.9 The control system must be able to withstand mechanical effects generated by operation of the machinery itself or by its environment such as shocks, vibrations, and abrasion. Control systems must be able to withstand the effects of the internal and external conditions under which the machinery is intended to function such as humidity, extreme temperatures, corrosive atmospheres and dust. The correct functioning of control systems shall not be affected by electromagnetic radiation, whether generated by parts of the machinery itself or by external elements in the conditions in which the machinery is intended to be used.

### 3.4.2 Failures in the system

3.4.2.1 No single failure in the power / control system should disable a safe operation of the lifting appliance, see schematic representation of the subsea lifting appliance [3.1.2]. Machine actuators, power transmission elements and working parts are excluded from the analysis.

3.4.2.2 In the event of failure, the operator shall be able to control a lifting appliance into the safe state position, allowing for example the operator to lower to seabed for disconnection. Safe state shall be defined as per [3.4.3.8].

3.4.2.3 No single failure in the power / control system should result in uncontrolled movements of the lifting appliance or the load - see schematic in [3.1.2]. Machine actuators, power transmission elements and working parts are excluded from the analysis.

3.4.2.4 Systems and units controlling movements of the lifting appliance shall be, as far as practicable, arranged so that a single failure in one system or one unit cannot adversely influence another unit or system.

3.4.2.5 Any single failure which could lead to a hazardous situation should be detected and communicated via an audible and visual alarm on the operator's main screen.

3.4.2.6 The list of hazards should be defined by Risk Assessment. The items listed in [A.1] Table A-1 - should be considered as a minimum.

3.4.2.7 A detailed assessment of the control system, including hydraulic, electric/electronic, and pneumatic, engine drive components or other relevant components for the design, should be performed at a component level, documenting the behaviour of the system in terms of single failures of individual components. The purpose of this assessment is to document fulfilment of the recommendations in [3.4.2]. It is recommended that FMECA in accordance with IEC 60812 or an equivalent standard presenting the same level of safety is performed.

3.4.2.8 FMECA may be used for new lifting appliances as well as for existing ones to support safety assessment. See [3.1.1.3].

### 3.4.3 Risk reduction and identification of safety functions

3.4.3.1 An iterative process of identifying safety functions is described in EN ISO 13849-1:2008 and EN ISO 12100:2010. During the process those documents should be evaluated together. As an equivalent alternative, IEC 61508/62061 may be used.

3.4.3.2 Other methods may be considered, however these shall be evaluated on a case by case basis.

3.4.3.3 A schematic representation of risk reduction process is described in Figure 1 in EN ISO 12100:2010.

3.4.3.4 A supplementary iterative process for design of safety related parts of the control system is described in Figure 3 in EN ISO 13849-1:2008. An equivalent alternative, IEC 61508/62061 may be used.

3.4.3.5 Conditions for triggering safety function and response times should be documented.

3.4.3.6 Determination of required PL for safety function should be executed according to Annex A of EN ISO 13849-1:2008. An equivalent alternative, IEC 61508/62061 may be used.

3.4.3.7 All aspects taken into account during the Risk Assessment process should be documented according to requirements given in EN ISO 12100:2012 6.4 and 7. All results of safety functions analysis should be highlighted in the risk assessment document.

3.4.3.8 Safe state for the lifting appliance should be defined by risk assessment performed during design stage.

3.4.3.9 Hardware In Loop, HIL testing is recommended as a tool for enhancing the quality of testing. Simplified method of simulation shall be considered as sufficient.

3.4.3.10 HIL tests may be performed internally by the manufacturer, however if such tests are performed internally, the test program and outcome from HIL testing shall be documented and submitted for 3rd party

verification.

3.4.3.11 HIL tests should be performed once the control system and software installations are complete and require no further changes. All modifications to the control system done after HIL tests shall be documented and archived. If changes are made after HIL tests, possible deviations between state after changes and HIL tests outcome shall be evaluated and documented.

3.4.3.12 Manufacturer shall list all possible reasons to design for auto-stop/shut-down or continue operation of the lifting appliance or its components and document this evaluation for 3rd party verification.

3.4.3.13 Relevant operational conditions and lifting phases as indicated in [1.9.3] should be considered in the risk assessment.

3.4.3.14 Redundancy of the control system functions, if implemented, should be achieved by physical duplication of critical components to ensure fail-safe operation of the functions.

3.4.3.15 It is recommended that functions indicated in Table 3-6, if installed on the lifting appliance, have redundancy.

**Guidance note:**

Some lifting appliances will not be equipped with AHC thus MRU will not be present.

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3.4.3.16 Deviation detection between redundant components should be implemented. Action after detecting deviation should be risk assessed and documented by the manufacturer. As a minimum an audio and visual alarm should be issued to warn operator. Operator should have the option to choose which of the redundant components to select as trusted input to the control system.

<b>Table 3-6 Functions recommended to be redundant as minimum</b>	
<i>No</i>	<i>Title</i>
1	MRU measurements for AHC function
2	Hook position measurements
3	Load measurement
4	Movement limiters (up, down)
5	Sensors which cause stopping / shutting down HPU. For instance, but not limited to: low level switch, high temp of electric motor etc.
6	Main/ knuckle boom angle measurement
7	Slewing angle
8	Sensors and actuators to trigger AOPS, if present

3.4.3.17 Parts of the software which contain safety functionality and interaction with other parts of the system shall be documented. Each safety function should be described separately, and shall contain conditions for activation and interaction with other parts of the system. “Copy-paste” from the program and set point values should also be included. However block diagrams or equivalent information presenting actions and relations between variables in the program will normally be sufficient.

3.4.3.18 Hardware and software should be verified and validated in accordance with EN ISO 13849-1 or IEC 61508/62061.

3.4.3.19 Modifications to software shall be traceable. The Manufacturer shall inform and document changes and scope of changes. Responsibility to follow up should be on the owner carrying out maintenance, upgrades and repairs.

### 3.5 Technical requirements for control / power systems

#### 3.5.1 General

3.5.1.1 This section provides technical requirements with respect to systems and related equipment.

3.5.1.2 Override functions should be limited by a timer; e.g. after a specified period (recommended 15min), an override function should be disabled. An operator should not be able to adjust the time value for activation of an override function.

3.5.1.3 In general it is recommended to place transformers on all power feeds, between remote I/O cabinets and use optic fibre for control system and other communication devices to prevent earth faults.

3.5.1.4 Subsea lifting appliances shall be equipped with mode selector enabling/disabling safety systems according to positioning of the hook.



3.5.1.5 Mode selector shall be arranged in a way that MOPS and AOPS shall be automatically available only for relevant phases of the operation. Where MOPS and AOPS are not recommended, those functions shall be automatically blocked - see [Table 3-7](#).

<b>Table 3-7 Safety Systems in different modes of operation</b>		
<i>Operation phase (mode, position of the hook)</i>	<i>Recommended safety function to be available</i>	<i>Comment</i>
Sea Sector – above the sea	Normally MOPS, EM-CY STOP, AOPS, see comment.	Not covered by this RP, see DNV STC 2.22
Sea Sector – subsea	MOPS EM-CY STOP (Risk Assessment shall reveal relevant category according to EN ISO 13850 see <a href="#">[3.5.3.1]</a> ) AOPS, if installed	
Deck lift (over own deck)	Normally EM-CY STOP, see comment.	Not covered by this RP, see DNV STC 2.22
Personnel lift	Normally EM-CY STOP, see comment.	Not covered by this RP, see DNV STC 2.22
Harbour mode	Normally EM-CY STOP, see comment.	Not covered by this RP, see DNV STC 2.22

### 3.5.2 Emergency operation

3.5.2.1 Emergency operation system should be activated within 120sec from failure of the main power/control system.

**Guidance note:**

General recommendation is that emergency power shall be provided through the slip ring unit. In case of slip ring failure, a cable shall be considered as a secondary means to secure the load and to operate lifting appliance to the safe position - see [\[3.2.6.4\]](#).

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3.5.2.2 Emergency operation activation including control of the emergency pump shall take place from the emergency operation station(s). All necessary valves, switches and indications should be clearly marked and reachable from that stand.

3.5.2.3 A single person shall be able to prepare the system for and control the lifting appliance during emergency operations. However if there is more than one emergency operation stand and the lifting appliance needs to be operated by more than one person, permanent communication equipment shall be available to coordinate operation in an effective manner.

3.5.2.4 Communication routines (as indicated in [\[3.5.2.3\]](#)) and dedicated equipment shall be easily available from control stands (permanently installed) and marked for their purpose.

3.5.2.5 Communication routines and equipment tests shall be included in the emergency operation tests during final testing on-board the vessel.

3.5.2.6 The main emergency operation station should be located in such way that all movements of the lifting appliance can be observed by the station operator. However, if that is not possible due to special design considerations, a permanent communication stand shall be located and installed where observation of all lifting appliance movements is possible. Communication shall be as described in [\[3.5.2.3\]](#).

3.5.2.7 The minimum emergency operation speeds shall not be less than 10% of the minimum required speeds. Only one function may be operated at a time. Speed shall be measured during movement (i.e. not from stationary) over a distance equivalent to 10% of the total operating range of that function (angle or length). Speeds shall be measured in both directions. An average value shall be considered as final measure. In addition following conditions shall be applied:

- Hoisting/Lowering measured with SWL on the hook.
- Slewing measured with empty hook, main boom 45°.
- Luffing measured with SWL on the hook starting from largest outreach.
- Folding function measured with SWL on the hook starting from 45° position, main boom 45°.

3.5.2.8 The emergency operation control devices shall be of hold-to-run type, and shall be clearly and permanently marked for their purpose.

### 3.5.3 Emergency stop

3.5.3.1 Risk Assessment shall document which of the emergency stop categories according to EN ISO 13850

shall be considered for a given lifting appliance.

3.5.3.2 Emergency stop loop shall be designed with double loop and monitored, abnormalities shall be detected. Audio and visual alarm shall be provided.

### 3.5.4 Main logic unit

3.5.4.1 When safety functions are implemented into Main Logic Unit CPU and I/O cards, those components should be fail safe. Performance Level of those components shall be equal to or better than Required Performance Level (PLr) for the safety function with the highest specified PLr, or equivalent, according to IEC61508/62061.

3.5.4.2 When safety functions are implemented in other components serving logic operation for the safety function, those components should be fail safe.

3.5.4.3 Fail safe components should be classified into suitable safety levels according to EN ISO 13849-1 Performance Level or IEC 62061 Safety Integrity Level.

3.5.4.4 Main logic unit should be connected to the dedicated and independent power supply circuit via a dedicated circuit breaker. Connecting other consumers to PLC power circuits is not recommended.

### 3.5.5 Alarm system

3.5.5.1 Sensors should not be used for multiple operations; i.e. in principle one sensor should be assigned to one function.

**Guidance note:**

Sensors (typically transmitters) shall measure the desired value, others (typically switch) shall act on function - starting, stopping, shutting down etc.

This principle shall not be applied to redundant sensors (encoders, load cell etc.) because failure of one will not disable function and monitoring. In terms of single failure this solution is safe.

Example: Pressure transmitter used to monitor the pressure value in the line may be used to issue an alarm, but cannot be used to control the valves.

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3.5.5.2 Alarms, when triggered, should attract the operator’s attention by means of audible and visual signals. It should be possible to reset, or mute audible signals when an alarm is acknowledged. However each new alarm shall re-trigger another audible signal.

3.5.5.3 It should not be possible to disable visual signals associated with the alarm, as long as the reason for triggering the alarm is still present.

3.5.5.4 Visual signals should not disappear automatically when the reason for triggering it has ceased. Resetting a visual alarm should be done manually (acknowledged by operator).

3.5.5.5 Cause and effect diagram for control system should be provided for 3<sup>rd</sup> party verification.

3.5.5.6 A list of items causing shutdowns should be indicated in the cause and effect diagram.

3.5.5.7 A list of recommended alarms and monitoring points for subsea lifting appliances are presented in [Table 3-8](#).

