
**Ships and marine technology —
Offshore wind energy — Port and
marine operations**

*Navires et technologie maritime — Énergie éolienne offshore —
Opérations portuaires et maritimes*

STANDARDSISO.COM : Click to view the full PDF of ISO 29400:2020



STANDARDSISO.COM : Click to view the full PDF of ISO 29400:2020



COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

	Page
Foreword	xi
Introduction	xii
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Symbols and abbreviated terms	25
4.1 Symbols	25
4.2 Abbreviated terms	29
5 General considerations	32
5.1 Introduction	32
5.1.1 General	32
5.1.2 Safety requirements	33
5.2 Jurisdiction	34
5.2.1 Introduction	34
5.2.2 Safety of life at sea	34
5.2.3 Environment	35
5.3 HSSE plan	35
5.4 Risk management	35
5.4.1 Introduction	35
5.4.2 Techniques to evaluate risks	36
5.5 Job safety analysis	36
5.6 Environmental impact study	37
5.7 Manning, qualifications, job and safety training	37
5.8 Daily progress and incident reporting	37
5.9 Personnel tracking	38
5.10 Approval by national authorities	38
6 Organization, documentation and planning	38
6.1 Introduction	38
6.2 Organization and communication	39
6.2.1 Project organization	39
6.2.2 Operational organization	39
6.3 Quality assurance and administrative procedures	40
6.4 Technical procedures	40
6.5 Technical documentation	41
6.5.1 Document numbering system	41
6.5.2 RAMS for port and marine operations	41
6.5.3 Operational schedule/programme	42
6.5.4 Contingency philosophy	43
6.5.5 Contingency planning and emergency procedures	43
6.5.6 Emergency response coordination plan	44
6.5.7 As-built documentation/Post construction file	45
6.5.8 Standards for data transfer to CAD systems	46
6.6 Certification and documentation	48
6.6.1 Introduction	48
6.6.2 Required or recommended documentation	49
6.7 Marine warranty survey	49
6.7.1 Introduction	49
6.7.2 Role of the marine warranty surveyor	49
6.7.3 MWS scope of work	50
6.7.4 Certificate of approval	50
6.8 Systems and equipment	51
6.8.1 Introduction	51

6.8.2	Marine vessels	51
6.8.3	Major equipment	51
7	Metoccean requirements	51
7.1	Introduction	51
7.2	Weather-restricted/weather-unrestricted operations	52
7.2.1	Weather-restricted operations	52
7.2.2	Weather-unrestricted operations	52
7.3	Metoccean conditions	52
7.3.1	Wind	52
7.3.2	Wave, wave period and swell conditions	53
7.3.3	Current	53
7.3.4	Other metoccean factors	53
7.3.5	Temperature	54
7.3.6	Marine growth	54
7.4	Metoccean criteria	54
7.4.1	Design criteria and operational limits	54
7.4.2	Return periods	55
7.4.3	Vessel response-based analysis	55
7.4.4	Probability distributions of sea state parameters	55
7.5	Operational duration, contingency and weather window	55
7.5.1	Planned operational duration	55
7.5.2	Weather window and contingency	56
7.5.3	Point of no return	56
7.5.4	Forecasted and monitored operational limits, metoccean reduction factor	57
7.6	Weather forecasts	58
7.6.1	Introduction	58
7.6.2	Forecast parameters	58
7.7	On-site monitoring	58
8	Onshore transport and nearshore transport	59
8.1	Introduction	59
8.2	Structural integrity calculations	59
8.3	Transport by road	59
8.4	Transport via inland waterways	59
8.5	Transport via nearshore waterways	60
8.6	Transport via railways	60
8.7	Transport frames and equipment	60
9	Intermediate storage areas	60
9.1	Introduction	60
9.2	Infrastructure requirements	61
9.2.1	Load bearing	61
9.2.2	Surface	61
9.3	Storage frames and equipment	61
9.4	Requirements of components for storage	62
9.5	Protection of components against environmental conditions	62
9.6	Structural integrity calculations	62
9.6.1	Introduction	62
9.6.2	Vortex shedding	62
9.7	Security measures	63
10	Pre-assembly	63
10.1	Introduction	63
10.2	Pre-assembly area requirements	63
10.3	Pre-assembly activities	63
10.4	Pre-assembly equipment	64
10.5	Structural integrity calculations	64
10.6	Vortex shedding	64
10.7	Security measures	64