<b>Table 3-8 Recommended minimum system alarm and monitoring points</b>			
<i>Event</i>	<i>Additional features</i>	<i>Alarm</i>	<i>Auto-stop/shutdown</i>
Ship/Rig MSB Common Alarm		R	
Distribution Board General Alarm		R	
UPS Common Alarm		R	
Emergency stop (location)	loop monitoring	R	shutdown
Overrides	timer for auto cancellation	R	
Control lever error		R	
Load 90% of rated capacity (platform curve) / overturning moment		R	
Overload 110% of rated capacity (platform curve) / overturning moment	movement possible only to favourable position	R	
Overload Protection systems (MOPS, AOPS, rated capacity limiter, over-moment protection)		activation alarm system failure alarm	

<b>Table 3-8 Recommended minimum system alarm and monitoring points (Continued)</b>			
<i>Event</i>	<i>Additional features</i>	<i>Alarm</i>	<i>Auto-stop/shutdown</i>
Speed	constant monitoring and indication		
Over speed		R	
Over acceleration		R	
Unexpected movement		R	
Communication error		R	
Boom, knuckle boom angle	constant monitoring and indication	limit switches activation alarm (max, min angle)	
Encoder error (or equivalent movement indicators)		R	
Motor controllers error		R	
Logic Unit Alarm		R	
Logic Unit I/O Alarm		R	
Internal Software Alarm		R	
HPU Tank Level	constant monitoring (L and LL switches)		
HPU Tank Temp	constant monitoring and indication		
Main pump, pump's motor Alarms		breaker trip temp alarm	
Filter Clogged		R	
Overturning moment high		R	
Hook position (high, low)	constant monitoring and indication, compensation for layers on the drum	limit switches activation alarm (max, min)	
Boom position (upper, lower)	constant monitoring and indication	limit switches activation alarm (max, min)	
Constant Tension	activation indication		
Slack wire detection (physical detection or view from camera)		R	
Fire/Gas Alarm		R	
Boom tip acceleration	constant monitoring and indication		
AHC - heating of steel wire rope or sheave block		R	
AHC bending cycles	counter		
Power loss to essential consumers (individually) see <a href="#">Table 3-1</a>		R	
Hoist brakes	monitoring of brake position (opened, closed) primary and secondary	R (Unintended activation / deactivation)	
Personnel lift	activation indication, monitoring of brake position (opened, closed)		
Emergency lowering	activation indication		
Emergency operation	activation indication		
HPU Pump pressure	for multi-pump application, pressure monitoring on each high pressure line for each pump	R	
Note: R – Recommended Some of the components/measurements may not be installed on every lifting appliance (might not be applicable). However if a component is present (measurement available) it is recommended that it is installed according to this table.			



### 3.5.6 Interfaces

#### 3.5.6.1 Interface between lifting appliance and vessel.

<i>Signal</i>	<i>Digital/Analogue</i>	<i>From LA</i>	<i>To LA</i>
DP Failure (common alarm)	DI		R
PMS (request, permitted, running)	DO/DI/DO	X	
ROV heading of ROV	AI		RA
ROV altitude/depth	AI		RA
ROV video signal	AI		RA
ROV Id	N/A		RA
HIPAP hook position	AI		RA

*Note:*  
 Information mentioned in the table might be provided in alternative way e.g. via communication protocol TCP/IP or other.

R – Recommended to have in the cabin  
 RA – Risk assessed if needed in the cabin  
 X – Functionality in the control system  
 LA – Lifting appliance  
 AI – Analogue Input  
 AO – Analogue Output  
 DI – Digital Input  
 DO – Digital Output

### 3.5.7 Overload protection systems

3.5.7.1 This RP does not require the installation of AOPS by default. Such requirement should result from a Risk Assessment and/or otherwise be specified by the user of the lifting appliance. However, if installed, it should as a minimum fulfil requirements given in DNV Standard for Certification No. 2.22 *Lifting Appliances*. Other standards may be considered relevant from case to case.

3.5.7.2 When evaluating installation of AOPS as a safety barrier against overload, the size of the crane compared to the size of the vessel should be considered. Smaller cranes lifting lighter loads are less likely to pose a significant risk to the vessel, e.g. capsizing – in such cases significant overload is more likely to result in damage to the crane itself. On the other hand, cranes capable of handling significant loads, compared to the size of the vessel, in first instance represent greater risks to the vessel.

3.5.7.3 The installation of MOPS is recommended. This function should as a minimum fulfil requirements given in DNV Standard for Certification No. 2.22 *Lifting Appliances*.

3.5.7.4 The MOPS button shall be installed only at the main control station of the lifting appliance and only at the left hand side of the operator (opposite the hand controlling the hoisting movement).

3.5.7.5 MOPS shall be hardwired and shall not be installed on any wireless remote controllers, regardless of the performance level of the safety measures provided. Hence, remote controls if provided, may be used to perform operations over own deck or during harbour mode only, i.e. where MOPS is not required.

### 3.5.8 Operator screen

3.5.8.1 Main page of the screen should as a minimum be equipped with information according to [Table 3-10](#):

<i>No</i>	<i>Element</i>
1	Interactive Load chart (responding to present position, mode and load)
2	Actual load, DAF, 90% and 110% alarms for the load
3	Information from Load Limiting System – warnings on 90% capacity with respect to the movements which will be blocked
4	Information about last three active alarms as a clearly visible text
5	Complete information about position of the hook

**Guidance note:**

Information does not need to be presented as text, it may be a blinking icon or other solutions according to available technology/design.

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### 3.5.9 Logging system

3.5.9.1 Recommendations presented in [3.5.9] are meant for subsea cranes.

3.5.9.2 The lifting appliance should be equipped with a data logging system. Data should be readily available for reference by the users of the lifting appliance.

3.5.9.3 Items which are recommended to be recorded, as a minimum, are listed in Table 3-11.

No	Element
1	Alarms, Warnings
2	Actions taken by crane operator
3	Load values, load chart (relevant 'load chart' which was selected for the operation. It is recommended that it shall contain info about DAF, de-rating, mode selected (platform lift, sea lift, harbour lift etc...))
4	Environmental conditions
5	Status of the crane (mode selected)
6	Overrides
7	Activation of safety functions
8	Load limiting system activation (blocking the movement) as event

3.5.9.4 Each event should include information about date and time of occurrence, date and time of acknowledgement and date and time of cancellation.

3.5.9.5 Alarms, warnings, overrides, environmental conditions, selected modes and activation of safety functions should be documented by internal printer. Depending on the design /layout, the printer may be located in the crane cabin or in vessels' office.

3.5.9.6 It should be possible to print a complete historical data log for a specific period of time, as defined by the user. Any modifications, changes, deletions, etc. to the file shall also be logged.

### 3.6 Documentation

#### 3.6.1 Design and design verification

3.6.1.1 Documentation shall be submitted to a 3<sup>rd</sup> party, as recommended in Table 3-12, if applicable for the lifting appliance.

3.6.1.2 Documentation mentioned in Table 3-12 should be subject to 3<sup>rd</sup> party verification, if such verification is requested by final user of the equipment.

3.6.1.3 Documentation mentioned in Table 3-12 should be prepared and submitted for each individual lifting appliance subjected to verification.

3.6.1.4 Risk Assessment and hazard identification should be performed prior to the design, to understand the required safety level and potential hazards.

3.6.1.5 Operational conditions, external operational risks and contingency plans shall be project specific, evaluated and established, agreed with owner of the installation and documented prior to the design. Normally manufacturer of the equipment shall have a leading role, in terms of establishing all necessary information and implementing corrective measures into the design, if necessary.

3.6.1.6 The design schedule should be sufficient to perform the design according to the recommendations in [3.4.1.3]; such input into the planning phase is considered crucial. The provision of warnings, instructions to operators and maintenance procedures as a substitute for inherently safe design practises and protective measures should be avoided.

No	Title
1	Risk Assessment see [3.4]
2	Cause Effect diagram see [3.5.5.5]
3	FMECA [3.4.2.7] to [3.4.2.8]
4	Safety Functions evaluation see [3.4]
5	Safety of the Slip ring see [3.2.6.3] and [3.2.6.4]
6	Evaluation of measures against contamination in hydraulic system see [3.3.2.12]
7	Software evaluation see [3.4.3.17] to [3.4.3.19]
8	Alarm list see [3.5.5]

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<i>No</i>	<i>Title</i>
9	Short circuit calculations see <a href="#">[3.2]</a>
10	Detailed technical safety evaluation of AHC (FMECA or equivalent)
11	General and detailed technical description of CS (incl. control loop diagrams and calculations).
12	Technical drawings (el. Diagrams, hydr. diagrams)
13	User, Service and maintenance manuals

## 4 Fabrication, inspection, certification and maintenance

### 4.1 Introduction

This chapter provides recommendations and guidelines for fabrication, maintenance, inspection and certification of subsea lifting appliances and equipment.

### 4.2 Fabrication

#### 4.2.1 Main principles

4.2.1.1 This section covers fabrication of new lifting appliances and related equipment. To assure satisfactory quality a risk assessment of the fabrication process should be carried out. The focus should be on the materials, fabrication procedures, required supervision and survey.

#### 4.2.2 Materials and fabrication

4.2.2.1 The requirements for materials and fabrication should be in accordance with a recognised standard.

**Guidance note:**

DNV Standard for Certification No. 2.22 *Lifting Appliances* or equivalent can be used.

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4.2.2.2 To assure satisfactory quality a risk assessment of the fabrication process should be carried out. The focus should be on the materials, fabrication procedures, required supervision and survey.

4.2.2.3 Traceability of material and components, etc. shall be in accordance with a recognised standard.

#### 4.2.3 Fabrication record - Manufacturing record book – MRB

4.2.3.1 Comprehensive fabrication records shall be maintained by the manufacturer in a traceable manner and be available for review. The following particulars shall be included, as applicable:

- a) manufacturer's statement of compliance
- b) reference to design specifications and drawings
- c) copy of design verification statement / report
- d) location of materials and indication of respective material certificates
- e) welding procedure specifications, WPS
- f) welding qualification test records, WPQ
- g) welders' qualifications certificates
- h) location of welds indicating where the particular welding procedures have been used
- i) heat treatment records
- j) location of non-destructive testing indicating where the particular NDT method has been used and its record
- k) certificates of loose gear and equipment
- l) load, pressure and functional test reports
- m) dimension control record
- n) flatness measurement test records
- o) slew bearing flatness, roundness measurement report, if done
- p) surface condition reports
- q) pressure test records
- r) list of instrumentation and electrical component
- s) instrumentation test records
- t) noise test records
- u) electrical test records
- v) communication test records
- w) lubrication reports and lubrication sampling test records
- x) surface corrosion protections and preservation records
- y) painting reports
- z) as-built part numbers and revisions
- aa) as-built drawings, if released by the manufacturer

ab) padeye and rigging, if available.

### **4.3 Maintenance, inspection and certification during operation**

#### **4.3.1 Introduction**

4.3.1.1 This section covers operational maintenance, inspection and certification of subsea lifting appliances and equipment. Guidance in terms of appropriate inspections following failures and repairs is also provided.

#### **4.3.2 Maintenance**

4.3.2.1 Maintenance should be carried out in accordance with the manufacturer's recommendations and latest edition of ISO 12480-1 10.5.

4.3.2.2 If used, other recognised standards should be individually evaluated by the owner / manufacturer.

4.3.2.3 In addition, applicable requirements from the classification society in question shall be fulfilled.

4.3.2.4 Systems protecting against corrosion and galvanic corrosion should be maintained and renewed as necessary during the lifetime of the lifting appliance. Coating systems, and other suitable methods / systems, e.g. anodes, galvanic protection, anti-corrosion systems, systems for desalination, etc. should be maintained and renewed as deemed necessary.

4.3.2.5 The system for lubrication of the lifting appliance should also be maintained and renewed as necessary during its lifetime.

4.3.2.6 If a lifting appliance is expected to be inoperative for extended periods of time, preservation should be carried out in accordance with the manufacturer's recommendation, requirements of the applicable classification society and certifying authority.

4.3.2.7 A documented planned maintenance system shall be provided for the subsea lifting appliance according to ISO 12480-1.

4.3.2.8 The documented maintenance system should as a minimum be based on the manufacturer's recommendations and applicable regulations.

4.3.2.9 Critical equipment and technical systems experiencing sudden operational failure which may result in a hazardous situation, shall be identified and records should be maintained in the maintenance system plan or separately electronically or on paper.