11	Port activities	64
11.1	Introduction	64
11.2	Accessibility of harbour areas	64
11.2.1	Water access	64
11.2.2	Inland access	65
11.3	Storage areas of quayside	65
11.4	Security measures	65
11.5	Quayside requirements	65
11.6	Port subsea soil requirements for jacking activities	65
12	Weight control	66
12.1	Introduction	66
12.2	Weight control classes	67
12.3	Weight and CoG constraints	67
12.4	Weight control monitoring	67
12.5	Dimensional control	68
12.6	Serial items	68
12.7	Weight determinations	68
13	Stability	68
13.1	Introduction	68
13.2	General requirements	69
13.3	Stability calculations	69
13.4	Intact stability	70
13.4.1	Introduction	70
13.4.2	Intact stability criteria	71
13.5	Damage stability	72
13.5.1	Introduction	72
13.5.2	Damage stability criteria	74
13.6	Single-barge transports	75
13.7	Multi-barge transports	75
13.8	Classed vessels	76
13.9	Self-floating structures	76
13.9.1	Introduction	76
13.9.2	Intact and damage stability	76
13.9.3	Upending and installation of self-floating and launched structures	77
13.10	Loadout operations	78
13.11	Watertight integrity and temporary closures	79
13.12	Inclining tests	79
14	Ballasting operations	80
14.1	Introduction	80
14.2	Ballast calculations for different stages	81
14.3	In ballast system	81
14.3.1	Operational aspects	81
14.3.2	Other operational considerations	82
14.4	Protection against damage and deterioration	82
14.4.1	Introduction	82
14.4.2	Freezing	83
14.5	Prevention of progressive flooding in damage condition	83
14.6	Control and indicating systems	83
14.7	Pumps	84
14.7.1	Introduction	84
14.7.2	Specification and layout	84
14.7.3	Pump performance curves and functional limitations	84
14.8	Valve arrangements	84
14.9	Vent systems	85
14.10	Air cushion system capacity	85
14.11	System testing	85

15	Loadout	85
15.1	Introduction	85
15.2	Categories of loadout	86
15.2.1	Introduction	86
15.2.2	Design: structural analysis during all loadout phases	87
15.2.3	Loadout planning	87
15.2.4	Cargo weight details and CoG information	87
15.2.5	Deck loading plan	88
15.3	Structure being loaded	88
15.4	Site and quay	88
15.5	Barge	89
15.6	Link beams, skidways and skidshoes	89
15.7	Moorings	89
15.7.1	Weather-restricted operation	89
15.7.2	Temporary mooring system	90
15.8	Grounded loadouts	90
15.9	Pumping and ballasting	91
15.9.1	Pump capacity	91
15.9.2	Recommended pump capacity	91
15.10	Loadouts by trailers, SPMTs or hydraulic skidshoes	92
15.10.1	Introduction	92
15.10.2	Structural capacity	92
15.10.3	Load equalization and stability	93
15.10.4	Vertical alignment	93
15.10.5	Skidshoes	93
15.11	Propulsion system design, redundancy and back-up	93
15.11.1	Propulsion system	93
15.11.2	Redundancy and recommendations	94
15.12	Float-on onto submersible barges or vessels	95
15.13	Lifted loadouts	96
15.14	Horizontal loadouts	97
15.15	Barge reinstatement and sea fastenings	97
15.16	Tugs	98
15.17	Management and organization	98
15.18	Loadout manual	98
15.19	Operating manual	98
16	Transportation	100
16.1	Introduction	100
16.2	General considerations	100
16.2.1	Manned tows	100
16.2.2	Unmanned tows	101
16.2.3	Navigation lights, signals and day shapes	101
16.2.4	Contingency	101
16.2.5	Motion responses	101
16.2.6	Verification of the transported object	101
16.2.7	Structural analysis during all transport phases	101
16.2.8	Transport planning	102
16.3	Weather routing and forecasting	102
16.4	Ports of shelter, shelter areas, holding areas	102
16.5	Inspections during the towage or voyage	103
16.6	Responsibility	103
16.7	Hazardous materials	103
16.8	Ballast water	104
16.9	Restricted depths, heights and manoeuvrability	104
16.10	Under-keel clearances	104
16.11	Air draught	105
16.12	Channel width	105
16.13	Survey requirements	105

16.14	Towline pull required, fleet composition and towing arrangement.....	106
16.14.1	Towline pull required	106
16.14.2	Towing fleet.....	107
16.14.3	Towing arrangement.....	107
16.14.4	Towline length.....	108
16.15	Tow out from dry dock.....	108
16.15.1	Introduction	108
16.15.2	Under-keel clearance	108
16.15.3	Side clearances	108
16.15.4	Air cushion/air pressure.....	108
16.15.5	Capacity of winching and towing arrangements.....	109
16.15.6	Positioning systems.....	109
16.15.7	Survey requirements.....	109
16.16	Inshore tow	109
16.16.1	Tow route and towing clearances.....	109
16.16.2	Positioning systems.....	110
16.17	Transport onboard a vessel/Offshore tow.....	110
16.17.1	Vessel selection	110
16.17.2	Stability	110
16.17.3	Sea fastening.....	110
16.17.4	Vortex shedding.....	112
16.17.5	Navigation systems.....	112
16.18	Transport manual.....	112
17	Temporary mooring and stationkeeping for marine operations	113
17.1	Introduction	113
17.2	Environmental criteria.....	113
17.3	Determination of mooring response.....	114
17.3.1	Analysis methods.....	114
17.3.2	General considerations on the mooring design	114
17.4	Sizing of mooring lines.....	115
17.4.1	General considerations.....	115
17.4.2	Line tension limits and design safety factors.....	115
17.4.3	Particular mooring conditions.....	116
17.5	Sizing of anchors.....	116
17.6	Sizing of attachments	117
17.7	Sizing of mooring line components.....	117
17.8	Clearances under extreme conditions.....	117
17.9	Clearances during positioning.....	118
17.10	Tensioning of moorings.....	118
17.11	Other stationkeeping means	118
17.11.1	Introduction	118
17.11.2	DP systems	119
17.11.3	Purpose-built mooring arrangements	119
17.11.4	Use of tugs	119
17.12	System for common reference stations	119
18	Offshore installation operations.....	120
18.1	Introduction	120
18.1.1	Foundation.....	120
18.1.2	Transition piece.....	120
18.1.3	Wind turbine generator.....	120
18.1.4	Offshore substation/Offshore accommodation platforms.....	120
18.1.5	Installation plan.....	120
18.1.6	Cargo weight details and CoG information	123
18.2	Installation site.....	123
18.2.1	Sea floor survey.....	123
18.2.2	Soil survey	124
18.2.3	Soil preparation.....	124

18.2.4	Site charts.....	124
18.2.5	Unexploded ordnance (UXO).....	125
18.3	Systems and equipment.....	127
18.3.1	Introduction.....	127
18.3.2	Vessels.....	127
18.3.3	Equipment.....	127
18.3.4	Position reference system.....	128
18.3.5	Ballast systems.....	128
18.3.6	Transport vessel interface with marine equipment.....	128
18.4	Positioning of vessels.....	128
18.5	Site reference system.....	129
18.6	Geotechnical site-specific assessment for jack-up operations.....	129
18.6.1	Introduction.....	129
18.6.2	Required soil investigations.....	129
18.6.3	Penetration analysis, punch-through and horizontal-vertical-interaction.....	130
18.7	Vessel operation manual.....	132
18.8	Jack-up preloading procedure.....	133
18.9	Ballasting.....	133
18.10	Lifted installations.....	133
18.10.1	Introduction.....	133
18.10.2	Installation of liftable jackets.....	133
18.10.3	Installation of templates for piles.....	134
18.10.4	Installation of piles.....	134
18.10.5	Installation of transition pieces.....	134
18.10.6	Installation of GBS.....	134
18.10.7	Transfer of items from a barge to the deck of a crane vessel/jack-up vessel.....	135
18.10.8	Installation of towers.....	135
18.10.9	Installation of WTG including nacelle, hub and blades.....	135
18.10.10		
	Installation of topsides of offshore substations/accommodation platforms.....	135
18.10.11		
	Operational aspects.....	135
18.10.12		
	Operational control parameters.....	136
18.11	Lowering by ballasting.....	136
18.11.1	Introduction.....	136
18.11.2	Operational aspects.....	136
18.11.3	Operational control parameters.....	136
18.12	Precise positioning on the sea floor by active and passive means.....	137
18.12.1	Introduction.....	137
18.12.2	Operational design aspects.....	137
18.12.3	Operational control parameters.....	137
18.13	Skirt penetration.....	138
18.13.1	Introduction.....	138
18.13.2	Gravity penetration.....	138
18.13.3	Suction penetration.....	138
18.13.4	Operational design aspects.....	138
18.13.5	Operational control parameters.....	138
18.14	Pile installation.....	139
18.14.1	Introduction.....	139
18.14.2	Operational design aspects.....	139
18.14.3	Operational control parameters.....	140
18.15	Grouting.....	140
18.15.1	Introduction.....	140
18.15.2	Grouting of pile/transition piece structure.....	140
18.15.3	Underbase grouting of pile/jacket structure.....	141
18.15.4	Operational design aspects.....	141
18.15.5	Preparations.....	141