##### **Guidance note:**

Typical critical equipment include but are not limited to brakes, slewing ring, slip ring, load cells, primary load bearing parts etc.

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4.3.2.10 Intervals of inspections and maintenance should be defined by the manufacturer.

4.3.2.11 Suitable methods should be considered in developing the maintenance system plan/schedule, e.g. use of risk assessment. The planned maintenance system should preferably be a computer based system, integrated with the planned maintenance system for the vessel in question.

#### **4.3.3 Inspections**

4.3.3.1 Regular inspections of subsea lifting appliances shall be carried out in accordance with the manufacturer's recommendations and latest edition of ISO 9927-1. Inspections and inspection intervals should be incorporated in the planned maintenance system. Records for the inspections are to be filed, see ISO 9927-1. If other recognised standards are applied, they should be evaluated on a case by case basis. In addition applicable requirements from the class society in question should be fulfilled.

#### **4.3.4 Failure of equipment**

4.3.4.1 In the event of equipment failure, a thorough inspection should be carried out. The operation should be deferred until it is confirmed that the operation can be continued safely. The decision to continue, to repair etc., should be assessed thoroughly and documented. A recognised method should be considered, e.g. risk assessment or similar.

4.3.4.2 The Certifying Authority should be consulted before any repairs and/or significant modifications are carried out on primary load bearing elements; repair methods, level of surveillance and/or re-testing and re-certification should be agreed between all parties. Where major repairs or modifications may affect the vessel integrity or stability, the Classification society shall be consulted.

### 4.3.5 Repair and replacement of components

4.3.5.1 In the event of component repair or replacement, appropriate methods e.g. inspection, consulting the manufacturer of the lifting appliance, use competent repair yard/workshop, etc. shall be conducted to determine acceptable extent of repair and testing.

4.3.5.2 Repairs shall be performed in accordance with quality and acceptance criteria provided in a recognised standard.

**Guidance note:**

Acceptance criteria and quality requirements for repairs can be found in latest revision of IACS Rec.No.47 *Shipbuilding and Repair Quality Standard*

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4.3.5.3 Repairs on subsea lifting appliances shall be carried out in accordance with manufacturer's guidance and possible Certifying Authority requirements - see ISO 12480-1 10.5.4. The extent and nature of any necessary repairs, surveillance activities and / or recertification shall be agreed by all parties. Where major repairs or modifications may affect the vessel integrity or stability, the Classification society shall be consulted.

4.3.5.4 Components and spare parts being replaced should conform to the Certifying Authority requirements and manufacturer's specification or equivalent standard. If certified components are to be replaced, only components with the same valid certification and documentation as for the original component shall be used, see ISO 12480-1 10.5.3.

4.3.5.5 Spare parts should be of equal or greater quality than the original components.

4.3.5.6 Components and spare parts should be delivered with a declaration stating that the component, or spare part, is free of asbestos, see [IACS UI SC249](#), *Interpretation of SOLAS II-1, Regulation 3-5 and MSC.1Circ.1379*.

### 4.3.6 Lifetime

4.3.6.1 The design lifetime of a subsea lifting appliances should be clearly defined. Determination of the design life time should be based on a comprehensive and specific assessment, taking into account hours of operation and maintenance, see latest edition of ISO 12482-1 or services like DNV "Crane Life Extension Program".

### 4.3.7 Condition monitoring in service

4.3.7.1 Condition monitoring of subsea lifting appliances should be considered. Special attention and focus has to be paid to components and machinery that are used more frequently. Some examples of parameters for condition monitoring are given below:

- a) Means for online checking of oil quality.
- b) Vibrations sensors.
- c) Temperature sensors / IR sensor for measuring temperature / overheating, e.g. on machinery items, sheaves, wires, fibre ropes etc.
- d) Strain gauges.

4.3.7.2 Equipment used for recording parameters used in condition monitoring of a subsea lifting appliance should preferably be chosen in consultation with the manufacturer. Furthermore, the classification society / Certifying Authority in question should be informed and consulted.

4.3.7.3 Equipment used to log and evaluate the service life of a lifting appliance should record appropriate and essential data. Such data may be used to support a more accurate assessment of the remaining service life of a lifting appliance and its components.

4.3.7.4 Selection of parameters used for condition monitoring depends on the type of the subsea lifting appliance. Typical parameters may include but are not limited to, load magnitude, load cycles, cyclic bend over sheaves, speed and distance registration and service dates for the lifting appliance and for individual components, see [\[3.5.9\]](#).

### 4.3.8 Condition monitoring for life extension

4.3.8.1 Condition monitoring for life extension should be carried out in accordance with a recognised standard. The inspection should be performed in accordance with latest edition of ISO 12482-1 or services like DNV "Crane Life Extension Program", or similar, reference is also made to [\[4.3.7.1\]](#) above.

4.3.8.2 If another recognised standard or service is used, it should be individually evaluated by the owner. The

result of the evaluation should be subject to review / acceptance by that Certifying Authority.

## 4.4 Steel wire rope

### 4.4.1 General

4.4.1.1 Steel wire ropes shall fulfil the design requirements provided in [Sec.2](#). This also applies when the rope is replaced.

### 4.4.2 Replacement, care, maintenance

4.4.2.1 Inspection of steel wire ropes shall be carried out in accordance with manufacturer's recommendations and a recognised standard.

**Guidance note:**

For inspection, replacement, care and maintenance of steel wire ropes, ISO 4309 *Cranes - Wire ropes - Care maintenance, Inspection and Discard*, should be used. In addition IMCA M 194 - *Wire Rope Integrity Management for Vessels in the Offshore Industry* or equivalent guidance standard should be used for wire ropes used subsea.

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4.4.2.2 When determining the condition of a wire rope all operational, technical, environmental factors and parameters shall be considered. These may for example be:

- a) No. of years in operation.
- b) Type of operation.
- c) No. of running hours of operation.
- d) Load cycles, wire load.
- e) Depth of operation.
- f) Type of, and arrangement for lubrication.
- g) Environmental conditions.
- h) Use of heave compensation.
- i) Overload cases (if applicable).
- j) Corrosion.
- k) Wear.
- l) Mechanical damage.

4.4.2.3 Suitable NDE methods should be used. In addition visual inspections, dimensional checks of the steel wire diameter and if possible, core checks are to be undertaken.

4.4.2.4 Any specialised NDE methods, equipment and personnel used shall be done so on a case by case basis.

**Guidance note:**

Reference to IMCA M197 - *Guidance on Non Destructive Examination (NDE) by means of Magnetic Rope Testing, or ultrasonic testing*.

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4.4.2.5 Destructive testing according to recognised standards or methods may also be carried out.

4.4.2.6 If a steel wire sample is extracted for testing, the sample shall be taken from a representative location along the wire rope, with due consideration to type of use, failure modes, wear etc.

**Guidance note:**

For multi fall lifting appliances where the wire end is connected to the structure of the lifting appliance, a test wire fitted on the lower block might be used for monitoring of corrosion on the wire.

For one fall lifting appliances, and multi fall lifting appliances where the wire end is connected to the block, a wire sample may be taken from the end for indication of the extent of corrosion.

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4.4.2.7 If a tension test is performed on a sample, the test result cannot be used as proof of the residual strength / condition of the remaining wire.

4.4.2.8 Corrosion problems can be worse after operations in deep water, due to ingress of salt water caused by high water pressure.

4.4.2.9 Discard criteria for steel wire ropes see - ISO 4309:2010 and IMCA M 194 can be used.

4.4.2.10 In order to improve the plan maintenance system for the steel wire rope, the owner / operator should consider carrying out further investigation of a discarded wire when practical.

#### 4.4.3 Condition monitoring of wire rope

Condition monitoring of wire rope should be performed in accordance with a recognised standard. The inspection should be done in accordance with the latest edition of ISO 12482-1. Other methods or services like the method for condition monitoring of wire rope as described below may be considered.

4.4.3.1 Subsea operations can require significant rope lengths, further, rope tend to experience uneven wear. It is therefore important to monitor the use and wear of the steel wire rope, to assess its condition and to assure safe operations.

**Guidance note:**

There is experience showing that steel wire ropes have been worn out after limited numbers of lifts only, due to the amount of load cycles caused by use of active heave compensation during operation.

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4.4.3.2 Crushing of the inner wire rope layers on winch drums shall be considered, with special attention to the cross-over zones. It is therefore of vital importance that the condition of the entire wire rope length, taking part in a subsea lift, is considered checked before the lift is carried out.

4.4.3.3 A wire rope heat and load monitoring system may be installed to provide more accurate information. Altering the section of deployed wire rope regularly should be considered, to reduce the number of bending cycles on a specific / limited section of rope.

4.4.3.4 Wire ropes should be inspected at regular intervals in accordance with recognised standards, e.g. ISO 4309.

4.4.3.5 Standards and methods used to predict an appropriate time to renew a given wire rope, ensuring an adequate level of safety, have been developed. The following principle can be used for steel wire ropes.

**Guidance note:**

Relevant standards are: ISO 12482-1, *Cranes-condition monitoring part 1*, as well as EN 13001-3-2 *Cranes-General design – Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*.

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#### 4.4.4 Method for condition monitoring of wire rope

The following describes a method for monitoring wire ropes during all lifting operations. Condition monitoring can be used to predict the remaining safe working life and to better predict when direct monitoring (e.g. visual inspection and NDE) is necessary.

4.4.4.1 In order to have control of the condition and integrity of a rope, the magnitude of the load, corrosion and the load cycles per unit length of the wire rope, need to be monitored. The fatigue point of the rope appears when the wire rope passes a rope sheave or spooling on drum.

4.4.4.2 A system can be implemented to record the following data (per unit length):

- 1) Continuous monitoring of wire load.
- 2) Change in load.
- 3) Operation time.
- 4) Bending cycle, normal/reversed.
- 5) Load cycles per unit length.

The data are used to calculate the remaining working cycles per rope unit length. The used rope force spectrum factor  $k$  is calculated per unit length by:

$$k = \sum \left( \frac{F_{cycle}}{F_{R0}} \right)^3 \times \frac{W_{cycle}}{W_{tot}}$$

Where:

- $F_{cycle}$  is the operational rope force
- $F_{R0}$  is the design rope capacity
- $W_{cycle}$  is the sum of load cycle corresponding to  $F_{cycle}$
- $W_{tot}$  is the total amount of load cycles.



The remaining Safe Working Life of the wire rope shall be checked by the following equation:

$$k \times W_{tot} \leq W_{design}$$

Where:

$W_{design}$  is the total number of bends at  $F_{R0}$ .

$W_{design}$  depends on rope design and dimension. The wire rope manufacturer should have the necessary experience with this value, based on testing and experience.

In addition, sheave diameter and lubrication shall be considered / compensated for.

Reversed bending need to be specially considered.

4.4.4.3 The condition monitoring system can be included in computer based systems, which will automatically inform the owner of the condition of the wire rope. Measures can be taken to extend the life of the rope by changing operation of the wire rope.

4.4.4.4 This RP proposes a methodology to perform condition monitoring of wire rope. However, adequate systems may be used. The system documentation should be forwarded to the Certifying Authority for review / acceptance.

## 4.5 Fibre rope

### 4.5.1 General

4.5.1.1 Fibre ropes shall fulfil the design requirements provided in [Sec.2](#). This also applies when the rope is replaced.

### 4.5.2 Replacement, care and maintenance

4.5.2.1 Inspection and maintenance of fibre ropes shall be performed in accordance with manufacturer's recommendations and validated methods that are applicable to the rope and its application.

#### Guidance note:

The inspection can be based on the latest edition of ISO 9554 *Fibre Ropes - General specification*, DNV-RP-E304 *Damage assessment of fibre ropes for offshore mooring*, or CI 2001-04, *Fibre Rope - Inspection and Retirement Criteria*.

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4.5.2.2 If other methods are used, these should be validated on a case by case basis, by the owner / manufacturer.

4.5.2.3 The condition of the fibre rope should be determined by monitoring the following parameters. Records of this data should be kept and be available for review.