18.15.6	Operational control parameters	142
18.16	Bolted connections of foundation	142
18.17	Welding of piles/foundation to topsides	142
18.18	Noise mitigation measures	142
18.19	Crew transfer to and from installation units	143
18.20	Offshore completion	143
18.20.1	Introduction	143
18.20.2	ROV inspection	143
18.20.3	Removal of temporary equipment	144
18.20.4	Scour protection	144
18.20.5	Final inspection	144
18.21	Project execution manual	144
19	Design and operation of lifting equipment	145
19.1	Introduction	145
19.2	Rigging geometry	147
19.3	Actions and action effects	147
19.4	Weight contingency factors	149
19.5	Dynamic amplification factors (DAFs)	150
19.5.1	Introduction	150
19.5.2	Lifts by a crane	150
19.5.3	Offshore lifts by cranes on two or more vessels	152
19.6	Representative hook load	152
19.6.1	One-hook lifts by a single crane	152
19.6.2	Two-hook lifts by two cranes	152
19.7	Representative lift weight per lift point	153
19.7.1	One-hook lifts	153
19.7.2	Two-hook lifts	153
19.8	Representative forces on a lift point	154
19.8.1	Representative vertical force	154
19.8.2	Representative force in line with the sling direction	155
19.8.3	Representative lateral force	155
19.9	Representative force for slings and grommets	156
19.10	Design values of actions and action effects	156
19.11	Strengths of slings, grommets and shackles	158
19.11.1	Steel cable slings	158
19.11.2	Fibre rope slings and fibre rope grommets	158
19.11.3	Working load limits and design strengths of fibre slings and grommets	159
19.11.4	Working load limit and design strength of shackles	160
19.12	Design verifications	160
19.12.1	Allowable hook load	160
19.12.2	Slings and grommets	161
19.12.3	Lift points and their attachment to the structure and supporting members	163
19.13	Lift point design	164
19.13.1	Introduction	164
19.13.2	Sling ovalization	164
19.13.3	Plate rolling direction and direction of loading	164
19.13.4	Pinholes	164
19.13.5	Cast padears and welded trunnions	165
19.13.6	Cheek plates	165
19.13.7	Padeyes	165
19.14	Clearances	165
19.14.1	Introduction	165
19.14.2	Clearances around lifted objects	166
19.14.3	Clearances around crane vessel	166
19.14.4	Clearances around jack-up crane vessel	167
19.14.5	Clearances around mooring lines and anchors of crane vessels	167
19.14.6	Clearances around array cable zones	168
19.14.7	Clearances around spud-can positions of jack-up vessels	168

19.15	Bumpers and guides.....	168
19.15.1	Introduction.....	168
19.15.2	Object movements.....	168
19.15.3	Position of bumpers and guides.....	168
19.15.4	Bumper and guide loads.....	169
19.15.5	Design considerations.....	169
19.16	Heave compensated lifts.....	170
19.17	Lifts using DP.....	170
19.18	Practical considerations.....	170
19.18.1	Access.....	170
19.18.2	Design of seafastening.....	170
19.18.3	Equipment.....	170
19.18.4	Slings.....	171
19.19	Certification requirements for lifting equipment.....	171
19.19.1	Standard lifting equipment.....	171
19.19.2	Custom-made lifting equipment.....	171
19.19.3	Recertification of lifting equipment.....	172
20	Laying, burial, jointing, and repair of sub-sea cables.....	172
20.1	Introduction.....	172
20.2	Planning and design.....	172
20.2.1	Cable dimensions and handling parameters.....	172
20.2.2	Seafloor survey — Specifically cable route corridors between turbines and substation(s).....	173
20.2.3	Vessel suitability.....	175
20.2.4	Cable storage and cable handling equipment.....	177
20.2.5	Navigation equipment — Positioning and control of vessel/cable interface.....	177
20.3	Cable loadout and offshore transfer.....	178
20.3.1	Introduction.....	178
20.3.2	Handling and lifting.....	178
20.3.3	Loadout by reeling, spooling, winding and coiling.....	178
20.3.4	Lifted loadout and offshore transfer.....	180
20.4	Cable laying.....	180
20.4.1	Introduction.....	180
20.4.2	Cable pull-in procedures.....	181
20.4.3	Laying.....	182
20.5	Cable protection.....	182
20.5.1	Introduction.....	182
20.5.2	Cable burial.....	182
20.5.3	Non-burial cable protection.....	183
20.6	Cable crossings.....	185
20.7	Landfalls.....	185
20.8	Cable jointing and repair.....	185
20.9	As-built survey.....	186
20.10	Cable integrity check.....	186
20.11	Cable installation manual.....	186
21	Construction management.....	186
21.1	Introduction.....	186
21.2	Marine coordination.....	187
21.3	Harbour coordination.....	188
21.4	Guard vessel.....	188
21.5	Reporting.....	188
21.6	Personnel tracking.....	188
	Annex A (informative) Additional information and guidance.....	189
	Bibliography.....	203

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*.

This second edition cancels and replaces the first edition (ISO 29400:2015), which has been technically revised.

The main changes compared to the previous edition are as follows:

- [Clause 3](#): terms and definitions revised; new entries inserted;
- [Clause 7](#), “Metocean requirements”: fully revised;
- [Clause 20](#), “Cable loadout and offshore transfer”: new subclause added;
- revisions made throughout most other clauses;
- [Annex A](#): revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document applicable to the offshore wind industry constitutes a comprehensive and common basis covering port and marine operations of all offshore structures installed and maintained by the offshore wind industries worldwide. Through its application, the intention is to achieve reliability levels appropriate for offshore wind farm components, whatever the type of structure and the nature or combination of materials used.

It is important to recognize that during port and marine operations the structural integrity of the component is an overall concept comprising models for describing actions, structural analysis, design rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design in isolation can disturb the balance of reliability inherent in the overall concept or structural system. It is necessary, therefore, to consider the implications involved in modifications in relation to the overall reliability of structures in offshore wind farms.

This document applicable to offshore wind farms is intended to provide a wide latitude in the choice of structural configuration, material and techniques without hindering innovation. Sound engineering judgment is, therefore, necessary in the use of this document.

This document was developed to provide comprehensive requirements and guidance for the planning, engineering and safe execution of port and marine operations for all types of offshore wind farm components including cable-laying and burial operations and installation and operation of floating turbines moored to the seabed.

Port operations for installation of components of offshore wind farms cover all component transport to the ports, whether marine or via inland waterways, any intermediate storage, as well as preassembly activities at the ports until placing the components close to any quayside for subsequent marine operations to start.

Marine operations for offshore wind farm structures cover loadout from the quayside, offshore transportation and installation phases when the structure is at risk from the marine environment including any marine logistics during offshore commissioning works, operation and maintenance, component exchange, repair operations and decommissioning or redeployment.

This document describes the principles of, and provides requirements and guidance for, port and marine operations associated with foundations, substructures, WTG, cables and topsides installed in offshore wind farms, from the point of view of planning, engineering, construction and documentation. Alternative requirements, methods and provisions can fulfil the intention of this document and may be applied, provided it can be demonstrated that they achieve at least the same level of assurance and reliability. The overall objective of this document is to ensure that port and marine operations are conducted within defined and recognized safety and reliability levels, wherever they are performed. Additional standards, codes and guidelines should also be taken into account, where applicable. Special attention should be paid to national regulations governing the area in which the port and marine operations are performed.

It is not the intent of this document to govern the design of structures, systems and components used in port and marine operations, beyond the principles given. Recognized codes and standards are normally accepted as the basis for the detailed design and the fabrication requirements of such components.

[Annex A](#) provides some background and some additional information to the main body of the document and it is intended that it be read in conjunction with the main body of the document.

This document is based on ISO 19901-6 while adapting it extensively to the specific requirements of the offshore wind industry.

NOTE Port and marine operations of offshore wind farms are covered in local, national and international regulations.

Ships and marine technology — Offshore wind energy — Port and marine operations

1 Scope

This document provides comprehensive requirements and guidance for the planning and engineering of port and marine operations of offshore wind farms, encompassing all documents and works related to such operations, e.g. the design and analysis of the components, systems, equipment and procedures required to perform port and marine operations, as well as the methods or procedures developed to carry them out safely.

This document is intended to be comprehensive, covering all relevant information related to port and marine operations necessary for loadout, offshore transport, installation, offshore commissioning works, operation and maintenance, component exchange, repair operations and decommissioning or redeployment of offshore wind farms.