- a) number of years in operation
- b) type of operation
- c) environmental conditions
- d) running hours of operation
- e) load cycles
- f) rope load
- g) use of AHC
- h) use of PHC
- i) number of bend cycles, if applicable
- j) overload cases (if applicable)
- k) external and internal wear
- l) condition of splice / fibre rope termination
- m) abrasion, cuts, filing / chafes and mechanical damage
- n) damage from exposure to sunlight, heat, moisture, chemicals etc.

4.5.2.4 Further, data from relevant sensors, if fitted, should be available during inspection of the fibre rope in question, e.g. IR, temperature sensors, any use of AHC, etc.

4.5.2.5 In order to assess the remaining strength of the fibre rope, destructive testing can be carried out

according to a recognised standard. If a fibre rope sample is cut off for testing, the sample should be taken from a representative section of the rope.

**Guidance note:**

Recommendations concerning destructive testing of fibre ropes will be provided in DNV-RP-E304 *Condition Management of Offshore Fibre Ropes*.

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**Guidance note:**

Guidelines for destructive testing of fibre ropes see, ISO 9554 *Fibre Ropes - General specification* and latest edition of CI 2001-04, *Fibre Rope – Inspection and Retirement Criteria*.

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### 4.5.3 Shape change – Guidelines

4.5.3.1 Fibre ropes are subject to shape change as a result of load and/or contact surfaces. The shape change may in some cases affect the performance of the rope, see [2.8.6]

### 4.5.4 Failure mechanism – Guidelines for inspection

4.5.4.1 The primary failure mechanism is internal abrasion between the strands, see [2.8.9]

### 4.5.5 Repair

4.5.5.1 Repair of load carrying fibre ropes should only be carried out by personnel authorised by the fibre rope manufacturer. The methods should be duly qualified.

**Guidance note:**

Requirements for repair and splicing of fibre ropes is given in latest edition of DNV-OS-E303 Offshore fibre ropes

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4.5.5.2 Splicing of the fibre rope for subsea lifting should only be carried out by personnel authorised by the fibre rope manufacturer. Load test after splicing will normally be required.

## 4.6 Sheaves

### 4.6.1 General

4.6.1.1 Regular inspections of sheaves shall be performed in accordance with latest edition of ISO 9927-1 and manufacturer's recommendation. Inspections of sheaves for fibre rope should also be carried out in accordance with latest edition of ISO 9554. Inspections should be incorporated into the planned maintenance system. Records of the inspections shall be kept.

4.6.1.2 If other recognised standards are used, they should be evaluated by the owner / manufacturer on a case by case basis. Regular sheave inspections should include, but not be limited to:

- a) Visual inspection of sheave and groove.
- b) Measurement of sheave groove with specialized templates in accordance with acceptance criteria from maker.
- c) NDE testing of sheaves, normally magnetic particle testing. Other methods, e.g. eddy current may be considered. For non-magnetic stainless steel dye penetrant, ultra sound or x-ray may be used.
- d) Regular testing of the central shaft by acceptable methods, e.g. dismantling and NDE testing may be required and if necessary more thorough inspection methods may be required.
- e) Bearings to be tested for adequate function and distortion.

4.6.1.3 The regular inspection of a sheave arrangement, including sheaves on submerged block, should verify that adequate lubrication in all operational conditions has been satisfactory and that wear is within acceptable limits. If not, manufacturer, competent repair yard / workshop etc. should be consulted.

4.6.1.4 For areas where high temperature may arise, e.g. in bearings, sheave groove, etc. monitoring of temperature should be considered. Further the type of lubrication may be considered.

4.6.1.5 Suitable methods and systems of corrosion protection shall be provided for submerged sheave block arrangements.

4.6.1.6 Extent of repair and survey of a sheave arrangement should be agreed upon with the Classification Society / Certifying Authority. If repair of sheave grooves, bolt holes etc. are to be carried out, e.g. by fitting new layer by means of welding and machining, this shall be carried out by a qualified welder using approved welding procedures, in accordance with approved procedures for heat treatment, hardening / quenching, etc.

Methods used should be documented by mechanical testing of the final product itself, or based on a representative test previously carried out.

## 4.7 Winches for lifting

### 4.7.1 General

4.7.1.1 Regular inspections of winches shall be carried out and incorporated into the planned maintenance system. Inspections should be carried out in accordance with the latest edition of ISO 9927-1 and the manufacturer's recommendations. Applicable class requirements shall also be fulfilled. Records and results of inspections and maintenance shall be filed and available, if required for review.

4.7.1.2 If other recognised standards are to be used, they should be evaluated on a case by case basis.

4.7.1.3 The surface of the drum should be inspected every time the rope is replaced in accordance with manufacturer's recommendation. If the interval for inspection exceeds 10 years, the certifying authority in question should be consulted. In case e.g. grooved sleeves etc. are attached to the drum it should be considered to remove these during inspection.

4.7.1.4 Drums should be inspected with acceptable and suitable methods, such as visual inspection, NDE for cracks detection and thickness measurements. Acceptance criteria to be given by manufacturer, the Certifying Authority or class society in question.

4.7.1.5 Winch side flanges, stiffeners and their connections to the drum should be regularly inspected for defects and permanent deformation.

4.7.1.6 Winch gears, tooth ring, spline, tooth pinion and shaft should be inspected regularly. At major overhauls the need for more thorough inspection, dismantling etc. should be considered, depending on manufacturer's recommendation and Certifying Authority / Class requirements.

4.7.1.7 Tugger winches should be maintained and inspected in the same manner as described above.

## 4.8 Certification of lifting appliances

### 4.8.1 General

4.8.1.1 Certification of subsea lifting appliances shall be performed in accordance with a recognised standard. Validity is mentioned on the certificate and in the relevant standard and is generally taken to be maximum 5 years. Satisfactory annual and periodic inspections and completion of required planned maintenance are required to maintain validity of the Certificate.

4.8.1.2 In addition the Certification should be carried out according to relevant statutory requirements. Further the manufacturer's recommendation should also be taken into account.

4.8.1.3 For a DNV certified lifting appliance, the scope for certification shall as a minimum be as for certification of "Subsea Cranes" in the current edition of DNV Standard for Certification No.2.22 *Lifting Appliances* and DNV Rules for Ships Pt.7 Ch.1 *Fleet in service - Survey requirements for fleet in service*.

4.8.1.4 If a lifting appliance is certified by other Certifying Authority, the lifting appliance and equipment should be evaluated by the (operator) owner / manufacturer, see [1.3.1.4]. The result should be presented to the Certifying Authority for acceptance.

4.8.1.5 For fibre ropes the scope for certification shall as a minimum be as for certification in the current edition of DNV-OS-E407 *Underwater Deployment and Recovery Systems*. If other recognised standards are used, they should be evaluated on a case by case basis.

### 4.8.2 Testing of subsea lifting appliance

4.8.2.1 If an existing lifting appliance is not built and certified according to "Subsea Crane", as defined in the current edition of DNV Standard for Certification No.2.22 *Lifting Appliances*, load testing at SWL from full retrieval depth should be undertaken. The test should be witnessed by the Certifying Authority.

4.8.2.2 Prototype testing, winch to winch testing, or other methods simulating relevant load conditions and ensuring satisfactory design may be sufficient. Such agreement / arrangement should be evaluated on a case by case basis, by the Certifying Authority.

#### Guidance note:

The winch shall be confirmed to have sufficient strength to pull at SWL over the maximum length of active hoisting rope i.e. with all active rope layers on the drum.

Other methods of demonstrating satisfactory design may be records of representative lift operations, representative tests covering the lifting capacity and sufficient length of hoisting rope or pertinent calculations documenting

sufficient capacity.

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4.8.2.3 Functional testing with a representative load and depth prior to commencing a specific operation may be considered necessary. The need for such testing should be determined by means of acceptable methods, e.g. risk assessment, requirements in marine operation standard, qualification scheme and calculations. Note that such testing may be a contractual pre-requisite.

4.8.2.4 Examples of components to be given special attention should as a minimum include, control systems, control system modifications, software changes, load measuring system, steel wire / fibre rope, rope sheaves, hooks and swivels, termination of ropes, slewing ring and fasteners and winch gears.

#### **4.8.3 Certification of components, loose gear and rigging equipment.**

The certification of components and loose gear as part of a subsea lifting appliance shall be carried out or accepted by the Certifying Authority, in accordance with a recognised standard and any relevant statutory requirements.

4.8.3.1 Loose gear and rigging equipment shall be certified according to a recognised standard.

##### **Guidance note:**

For detailed requirements for certification of loose gear and rigging equipment reference is made to DNV-OS-H205 *Lifting operations*.

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## 5 Operation

### 5.1 Introduction

This section covers operational recommendations related to planning and performing subsea lifting operations.

### 5.2 Planning

#### 5.2.1 General

The general requirements for planning of marine operations are described in DNV-OS-H101 Sec.2 and for subsea lifting operations in DNV-OS-H206 Sec.2. Risk management should be considered in the planning, DNV-RP-H101 gives guidelines and recommendations for controlling risks.

Table 5-1 shows a general engineering flowchart illustrating typical steps in an engineering process.

Table 5-1	
<p>Engineering Flowchart</p> <pre>             graph TD                 A[Design brief, Regulations, Standards, Specification] --&gt; B[General SOW]                 B --&gt; C[Object particulars]                 C --&gt; D[High level Procedure (vessel/asset selection)]                 D --&gt; E[Detail SOW, Design basis]                 E --&gt; F[Analysis]                 F --&gt; G[Review against capabilities]                 G --&gt; H{Ok}                 H -- No --&gt; I[Re-design]                 I --&gt; F                 H -- Yes --&gt; J[Solvable by engineering?]                 J -- No --&gt; K[Procedures / operation limits]                 K --&gt; L{Ok}                 L --&gt; M[Review against capabilities]                 M --&gt; N{Ok}                 J -- No --&gt; M                 M -- No --&gt; I                 N --&gt; End[ ]                 style End fill:none,stroke:none             </pre>	<p>Typical project phases / steps</p> <ul style="list-style-type: none"> <li>• Initiation of project</li> <li>• Feasibility study/ concept selection</li> <li>• Clarify rules and regulations</li> <li>• Qualification of new technology?</li> <li>• Establish Design Brief</li> <li>• Establish project plan</li> <li>• HAZID</li> <li>• Basic engineering design</li> <li>• Pre-feed / Feed</li> <li>• High level procedure</li> <li>• HAZOP?</li> <li>• Detailed engineering</li> <li>• Document verification</li> <li>• HAZOP</li> <li>• Semi quantitative risk analysis</li> <li>• Implementation of HAZOP items</li> <li>• SJA</li> <li>• Construction</li> </ul>

## 5.3 Documentation

### 5.3.1 General

The lifting operation should be documented by drawings, calculations and operational procedures.

The preparations, equipment, limitations, communication, responsibilities and the lifting operations shall be well described. The drawings should clearly present, as a minimum, the relevant phases as described in section [1.9.3].

**Guidance note:**

For more details of recommended operational documentation see: DNV-OS-H101 Sec. 2 B 500, DNV-OS-H205 and DNV-OS-H206 or equivalent standard / code.

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## 5.4 Organisation

### 5.4.1 General

Organisation and responsibility of key personnel involved in subsea lifting operations shall be established and described prior to execution of the operations. Transfer of responsibility and change in communication lines shall be clearly described in the steps of the operation, see DNV-OS-H101. Sec.4 - E or equivalent standard.

## 5.5 Qualification of personnel

### 5.5.1 General

Relevant personnel shall be qualified according to operator, flag state and national legislative requirements.

**Guidance note:**

It is recommended that ISO 12480-1 *Cranes –Safe use*, NORSOK standard R-003 *Safe use of lifting equipment* or another recognised standard is applied for defining the competence requirements.

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**Guidance note:**

ROV manning level and crew qualifications should follow the requirements given in NORSOK U-102, Section 6 or another recognised standard.

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## 5.6 Environmental conditions

### 5.6.1 General

Environmental conditions are natural phenomena which contribute to structural stresses and strains, impose operational limitations/restrictions or navigational considerations. Subsea installations will normally be weather restricted operations and the planning shall include a thorough evaluation of relevant environmental conditions.