This document is applicable to port and marine operations for offshore structures including:

- lattice structure foundations made from steel;
- concrete gravity base structures (GBS);
- piled steel foundation or mixed steel and concrete foundation structures;
- subsea templates and similar temporary structures or installation aids;
- steel or mixed material towers, nacelles and blades forming part of the wind turbine generators (WTG);
- floating turbines moored to the seabed;
- self-elevating offshore units for offshore substations or offshore accommodations platforms;
- launching systems at sea from quay side or onshore;
- array cables within the wind farms as well as export cables connecting the wind farm to the grid.

This document is also applicable to modifications of existing structures, e.g. installation of additional modules, exchange of components or decommissioning, and to marine operations during the service life of the windfarm related to the technical maintenance works.

It is not applicable to the following operations:

- construction activities, e.g. in a fabrication yard onshore, where there is no exposure to the marine environment;
- road transport onshore;
- diving.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19901-7, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19905-1, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups*

IMCA LR 008, M 179, *Guidance on the Manufacture and Safe Use of Cable Laid Slings and Grommets*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 action

external load applied to the *structure* (3.153) (direct action) or an imposed deformation or acceleration (indirect action)

Note 1 to entry: An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

Note 2 to entry: An earthquake typically generates imposed accelerations.

[SOURCE: ISO 19904-1:2006, 3.5]

3.2 action effect

effect of *actions* (3.1) on structural components

EXAMPLE Internal forces, moments, stresses, strains, rigid body motions or elastic deformations.

[SOURCE: ISO 19904-1:2006, 3.5]

3.3 adverse weather

meteorological and oceanographic conditions which can affect people, operations, equipment or facilities, to such an extent that precautionary measures must be taken to safeguard the facility to maintain a safe system of work

Note 1 to entry: Adverse weather includes, snow, ice, hail, lightning, heavy rain, high wind, low cloud base, poor visibility, severe sea states and strong *currents* (3.32). Weather conditions can change quickly and the effects of short-term variations such as wind gusts must be considered.

3.4 air cushion

air pumped into underbase compartments of the *structure* (3.153)

Note 1 to entry: An air cushion is normally applied in order to reduce the draught and increase the freeboard and/or to alter the structural loading.

[SOURCE: ISO 19903:2006, 3.10, modified - Note 1 to entry has been slightly reworded for clarity.]

3.5

alpha factor**metocean reduction factor**

maximum ratio of operational criteria/design environmental condition for weather restricted *marine operations* (3.82) to allow for weather forecasting inaccuracies

Note 1 to entry: See also 3.91.

Note 2 to entry: [SOURCE: Reference [56], modified for clarity.]

3.6

array cable

cable between *wind turbine generators* (3.176) (WTG) and between a WTG and the *offshore substation* (3.102) connecting the WTGs with the *offshore substation* (3.102)

3.7

as-built data**as-laid data**

data coming from final as built survey once every cable or *structure* (3.153) have been connected and tested and possibly corrected or repaired

Note 1 to entry: Final as built report includes final status of the field.

Note 2 to entry: "as-laid data" are coming from survey performed just after laying the cable or after structure installation before any test and connection. Data includes position in 3D, status, possible damages location and picture if possible, possible debris location around within target box or corridor including picture if possible.

3.8

assembly

designed and fabricated group of bulk and equipment items that form one unit

[SOURCE: ISO 19901-5:2016, 3.1.1]

3.9

ballast

variable solid or fluid content in order to change the draught, stability, trim and/or heel of a *structure* (3.153) afloat

[SOURCE: ISO 19901-5:2016, 3.1.2, modified for clarity.]

3.10

ballast system

system used to change the draught, stability, trim and/or heel of a *structure* (3.153) afloat

3.11

barge

simple floating vessel, normally non-propelled, on which material components of an *offshore wind farm* (3.103), material, people and equipment can be transported

3.12

basic variable

one of a specified set of variables representing physical quantities that characterize *actions* (3.1), environmental influences, geometrical quantities or material properties, including soil properties

[SOURCE: ISO 19900:2013, 3.7]

3.13

bending efficiency factor

factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in *strength* (3.152) caused by bending around a shackle, *trunnion* (3.165), *padear* (3.108) or crane hook

[SOURCE: ISO 19901-6:2009, 3.9]

3.14
blade

one of a number of structural members with aerodynamic lift surfaces assembled around the *hub* (3.70) of a wind turbine

3.15
bollard pull

conventional measure of the pulling of a vessel defined as the force by a vessel under full power on a shore-mounted bollard through a tow line

Note 1 to entry: Bollard pull is expressed in kilonewtons.

[SOURCE: ISO 19901-6:2009, 3.10]

3.16
bolting

work carried out to join two components of the *wind turbine generator* (3.176) or between *foundation* (3.60) and *tower* (3.160) by means of a bolted connection

3.17
bridging document
interface document

document that aligns and co-ordinates the requirements and responses of various parties in relation to a specific aspect of a project

Note 1 to entry: A bridging document is commonly used to align and coordinate the emergency response procedures for *owner* (3.107) and contractors and clarify the interfaces between the various safety management systems used during construction.

[SOURCE: ISO 19901-6:2009, 3.11]

3.18
bumper

temporary *structure* (3.153) designed to protect structures or modules during the initial fitting stage of an installation operation

[SOURCE: ISO 19901-6:2009, 3.12]

3.19
cable burial

process to bury a cable into the *seabed* (3.128) up to a defined *depth of lowering* (3.37) which is either previously laid on the seabed and then buried, or which is simultaneously laid and buried, or, when a trench is previously made, which is laid into the trench and then buried, using specific equipment

3.20
cable laying

operations related to paying out an *array cable* (3.6) or an *export cable* (3.51) from a cable lay vessel onto the *seabed* (3.128)

Note 1 to entry: For array cables, the operations between the *1st-end pull-in* (3.22) and the *2nd-end pull-in* (3.23) if the array cables are not immediately buried.

3.21
cable pull-in

activities and equipment to be carried out and used to safely pull *array cables* (3.6) or *export cables* (3.51) through the *J-tubes* (3.74) and/or *foundations* (3.60)

3.22
1st end pull-in

pulling the first end of a section of an *array cable* (3.6) or *export cable* (3.51) into the *foundation* (3.60) of a *wind turbine generator* (3.176) or an *offshore substation* (3.102)

3.23**2nd end pull-in**

pulling the second end of an *array cable* (3.6) or *export cable* (3.51) into the *foundation* (3.60) of a *wind turbine generator* (3.176) or an *offshore substation* (3.102)

3.24**cable burial risk assessment****CBRA**

risk based approach to determine the optimal *depth of cover* (3.36) for an *array cable* (3.6) or *export cable* (3.51) taking into account e.g. anchor risks, water depth, frequency and size of vessels in transit in the vicinity of cable routes, changes in *seabed* (3.128) profile

3.25**cable testing**

tests conducted with either *array cables* (3.6) or *export cables* (3.51) and, where relevant, also the fibre optics cables in order to verify the functionality of the cables as well as mechanical and physical properties of the cables

3.26**CoG envelope**

defined constraint volume within which the centre of gravity (CoG) of an *assembly* (3.8) or a module shall remain

[SOURCE: ISO 19901-6:2009, 3.14]

3.27**commissioning**

activities after *mechanical completion* (3.90) including electrical testing and start-up of *wind turbine generators* (3.176), *offshore substations* (3.102), *foundations* (3.60), *array cables* (3.6) and *export cables* (3.51)

3.28**consequence factor**

factor applied to critical structural components in the design of lifting operations to ensure that these components have an increased factor of safety in relation to the consequence of their failure

Note 1 to entry: Consequence factors are additional safety factors, applied to critical structural components of the lifted object over and above the normal safety factors used in a working stress design (WSD) analysis of the lifted object. They are, accordingly, applied to *lift points* (3.76), their attachments to the object and components in the object supporting lift points. They are not intended for application to slings, *grommets* (3.62) and shackles.

[SOURCE: ISO 19901-6:2009, 3.15]

3.29**construction afloat**

addition of material or outfitting to the *structure* (3.153) while afloat

[SOURCE: ISO 19901-6:2009, 3.16]

3.30**crane vessel**

vessel, ship or *barge* (3.11) on which lifting equipment is mounted

Note 1 to entry: For the purposes of this document, this term includes jack-up vessels, crane barges, crane ships, derrick barges, shear-leg barges and semi-submersible crane vessels.

[SOURCE: ISO 19901-6:2009, 3.17]

**3.31
cribbing**

arrangement of timber baulks, secured to the deck of the *barge* (3.11) or vessel, designed to support the cargo

Note 1 to entry: Cribbing is generally arranged at strong points of the deck and/or cargo.

[SOURCE: ISO 19901-6:2009, 3.18]

**3.32
currents**

flow of water past a fixed *location* (3.81) usually described in terms of a current speed and direction

Note 1 to entry: Convention is that direction is that to which a current flows.