**Guidance note:**

See DNV-OS-H101 Sec.3 and DNV-OS-H206 or equivalent standards for specific guidance and recommendations.

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## 5.7 Loads and structural design

### 5.7.1 General

5.7.1.1 All loads and load effects which may influence the operational procedure or design of structures during the subsea lifting operation shall be analysed and considered in the planning phase.

**Guidance note:**

Requirements to loads and structural design are given in DNV-OS-H206 Sec. 3 and Sec. 5 or an equivalent standard.

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5.7.1.2 The different phases (see [1.9.3]) of the lifting operation are characterized by different forces and

effects. See [Table 5-2](#). The table is not complete so each operation needs to be considered case by case.

<b>Table 5-2 Forces and effects in different phases of a subsea lift</b>						
<i>Effect \ Phase</i>	<i>Lift from other vessel</i>	<i>Lift from same vessel</i>	<i>Over board</i>	<i>Splash Zone</i>	<i>Lowering</i>	<i>Landing</i>
Vertical loads						
Weight of object	X	X	X	X	X	X
Snap force	X			X	X	X
Vertical force due to REP motions	X		X	X	X	X
Buoyancy Force				X	X	X
Wave excitation Force				X		
Drag force from moving object				X	X	X
Mass force				X	X	X
Added mass				X	X	X
Horizontal loads						
Hook off centre CoG	X	X				
Wind	X	X	X	x		
Tuggerline / Guide loads	X	X	X	X		
Lateral force due to motions in REP	X		X	X		
Current				X	X	X
Inertia force (moving object)	X	X	X	X	X	
Drag force from moving object				X	X	X
Special concerns						
Re-entry when offshore lift	X					
Wave damping Force				X		
Slamming force				X		
Moon pool operations				X		
Partly air filled object				X	X	X
Free water surface				X	X	X
Horizontal offset						X
CoB different than CoG				X	X	X
Buoyancy changes over time				X	X	
Hydrodynamic interaction	X		X	X	X	X
Skewloads	X	X	X	X	X	X
Hydrostatic Pressure				X	X	X
Pull-down				X	X	
Pull-in				X	X	
Resonance			X	X	X	X
Soil resistance / suction						X
Stability of lifted object	X	X		X	X	
Retrieval						
Water exit force				X		
Trapped Mud	X	X	X	X	X	X
Trapped Water	X	X	X	X		
X: relevant forces and effects						



## 5.7.2 Calculation of loads

5.7.2.1 Table 5-3 indicates different forces and effects to be considered for a subsea lift, including a reference to relevant DNV documents where calculation methods for these effects can be found.

Effect \ Doc	DNV-RP-H103		DNV-OS-H205	DNV-OS-H206
		Simplified		
<b>Vertical loads</b>				
Weight of object	3.2.2	4.2	3.1.1	3.3.1 / 5.3.1
Snap force		4.7		5.3.1
Vertical force due to REP motions	9.2 / 9.3	4.3.3	3.2	5.2.4
Buoyancy Force	3.2.3	4.3.6		3.3.1
Wave excitation Force	3.2.7			
Drag force from moving object	3.2.8	4.3.8		
Mass force	3.4.2	4.3.7		
Added mass	3.3	4.6.3		
<b>Horizontal loads</b>				
Hook off center COG				
Wind			3.1.3	3.3.3
Tuggerline / Guide loads			2.3.2	
Lateral forces due to REP motions				3.3.6
Current	3.2.4			3.3.3
Inertia force (moving object)	3.2.5			
Drag force from moving object	3.2.8			
<b>Special concerns</b>				
Re-entry when offshore lift				
Wave damping Force	3.2.6			
Slamming force	3.2.9	4.3.5		
Moonpool operations	3.5			
Partly air filled object	3.6.2			5.6.1.6
Free water surface	3.6.3			5.6.1.6
Horizontal offset	5.2.2			
COB different than COG	3.6			3.3.1
Buoyancy changes over time	3.4.2	4.3.6		
Hydrodynamic interaction	9.2.2			
Skewloads			3.3	
Hydrostatic Pressure				3.3.2
Pull-down				3.3.5
Pull-in				3.3.5
Resonance	5	4.3.3		5.7.1
Soil resistance / suction				7.3.2
Stability of lifted object	3.6			
<b>Retrieval</b>				
Water exit force	3.2.11			
Entrapped Mud				3.3.8
Entrapped Water				3.3.8

5.7.2.2 In order to establish the relative motion between the waves and the lifted object, it is necessary to determine the motions of the REP. See [2.4.3.7]. Reference is also made to DNV-OS-H102, Sec.4B, DNV-OS-H206 Sec.3.2 and DNV-RP-H103.



### 5.7.3 Structural analysis and capacity checks

5.7.3.1 Structural analyses for the lifted object shall demonstrate sufficient strength, including relevant limit state acceptance criteria.

**Guidance note:**

For a detailed methodology see DNV-OS-H102 and DNV-OS-H206 Sec.3 or other relevant standards.

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### 5.7.4 Stability of lifted object

5.7.4.1 Situations where stability of a lifted object during lifting operations is particularly relevant include:

- Tilting of partly air-filled objects during lowering.
- Effects of free water surface inside the object.
- CoG located above lifting points.
- Difference between CoG and CoB forces acting on the object.

**Guidance note:**

For further details on stability of the lifted object see DNV-RP-H103 *Modelling and Analysis of Marine Operations* or other relevant standard. For a detailed methodology see DNV-OS-H206.

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## 5.8 Qualification of vessel and lifting appliance

### 5.8.1 General

5.8.1.1 The lifting appliances and vessel should comply with the requirements in DNV-OS-H205 Sec.2.2.

### 5.8.2 Positioning capability

5.8.2.1 Positioning of a vessel is an important aspect of subsea lifting operations.

**Guidance note:**

Most lifting operations are performed using vessels with adequate Dynamic Positioning. Recommendations for selection of DP-class, DP-capability, reference system and operation guidance can be found in DNV-RP-E307 *Dynamic Positioning Systems - Operation guidance*.

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### 5.8.3 Stability

5.8.3.1 Adequate stability and reserve buoyancy shall be ensured for all vessels and floating objects during all stages of a lifting operation, including relevant contingency scenarios.

**Guidance note:**

See DNV-OS-H101 Sec.5 for general stability requirements. See also DNV-RP-H104 for guidance on managing risks associated with Ballasting, Stability and Water Tight Integrity during planning and execution of the operation.

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## 5.9 Operations

### 5.9.1 Introduction

5.9.1.1 DNV-OS-H206 gives specific guidance and recommendations for load-out, transport and installation of subsea objects. Operational risk should be evaluated and handled in a systematic way (see DNV-OS-H101, Section 2C).

5.9.1.2 Objects with lower weights (typically < 50 tonnes) and larger surface areas/circumference might introduce challenges that are less common with heavier objects - the loads and load effects shall be considered specifically - this might be especially critical if lifting appliances with much higher capacities are utilised. For some objects the CoB might not coincide with the CoG. The effect of inertia forces, drag forces caused by wind / waves / current, should be evaluated for the various phases of the operation. A thorough risk assessment should be performed in order to identify risks and implement mitigation measures.

5.9.1.3 DNV-OS-H205 provides specific guidance and recommendations for Engineered onshore, inshore and offshore lifting operations. Weight limitations (upper or lower bound) are not specified herein, however, requirements in other standards and local/international regulations may be relevant and governing, for objects with lower weights (typically less than 50 tonnes) and for operations involving routine lifts.

**Guidance note:**

Engineered lifts may be planned, designed and performed according to requirements in DNV-OS-H101.

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5.9.1.4 DNV-RP-H102 gives guidelines and recommendations for removal of offshore installations. Objects that are removed will normally either be re-used or dismantled for recycling.

Pre-qualification	Feasibility/suitability studies Production and procurement
Pre-mobilization	Survey of vessels and equipment Fit-up tests of equipment Certification of equipment
Mobilization	Familiarization, briefing and training Inspection and testing
Operation	Set-up and trials Pre-survey Safe job analysis Operation criteria assessment Toolbox talk/ communication check Perform operation Monitor design parameters
Post-operation	Clean up Post-survey Reporting Experience transfer

**5.9.2 Operation of lifting appliance**

5.9.2.1 Operation of the lifting appliance shall be in accordance with the operation manual provided by the manufacturer and where applicable ISO 12480-1.

**5.9.3 Pre-lift, lift-off from deck and over-boarding**

5.9.3.1 The significant challenge during this phase is to maintain sufficient control over the horizontal motion of the object, e.g. avoid uncontrolled swinging and limit the vessel motions if applicable. If control of the load/ orientation/ position of the object are needed, considerations should be given to the following:

- a) Snap loads in the load/orientation/position device should be avoided.
- b) Contingency in case of failure of control devices should be provided.
- c) Examples of control devices can be tag lines, tugger lines, bumpers and guides.

5.9.3.2 In general the following items may be considered. The list is not exhaustive, and not all items may be relevant for all operations. Generally a specific list for the actual operation should be prepared.

- a) Any subsea release systems should be checked and function tested prior to over-boarding if possible.
- b) Any markings should be checked for suitable location, orientation and visibility for subsea application. Markings on objects should be unambiguous and should be approved/accepted by the ROV operators. ROV operators shall be familiarised with the lifting/tooling/access etc. prior to commencing the lifting operation. Buoyancy elements to be considered, e.g. for picking up from sea bed. Objects may sink into soft sea bed upon landing, alternatively e.g. concrete mats or rock dump may be used for landing or for temporary storage of the object on sea bed.
- c) Operational limits shall be clearly defined for all subsea operations. Requirements for weather forecast and monitoring are given in DNV-OS-H101 Sec.4. Effects of e.g. unexpected swell and current could be critical and the forecast and monitoring should therefore include all relevant parameters.
- d) Maintenance and historical data should be evaluated before the operation.
- e) Load indicator should be checked / calibrated.
- f) AHC should be checked / tested before subsea operation.
- g) Start of weather restricted operations is conditional on an acceptable weather forecast. Vessel heading might be into the predominant weather direction to minimise roll motions and the environmental loads (e.g. “green water”) on the vessel. Even if theoretical design suggests feasible operations, the actual and possibly deteriorating condition on deck shall be assessed prior to commencing operations and all parties must agree on the safe conditions. For details of critical design parameters, see DNV-OS-H206 Sec.2.1.
- h) Any cutting of sea fastening should be such that no/limited vertical restraint will occur during lift-off.

Height under hook should be considered including remaining sea fastening.

- i) Loose items: lifted object should be checked for loose items prior to lifting.
- j) Trial lift / inshore trials may be considered for unproven operations, equipment and systems. For lift arrangements where the crane hook height could be a limiting factor, consider performing a practice run by the crane operator with a measured rope hanging from the crane block (or by other means to represent the lift arrangement height) for visual verification whether lift is clear of all obstacles (i.e. vessel bulwarks, deck equipment, etc.).
- k) Positioning devices, transponders or e.g. light sticks on crane wire/hook or lifted object shall be considered for location of crane hook or object in the water column. For tandem lifts, means of measuring the tilt (e.g. inclinometer monitored by ROV) of the object should be provided.
- l) Roll damping - if an active or passive vessel roll damping system is used, it shall be sufficiently tested and documented. The system should not introduce any increased risk to the operation.
- m) Relevant areas shall be barriered off before the lifting operation commences. Consider position of personnel on deck, with regard to position of the load, tensioned wires etc. The operational aspects for lifting operations in air are given in DNV-OS-H205 Sec.2.3 and are normally applicable also for subsea operations. All clearances should be properly assessed for all stages of the lift.
- n) Care must be taken to centre the lifting appliance connection point over the lift rigging to avoid uncontrolled horizontal shifts of the lifted object during lift-off.
- o) Increasing the load in the lifting appliance stepwise is normally beneficial in order to control and ensure that the lift rigging arrangement is aligned properly, and ensuring that horizontal shifting of the object is minimized. To avoid any potential damage to object or vessel equipment due to shifting, bumpers, pivoting arrangements or guides might be considered. See details in DNV-OS-H205 Sec.2.3.
- p) For lifts where line of sight for the crane operator is obstructed (blind lift), adequate aids need to be implemented to ensure a safe lifting operation and good communications.
- q) Restrictions due to SIMOPS shall be clarified prior to start of operation. Any possible interference from e.g. nearby vessel(s) positioning systems/thrusters/discharges/intakes needs to be considered.
- r) Tag lines/tugger lines may be used in order to prevent horizontal/rotational motions of the lifted object during lift off from deck and for manoeuvring of object clear of transport vessel if the clearances are found to be too marginal. Consequences of snap loads must be considered in tag lines/tugger lines, and also to be considered with respect to barrier philosophy. Release of tag lines /tugger lines might be done by e.g. cutting with ROV, using slip through tag line(s). See also [2.10].
- s) Guide wires might be used for guiding/rotational control during lowering or hoisting.
- t) Safe over-boarding and hoisting/lowering location shall allow sufficient distance from subsea assets to avoid potential for dropped objects hitting subsea assets. See DNV-OS-H102 Sec.3 F300 *Dropped objects*.
- u) Landing area should be inspected/surveyed and approved.
- v) Rigging design should take into account the potential for accidental or unintended disconnection of the load during all lifting phases.
- w) For any items of the lifted object that need temporary lashing this should be designed to allow for the expected loads.

#### **5.9.4 Lifting through splash zone**

5.9.4.1 See DNV-OS-H205 Sec. 2.3 *Operational aspects* and DNV-OS-H206 Sec.2.10 *Operational requirements*.

5.9.4.2 In general the following items may be considered. The list is not exhaustive, and not all items may be relevant for all operations. Generally a dedicated list for the actual operation should be prepared.

- a) Slamming loads in splash zone. Potential for damage to object due to slamming loads. Potential for snap forces due to slack slings. Load in the lifting appliance will change through splash zone/submerged due to buoyancy effect, drag loads due to lowering/hoisting, wave induced loads. Slack slings due to wave action, lowering speed to be carefully assessed. Snap forces shall as far as possible be avoided. See DNV-OS-H206 Sec. 5.2.1.5 and DNV-RP-H103 Sec. 4.7. PHC systems can be used in this phase to reduce/prevent snap loads.
- b) Shift/tilt of lifted object. When submerged, the centre of buoyancy might not be in vertical line with centre of gravity. See DNV-RP-H103 Sec.3.6 *Stability of lifting operations*.
- c) Time needed for pressure equalisation / flooding of open object needs to be accounted for. Where the structure allows for free flooding, sometimes this may be through small vent holes and thus free flooding may take some time. Allowance within the lowering operation, and design of the structure should allow for this e.g. stop the lowering at 50m (out of splash zone) to allow for free flooding to be completed with ROVs monitoring vent holes to confirm when venting has stopped. As the structure is lowered, further checks

(hold points) may be required.

- d) Effect on stability of object: tilting/shifting.
- e) Heavy loads, in relation to the lifting appliance capacity, are often better for handling (lifting appliances, load sensors and AHC issues related to light weights).
- f) Large horizontal area objects need special considerations during design phase. Such objects might be lowered in a vertical orientation through splash zone and upended subsea.
- g) Visual observations capabilities are limited down to approximately 50 m water depth due to ROV limitations in wave affected zone. Only available information is the load cell reading and depth reading at the control station.
- h) Tag lines/tugger lines might be released by ROV or by other means and should be considered in the planning and design phase.
- i) For lighter objects, relative to crane or winch capacity, reading from load cells might be inaccurate.

### 5.9.5 Transfer

5.9.5.1 This section covers transfer of the load from one lifting appliance to another, for instance from a crane to a winch. Care should be taken during load transfer on following points:

- a) Length of transfer rigging.
- b) Access for ROV to connect/disconnect rigging.
- c) Load transfer monitoring (visual slack by ROV plus load cell reading).
- d) Depth of load transfer due to ROV capabilities with regard to working close to surface.
- e) Design of rigging to be ROV friendly/operable.

5.9.5.2 The rigging and connection arrangement should be designed for safe and efficient connection and disconnection. “Handshaking” between vessel lifting appliances may typically be relevant for contingency situations due to failure of main lifting device. Crane off-lead and side-lead angles should be considered.

5.9.5.3 The procedure for load transfer should be detailed and the rate of load pick-up and release should be defined. Communication is deemed critical for a successful operation. Vessel position and stability during load transfer to be detailed step by step in procedure. Only one action should be performed at a time.

5.9.5.4 Sufficient clearances between the vessels and the lifted object shall be ensured.

5.9.5.5 ROV may be used for monitoring, hook-up and release activities. Any potential interference between thrusters, inlets and discharges from involved vessels or nearby vessels should be evaluated.

### 5.9.6 Lowering through water column

5.9.6.1 In general the following items may be considered. The list is not exhaustive, and not all items may be relevant for all operations. A dedicated list for actual operations should be prepared.

- a) Lowering at a defined maximum speed to ensure stability of the lifted object.
- b) Safe deployment zone (in case of dropped object) and separation from subsea assets to be considered. Sufficient horizontal offset should account for drag and current where the current velocity may be time-dependent and its magnitude and direction may vary with water depth. The horizontal travel distance of a dropped object may be greatly influenced by its geometrical characteristics.
- c) Snagging and entangling of lines to be avoided.
- d) The load on the lifting appliance will increase with water depth due to weight of steel wire and this effect needs to be considered in the design phase.
- e) Consider following object by ROV to monitor stability and position of lifted object and possibly rotational control.
- f) Use of motion damping systems or devices to be carefully considered in the design phase.
- g) The object may be lowered to a safe height above the highest subsea structure or the sea bed keeping a horizontal offset from the final landing position ensuring sufficient separation from any subsea assets. Guide wire(s) and clump weight(s) might be used to control the position and heading.
- h) Subsea winches might be used to control the heading and position. Winches should allow for easy operation (ROV or remotely), easy connection/disconnection of tugger lines. The winches should be checked to ensure that they can operate on the seabed conditions expected.
- i) Dynamic forces on cable and lifted object see DNV-RP-H103 Sec. 5.3.
- j) For deep sea deployment the risk of resonance during lowering should be considered and managed accordingly. Use of PHC will in some cases change the natural frequency of the rigging to fully avoid the

risk of resonance.

- k) For multi-fall rope arrangements the potential for twisting of the ropes should be reviewed at the planning stage.

### 5.9.7 Landing

5.9.7.1 In general the following items may be considered. The list is not exhaustive, and not all items may be relevant for all operations. Generally a specific list for the actual operation should be prepared.

- a) Inspect by ROV or by using other means if required, to monitor and verify that the motion, position and installation tolerances for the object are within the set criteria prior to landing.
- b) Select lifting appliance mode. AHC characteristics such as time, wear, fatigue, speed and capacity to be carefully considered. AHC and/or PHC can be used to minimize the velocity and the impact on the structure. Selection of operation mode to be carefully assessed in relation to the lifting appliance being used and the present vessel motions to avoid overloading any part of the system and equipment. Change of lifting appliance mode should be risk assessed, carefully considered and included in the procedure and marked as a hold point.
- c) Monitor/observe by ROV or other means as required to ensure that relevant parameters are within the defined acceptance criteria during the landing phase.
- d) Landing to be performed with a lowering speed at or below the defined maximum allowable speed. The maximum allowable landing speed is the sum of rope pay-out speed plus vertical heave velocity of the object. (Heave velocity may be reduced if AHC or PHC is used).
- e) Orientate the object to the correct heading during landing. ROV installation aids should be considered during the equipment design; this may include ROV docking beam, docking platform, ROV handles, etc.
- f) Installation/landing is usually subject to client acceptance.
- g) Suction loads or locking loads during landing should be considered, and if necessary the effect might be minimized by for instance using constant tension, or PHC.
- h) Visibility subsea might be limited and might prolong the operational time. This needs to be accounted for in the planning and design process.
- i) A point of no return should be defined, e.g. after disconnecting rigging. Contingency situation; in some cases it could be possible to wet-store, disconnect rigging and re-connect rigging at a later stage (if this is accounted for in rigging design)
- j) Lift rigging may be released by e.g. acoustic release system, ROV operable hook, ROV shackle or by ROV cutting tool. Caution to frequency management when using acoustic release for structure lifting rigging.
- k) Release of lift rigging could lead to torque build up in wire and this should be accounted for.
- l) For a potential vessel drive-off or drift-off situation a quick release function might be included in the lift rigging arrangement if deemed critical.

### 5.9.8 Relocation

5.9.8.1 Relocation as covered here is typically horizontal movement of lowered object from offset position to final location, or the reverse.

- a) Objects to be installed on subsea structures may be lowered down to a clump weight by aid of guide wire(s) connected to the clump weight by Guideposts. This to minimise the risk for dropped objects hitting subsea assets.
- b) For rotational control guide wires may be used. Care must be taken to avoid twisting of guide wires or entanglement by ROV tethers. Rotation of lifted object may be controlled by the tension level in the individual guide wire, or by e.g. ROV.
- c) When the object is lowered down to typically midway distance between the clump weight and the final landing location the vessel may be moved half way between the clump weight and the final location while adjusting the tension in the guide wires. Guide wire winches should be in constant tension mode. Then the guide wire nearest to the final landing location to be slacked off and transferred to the relevant guide post. Repeat the operation for the next guide wires as relevant.
- d) For transfer operations not using guide wires for rotational control the vessel heading or other methods may be applied. Examples of other methods for rotational control can be more than one lifting appliance, subsea guide, subsea winch, steering bridle, ROV etc.

### 5.9.9 Task completion

5.9.9.1 In general the following items should be considered. The list is not exhaustive, and not all items may be relevant for all operations.

- a) Employed equipment to be recovered or parked subsea as relevant.
- b) Any testing to be performed as required.
- c) Any surveying and mapping activities to be performed as required.

#### **5.9.10 Recovery of lifting gear.**

*5.9.10.1* The lift rigging may be allowed to be water drained prior to landing on deck if relevant.

*5.9.10.2* When recovering the lifting arrangement and other objects, care should be taken if any tilting is expected. If the lift rigging is tilting, it may be hazardous to land it on deck and special precautions may be required.

*5.9.10.3* The need for bumpers and guides when landing the lifting gear on the deck should be evaluated.

*5.9.10.4* Tag lines/tugger lines may be attached by ROV to enable rotational control when lifting on board the vessel.

*5.9.10.5* Prior to lifting out of the water a visual check of the condition of the spread to be carried out by ROV.

- a) Control of gear.
- b) Loose lines/loads.
- c) Barrier off deck and ensure deck crew is safely positioned in case of dropped objects from rigging during recovery to deck.
- d) The lift rigging should be inspected for damage and any damage should be reported and documented.

#### **5.9.11 As-left survey**

*5.9.11.1* As-left survey may include e.g. ROV visual survey, video recording, mapping of coordinates etc.

#### **5.9.12 Reporting and evaluation**

*5.9.12.1* Lessons learned should be documented for any future projects as relevant. Any damages should be documented and reported to the relevant parties. If fatigue or wear is an issue, a lift log should be considered or may be required by relevant parties or authorities.

#### **5.9.13 Reverse or recovery operation**

*5.9.13.1* Retrieval to the vessel may not always be possible. It requires special considerations and possibly more strict weather criteria than during over-boarding. Potential for suction or snagging loads during lifting off from the seabed should be considered. Constant tension or heave compensation can be used to control the load during lift off, see [App.C](#).

#### **5.9.14 Temporary parking subsea**

*5.9.14.1* Temporary parking should be considered in the planning phase, as part of the operation or as contingency. To ensure stability of the parked object on the sea bed e.g. concrete mats, rock/gravel dump may be prepared. The parked object may be located and identified by e.g. surface-/subsea buoy, light stick or transponder.

*5.9.14.2* It may not be possible to properly inspect equipment stored subsea for a prolonged period of time. Care must be taken with respect to validity of certificates, warranties etc. If an object is parked on location for long periods, i.e. between two annual seasons, possibilities of replacement of e.g. loose lifting slings should be evaluated. Preferably equipment with documented properties for extended subsea application or storage shall be used. Any other phenomena and/or activities that may affect or impact the object, e.g. trawling or dropped objects should be considered.

#### **5.9.15 ROV operations**

*5.9.15.1* If ROV/s are critical to the operation and no safe state can be achieved without them, redundancy measures shall be considered. Redundancy measures may be e.g. spare ROV, spare parts or added contingency time for repair/replacement operations. For limitations and recommendations see DNV-OS-H206 Sec. 2.9 *ROV Operations*.

#### **5.9.16 Simultaneous operations**

*5.9.16.1* Normally simultaneous operations (SIMOPS) shall be risk assessed by all involved parties to identify all risks, clashes, interferences and required risk mitigation actions.

**Guidance note:**

IMCA M 203 *Guidance on Simultaneous operations (SIMOPS)*

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5.9.16.2 Items to be considered for SIMOPS could include:

- a) Definition of scope, procedures and controls.
- b) Constraints and hazards relating to each SIMOP activity including weather limitation.
- c) Scheduling.
- d) Risk register.
- e) Proximity limitations for vessels and equipment.
- f) Positioning limitations, i.e. interference between position reference systems, DP-footprints.
- g) Communications, bridging document, sequence of activities, primacy.
- h) Permit to work system.
- i) Contingency actions and escape routes.

Special considerations could include:

- a) Vessel position control.
- b) Loads on the lifting appliance.

5.9.16.3 A SIMOPS document containing a relevant and thorough description of the operations should be issued.

**Guidance note:**

Note that NORSOK D-010 also gives requirements for SIMOPS in connection with drilling activities. I.e. a vessel working close to a drilling rig will also be defined as SIMOPS.

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5.9.16.4 Risk assessment shall be performed to determine the need and equipment for monitoring, data acquisition, analysis and documentation. Examples of parameters for monitoring include wave height, direction and period, wind speed and direction, temperature, vessel motions, current profile, crane load, DP-footprint, rope/sheave temperature. In general any critical parameters, as identified in risk assessment exercises, as required by company, contractors or relevant authorities shall be monitored and evaluated as relevant.

## 5.10 Contingency operation

### 5.10.1 General

5.10.1.1 Possible fault scenarios for the lifting operation shall be identified and contingency actions shall be planned for.

**Guidance note:**

Recommendations for contingency planning can be found in DNV-OS-H101 Sec.2 A400.

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5.10.1.2 Immediate safe retrieval of object to deck is not always feasible and possibilities for emergency landing/ wet storage should be evaluated.

## 5.11 HSE Management system

### 5.11.1 General

5.11.1.1 Most vessel management systems satisfy the requirements of the International Safety Management Code - ISM Code. For subsea lifting operations the vessel Safety Management System - SMS should be bridged with the project HSE/QA management system. Procedures for handling deviations from approved procedures should be in place.

## APPENDIX A HAZARDS

### A.1 List of significant hazards

#### A.1.1

Risk assessment shall be performed for each individual lifting appliance intended for subsea operations.

#### A.1.2

Table A.1 is generic and presents the minimum hazards which should be considered by the manufacturer. However, risk assessment should not be limited to [Table A-1](#) and should be specific for all equipment subjected to analysis.

#### A.1.3

Risk Assessment should include operational conditions, specific for the vessel where the lifting appliance will be installed, including typical lifts planned for and to be performed by the lifting appliance.

#### A.1.4

It is recommended that results of such risk analyses are accepted by user / owner, before completing the design phase of lifting appliance.

#### A.1.5

Safe states for different lifting phases as described in [\[1.9.3\]](#) shall be determined.

Table A-1 Generic list of hazards											
Hazards	Severity	Frequency (time of exposure)	Risk as a product of severity and frequency	Safety barrier, risk reducing measure	Severity	Frequency (time of exposure)	Risk as a product of severity and frequency	Safety function implemented (Yes, No, what safety function)	PLr – according to EN ISO 13849-1	PL – according to EN ISO 13849-1	Other columns shall be implemented according to
A	B	C	D	E	F	G	H	I	J	K	M <sub>1</sub> - M <sub>n</sub>
<b>Guide note:</b> to be identified, detailed and named more specifically by the manufacturer. Main focus areas (but not limited to) are listed below in this column	<b>Guide note:</b> Risk before safety barrier				<b>Guide note:</b> Risk after safety barrier			<b>Guide note:</b> (Or equivalent according to IEC 61508/62061)			
Drop of the boom											
Drop of the load											
Drifting off the load while subsea without AHC activated											
Drifting off the load while subsea with AHC activated											
Dangerous load movements (resonance, twisting, swinging)											
Unintended movement (slewing)											
Unintended movement (hoisting)											
Unintended movement (lowering)											
Unintended movement (luffing)											
Unintended movement (folding)											



<b>Table A-1 Generic list of hazards (Continued)</b>										
Dangerous movements of the vessel (operational limitations)										
Crane movements outside operational limitations										
Overloading (hook entangled to the sea bottom or other object subsea)										
Overloading (load sucked to the bottom)										
Overloading (improper measurements, not physical overload)										
Wrong reading of the system sensors, failures in sensors, deviations										
Over travel of the hook										
Over travel of the boom										
Over travel of the other parts of lifting appliance										
Slack rope										
Collisions with ship structure										
Crashing the load into bottom due to elongation effect when risk of immediate stop due to single failure is present – safe state shall be determined.										
Unstable forces in the wire when risk of immediate stop due to single failure is present, while load is in the splash zone (overload, slack wire, snapping) – safe state shall be determined.										
Hook close to the other structure (seabed structure, supply boat, barge) when risk of immediate stop due to single failure is present – safe state should be determined.										
Complete blackout during operation subsea – safe state and contingency plan should be determined.										
AHC failing during landing – safe state should be determined.										
Tensioning system failing during different operational scenarios. Safe states should be determined.										
Incorrect speed / position control and indication (subsea lowering)										
Incorrect speed / position control and indication (subsea lifting)										
Incorrect speed / position control and indication (landing)										
Incorrect speed / position control and indication (picking up the load)										
Lack of braking capacity										
Lack of load holding capacity										
Heat during hoisting										
Creeping (acceptance criteria and detection method should be specified). Safe state should be determined.										
Heat generation during emergency lowering										
AHC: handling of the heat generation										
Total blackout										

<b>Table A-1 Generic list of hazards (Continued)</b>										
Partial blackout										
Unintended activation of safety function										
Unavailability of the safety function										
Failures in the control system: 1) UPS failures. 2) Specific PLC Input failure. 3) Specific PLC Output failure. 4) Failure of the specific analogue signals. 5) CPU failure. 6) Specific 24V DC Power supply failure. 7) Specific control transformer failure. 8) Specific minor software failure. 9) Specific major software failure. (program hanging). 10) Specific failure of the safety components. 11) Specific failure in the safety function.										
Electric lightning, overvoltage-protection										
Hydraulic pipe rupture HP side										
Hydraulic pipe rupture LP side										
Hydraulic motor failure during operation										
Hydraulic motor over speeding										
Hydraulic pump failure during operation										
Improper load positioning										
Contamination. Foreseeable plan if particles are determined, to take preventive actions, install particle detectors or filters with feedback to monitoring system.										
AHC failure while landing 1) AHC most possible failure modes. 2) AHC most sensitive components (critical components failure). 3) Worst case operational scenario evaluation and operational limits for AHC.										
Improper rope tensioning (too low)										
Improper rope tensioning (too high)										
Lack of communication										
Weather conditions (sea state)										
Weather conditions (wind speed, direction)										
Weather change during operation using AHC										
Identification of 5 most possible and critical operations to identify scenarios of operation.										

Note: Table to be completed by the manufacturer

## APPENDIX B SYSTEMS OVERVIEW

### B.1 Recommended systems overview

#### B.1.1

It is recommended that the following equipment (as a minimum) is designed with systems specified in [Table B-1](#).

<b>Table B-1 Recommended systems overview</b>					
<i>System</i>	<i>Equipment</i>	<i>Subsea Crane</i>	<i>Deck Winch (other types than for A-frame)</i>	<i>A-frame (including winch)</i>	<i>Tugger Winch</i>
AHC		O	O	O	N/A
MOPS		R	O, for Heavy Lift* equipment R	O, for Heavy Lift* equipment R	O
AOPS		O	O	O	N/A
Alarm and Monitoring minimum according to <a href="#">[3.5.5]</a>		R	R	R	O
Load Cell measurement and indication		R	R	R	R
Hook Position measurement		R	R <sup>1)</sup>	R	N/A
Emergency means to operate to the safe state		R	R	R	R
Tensioning System <sup>2)</sup>		R	R	R	R
Anti-collision protection		R	N/A	R	N/A
Fail Safe Philosophy – Fail to Safe		R	R	R	R
DNV 2-22, Movements outside operational limits – Limit Switches		R	R	R	R
DNV 2-22, Dangerous crane movements, emergency stop		R	R	R	R
DNV 2-22, 2 way communication arrangements		R	R	R	R
DNV 2-22, Slack wire rope arrangement at the drum, when drum is not visible		R	R	R	R
DNV 2-22, Fail safe braking in case of power failure		R	R	R	R
<b>Note:</b> R = recommended, O = optional, N/A = not applicable Heavy Lift equipment = equipment with lifting capacity in excess of 2.500kN.  1) Hook position measured by ROV is sufficient 2) Constant tension / variable tension system.					

## APPENDIX C MOTION COMPENSATION SYSTEMS

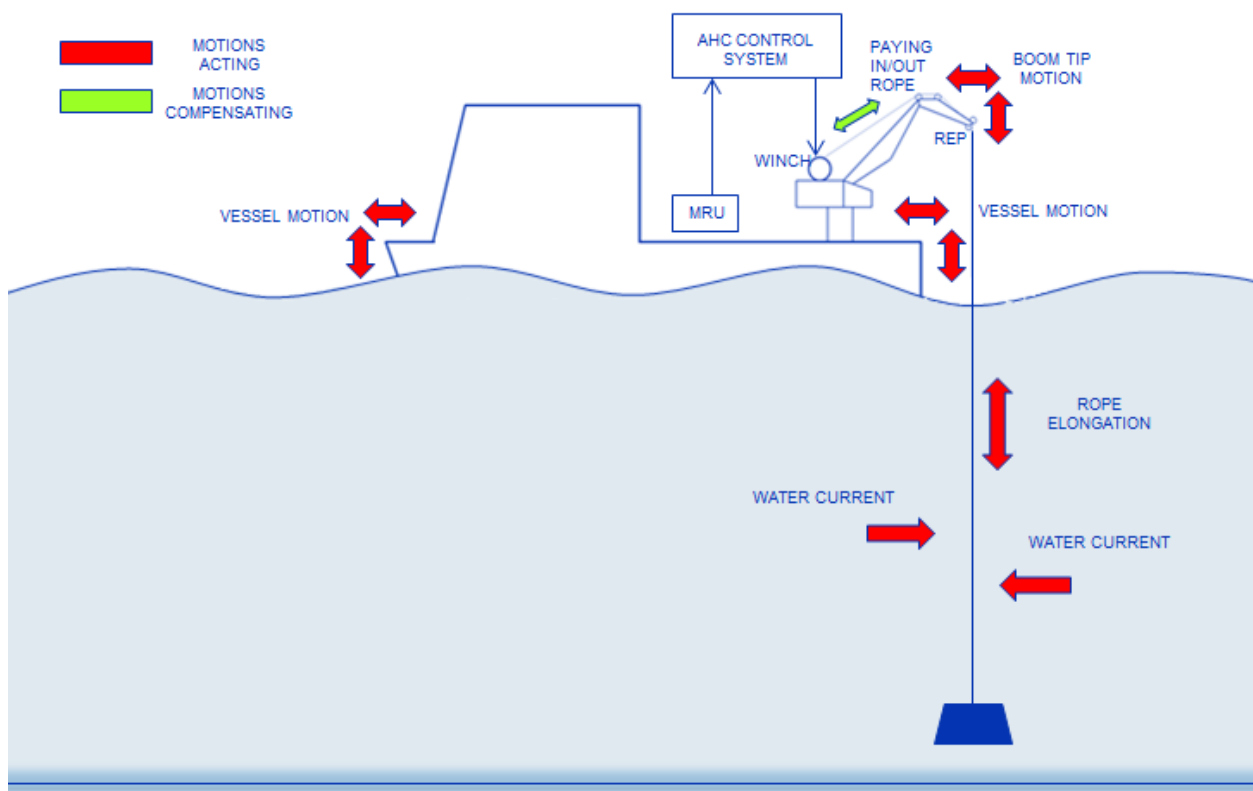
### C.1 General

When performing subsea lifting, the waves will introduce additional and unwanted motion of the REP and the load. Modern cranes and winches can be equipped with active and passive systems for reducing the effect of unwanted motions by heave compensation and constant tensioning. In some situations PHC will be the preferred option over AHC and vice versa; they may also be used in combination.

### C.2 Active heave compensation system

#### C.2.1 Main principles

AHC, described in this Appendix, is considered to be a system which compensates for the unwanted motion of REP, by paying in and out the rope. Active systems are built with closed loop control, including feedback, e.g. from MRU.



**Figure C-1**  
**Schematics of active heave compensation system**

#### C.2.1.1

Active Heave Compensation limitation/characteristics:

- First order motion - Stroke - deviation.
- Second order motion – Required Speed.
- Third order motion – Required Acceleration.
- Response time, AHC control system delay before a to c is performed.
- Resulting accuracy for a to d.

#### C.2.1.2

Lifting off in Tension Control mode provides the operator with control over line tension whilst performing the lift, under circumstances during which there is a clear danger of excessive tension induced by dynamic movements.

#### C.2.1.3

Lifting off in AHC mode gives the operator control of the speed, whilst performing the lift under circumstances during which there is a clear danger of excessive loading. Thus AHC shall only be used when combined with

measures to avoid excessive loads.

#### C.2.1.4

MRU is normally not installed at the REP, hence the control system has to apply mathematical algorithms to recalculate the values sent from MRU to understand accelerations on the REP.

#### C.2.1.5

AHC if installed, enhances safety with respect to damage experienced by the equipment, it does not improve safety in terms of the lifting appliance or vessel.

#### C.2.1.6

AHC if installed increases the operational window with regard to weather conditions. However, recommendation given in [C.2.1.18] should be considered.

#### C.2.1.7

Normally it is not required that AHC has to fulfil power requirements for simultaneous operation with crane movements. However, AHC has to work along with hoisting motion, but not slew and boom motions.

#### C.2.1.8

The performance of the AHC system shall be documented. A well-documented description of the system and its application during operation shall be available. The performance of the system can be documented by testing and operational records.

- a) Heave compensator efficiency factor on stroke length and /or max pay out/in speed should generally not be taken higher than 80% of the theoretical values within specified operating range.
- b) To use an efficiency factor of 80%, system performance of 90% of theoretical values shall be documented.
- c) It is recommended that the efficiency factor is calculated as 2 times the difference between the theoretical - and documented performance. However the maximum efficiency factor cannot be taken greater than 90% of theoretical value.
- d) The test results and operational records applied as basis for determining the efficiency factor need to be from operations that are comparable with regard to environmental conditions, depth, weight of object and other effects influencing the performance of the heave compensation system.
- e) Simulation methods for environmental conditions may be used if methodology applied is accepted by user of the equipment / owner.

#### C.2.1.9

The AHC ability to stabilize the vertical movement of the load by compensating for motion at the REP varies significantly with water depth. A trial lift should be performed prior to critical operations at full depth. The AHC performance should be evaluated on a case by case basis.

##### **Guidance note:**

Analysis of the subsea operations can be carried out according to DNV-RP-H103 *Modelling and analysis of marine operations*.

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#### C.2.1.10

During AHC testing, the manufacturer should prove performance values expressed in the AHC technical specification, including recommendation stated in [C.2.1.7].

#### C.2.1.11

The AHC manufacturer shall perform Risk Analysis as described in section [3.4].

#### C.2.1.12

The AHC manufacturer shall determine and document the required Performance Level for functions included in the AHC system according to EN ISO 13849-1 Annex A.

#### C.2.1.13

The AHC manufacturer shall verify that the actual Performance Level of the safety functions is equal to or greater than Required Performance Level.

#### C.2.1.14

A detailed assessment of the control system, including both hydraulic and electric/electronic components should be performed on component level to document the behaviour of the AHC system in terms of single

failures.

*C.2.1.15*

There may be different methods for performing such analysis. However it is recommended that Failure Mode Effect and Criticality Analysis - FMECA in accordance with IEC 60812 is performed for that purpose.

*C.2.1.16*

The effect of failure in the AHC system on the lifting appliance should be assessed.

*C.2.1.17*

It is recommended to have necessary condition monitoring of the system available for the operator, to detect abnormal conditions that may lead to critical failures. Alarms should be initiated for abnormal conditions.

*C.2.1.18*

If a planned lift relies on AHC operability, consequences of AHC failing shall be evaluated and compensating measures shall be in place to mitigate risks. An accidental case assuming malfunction of the system should be investigated to ensure that the product criteria are fulfilled for the accidental limit state - ALS load case. See DNV-OS-H102.

*C.2.1.19*

Power failure during AHC operations shall not lead to critical failures / major hazard.

*C.2.1.20*

Visual monitoring of the load during all subsea lifts is recommended.

*C.2.1.21*

Operating a lifting appliance in AHC mode when attached to a subsea structure, without evaluating the risk of AHC failure is not recommended - reference is also made to item [\[C.2.1.17\]](#).

*C.2.1.22*

The AHC system shall be designed to allow for certain loss of fluid during operation to bring the lifting appliance to a safe state.

*C.2.1.23*

[Table C-1](#) shall be filled in by the manufacturer to describe operability of the system. Content of table is shown as example only.

<b>Table C-1 AHC vs. Rope tensioning</b>					
<i>Phase</i>	<i>Modes</i>	<i>Active Heave Compensation</i>	<i>Constant Tension (variable setpoint)</i>	<i>Comment</i>	<i>Other modes Etc.</i>
In air		NA	NA	Tugger winches are recommended to avoid rotation	
Splash zone (tugger winches control horizontal movement) Risk: slamming		Not allowed unless proven otherwise*	R	Tugger winches are recommended to avoid rotation * in the future a winch will be able to pay out the wire fast enough.	
Subsea lowering risk: resonance		O - based on pre-calculations	O – resonance		

Table C-1 AHC vs. Rope tensioning (Continued)					
Phase	Modes	Active Heave Compensation	Constant Tension (variable setpoint)	Comment	Other modes Etc.
Seabed landing		R - only when suction forces or soil friction is not present			
(recovery) seabed lift-off			R when suction to bottom is an issue		
Transfer Winch <-> Crane (in general, transfer from one lifting appliance to another).		O	O - or better NA since there is no use/point for it		
<i>Note:</i> R = recommended O = optional NA = not allowed					

### C.3 PHC systems consisting of spring - Damper system

#### C.3.1 General

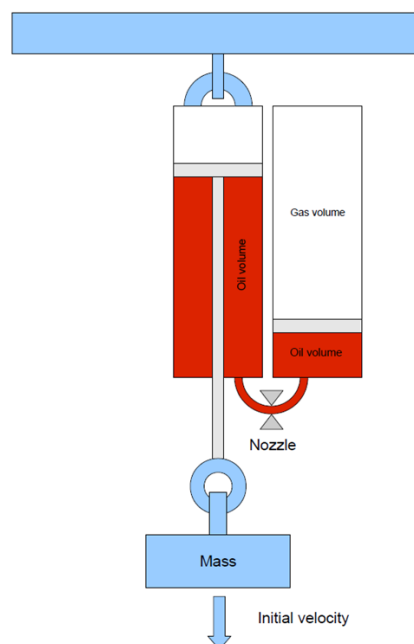
The main purpose of the PHC system is to protect the crane and the lifted object from the forces caused by vessel motions / hydrodynamic effects, to help stabilize the load and prevent slack wire. REP movements are compensated by the stroke of the PHC system, thereby limiting fluctuating loads on the system.

Reducing peak loads resulting from sudden dynamic movements and forces e.g., during splash zone crossing can be achieved by passive shock absorbing systems working independently of the crane.

##### C.3.1.1 Application

PHC systems consisting of spring and damper are typically used for the following application areas:

- Subsea retrieval – Maintain constant tension during lift off to reduce forces in crane and the lifted object for subsea recovery operations.
- Heave compensation – Reduce load movements and velocity, reduce landing speed.
- Splash zone – Reduce forces in the crane and lifted object through the splash zone.
- Resonance avoidance – Avoid system resonance, particularly for deep water lowering operations.
- Load tensioning – Keep load in position while being fastened.



**Figure C-2**  
**Schematics of passive heave compensation system**

### *C.3.1.2 Operating principles:*

Key parameters to consider when selecting a PHC system include:

- a) Maximum possible extension of the piston rod.
- b) Dampening characteristics. Typically different for in- and out stroke.
- c) Spring stiffness. Force versus stroke characteristics.
- d) Zero stroke force. Force needed to initiate stroking.

A full stroke of the PHC is un-acceptable. A sufficient margin based on movement of REP, stroke length, stiffness of the lifting system and hydrodynamic properties should be documented.

Damping and stiffness characteristics may be optimized for specific lifts by changing valves, oil level and accumulator pressure. Active or passive control systems changing the characteristics during the lifting operation may also be used.

When used for heave compensation, the PHC system should have a flat spring versus stroke curve to minimize spring forces. Dampening forces from the PHC system should be carefully evaluated.

When used for heave compensation, the PHC system will be more efficient for objects with high drag forces and large added mass, such as manifolds, mud mats and protection covers and for objects which have a large difference between weight in water and weight in air, e.g. suction anchors and closed pipes. For other application areas / operations this limitation will not be relevant.

The effect of using a PHC system will vary depending on the lifting phase, the weight and geometry of the lifted object and the sea state. This should always be evaluated prior to configuring the PHC units and running the operation.

### *C.3.1.3 PHC used with other systems*

Modern cranes and winches may be equipped with both active and passive systems for heave compensation and constant tensioning.

Active heave compensation systems based on compensation of boom tip movements only may be used in combination with a PHC.

Constant tensioning systems or winch/crane operating modes which compensate for tensioning shall not be used in combination with a separate PHC system, due to risk of interference, unless calculations demonstrate that the systems can be combined.

### *C.3.1.4 Landing*

A significant reduction in landing speed can be obtained for a well-designed PHC system. The efficiency of the PHC system is dependent on the average stiffness of the PHC being less than the sum of forces acting on the load.

### *C.3.1.5 Retrieval*

Retrieval of objects from the sea floor may cause large forces in the lifting appliance and the wire due to a combination of vessel movements, suction forces and possible sudden release. PHC systems are suitable for absorbing these forces, maintaining constant tension and will prevent the direct coupling between the load and the boom tip movement.

The PHC system may be tuned such that it has zero strokes at static weight of the object in water. The stiffness of the system will be varied according to the expected suction forces, while the dampening will be relatively large in order to absorb rapid release of the object from the sea floor.

### *C.3.1.6 Load tensioning*

A PHC system will decouple the motion of the REP from a load which is fastened to the sea bed or to a subsea structure. It is therefore possible to use a PHC system to keep a load in position without releasing the tension in the wire.

## **C.4 Nylon stretchers**

### **C.4.1 Main principles**

Nylon stretchers can be added to the rigging when high resonance motions are expected during installation. Due to the low stiffness of the stretcher it can be used to shift the natural frequency of the lowering system away from resonance frequencies.

#### *C.4.1.1*

Nylon stretchers are particularly suitable for deep to ultra-deep water operations, when lowering through the water column and set-down of structures on the seabed. Nylon stretchers should normally not and only after due consideration be used for lowering through the splash zone where there are limitations on crane height and



large and sudden changes in loads.

#### *C.4.1.2*

It is recommended to avoid abrasion and permanent loading since such influences tend to permanently deform the stretcher.

#### *C.4.1.3*

Fibre ropes are made from materials with visco-elastic properties, i.e. their stiffness characteristics are not constant, but vary with load duration and magnitude, the number and frequency of load cycles. The behaviour of nylon ropes under dynamic loading should be tested using a series of systematic tests, considering variations in loading and oscillation period.

#### *C.4.1.4*

Like other passive compensation systems, nylon stretchers are sensitive to their loading condition. It is therefore important to allow for some inaccuracies in the design load of the installed structures.