[SOURCE: IEC 61400-3: 2009, 3.2]

**3.33
deadweight**

total carrying capacity of a vessel

Note 1 to entry: This includes cargo weight, deck cargo, snow and ice, marine growth, *ballast* (3.9) water, consumables and crew onboard a floating unit.

[SOURCE: ISO 19901-6:2009, 3.1, modified for clarity.]

**3.34
deck mating**

marine operation (3.82) in which the *platform* (3.111) *topsides* (3.158) are floated into position and connected to the *support structure* (3.155)

Note 1 to entry: This operation is normally conducted by ballasting and deballasting of the support structure.

[SOURCE: ISO 19901-6:2009, 3.20]

**3.35
decommissioning**

process of shutting down a *structure* (3.153) in an *offshore wind farm* (3.103) and removing it from its *location* (3.81) at the end of its service life

[SOURCE: ISO 19900:2013, 3.14, modified for clarity.]

**3.36
depth of cover
DOC**

value describing the vertical distance from mean back-fill level to top of cable; i.e. the thickness of material on top of the cable after trenching/burial

**3.37
depth of lowering
DOL**

value describing the vertical distance from mean *seabed* (3.128) level to top of cable

**3.38
design criterion**

quantitative formulation that describes the conditions that shall be fulfilled for each *limit state* (3.77)

[SOURCE: ISO 19901-6:2009, 3.22]

3.39**design value**

value derived from the *representative value* (3.118) for use in the *design verification* (3.169) procedure

[SOURCE: ISO 19900:2013, 3.18]

3.40**determinate lift**

lift where the slinging arrangement is such that the sling forces are statically determinate and not significantly affected by minor differences in sling length or elasticity

[SOURCE: ISO 19901-6:2009, 3.25]

3.41**displacement**

weight of the volume of water displaced by a floating *structure* (3.153)

Note 1 to entry: The weight of the water displaced is the sum of the lightship weight, *deadweight* (3.33) and anchoring system load including vertical component of the mooring pre-tension.

[SOURCE: ISO 19901-6:2009, modified - Note 1 to entry has been slightly reworded for clarity.]

3.42**drift-off**

unintended lateral move of a dynamically positioned (DP) vessel off of its intended *location* (3.81) relative to the *platform* (3.111) or *OWF* (3.103) asset working with, generally caused by the loss of stationkeeping control or propulsion

[SOURCE: ISO 13624-1:2009, 3.1.25, modified - "wellhead" replaced with "platform or OWF asset working with".]

3.43**dunnage**

arrangement of timber on deck of a *barge* (3.11) or vessel laid out to support the cargo

[SOURCE: ISO 19901-6:2009, 3.27]

3.44**dynamic action**

action (3.1) that induces acceleration of a *structure* (3.153) or a structural component of a magnitude sufficient to require specific consideration

[SOURCE: ISO 19901-7:2013, 3.8]

3.45**dynamic amplification factor****DAF**

ratio of a *dynamic action* (3.44) effect to the corresponding static action effect provided as a factor to account for the dynamic effects on a crane while lifting an object — where applicable

Note 1 to entry: An appropriately selected DAF can be applied to static actions to simulate the effects of dynamic actions.

[SOURCE: ISO 19902:2007, 3.16]

3.46**dynamic lift weight**

gross weight (3.63) times the *dynamic amplification factor* (3.45)

[SOURCE: ISO 19901-6:2009, 3.46, modified for clarity.]

3.47

electrical completion

electrical works inside a *wind turbine generator* (3.176) (WTG) conducted after finalization of *mechanical completion* (3.90) in order to allow for energization of the WTG

3.48

emergency response cooperation plan

ERCoP

document bridging emergency response plans of various parties working at an *offshore installation site* (3.100) in order to achieve a mutually aligned procedure in case of emergency

3.49

exclusion zone

area submitted to specific restrictions regarding marine activities

3.50

exclusive cable zone

area within the *offshore installation site* (3.100) designated exclusively for the *array cables* (3.6) of the wind farm and for the offshore installation works of the cable supplier, as well as area around *export cables* (3.51) and interconnector cables between substations exclusively for installation works for export/interconnector cables

Note 1 to entry: The exclusion cable zone can be defined for a specific period of time depending on the project requirements.

3.51

export cable

cables connecting an *offshore wind farm* (3.103) with the shore via a cable connection between one component of the wind farm and the onshore network

3.52

failure mode and effect analysis

FMEA

analysis of possible failures of any component of the safety device and determination of their consequences for the overall safety function, allowing the classification of any failure as safe, dangerous, detected or undetected with respect to the safety function

3.53

fibre rope

rope made of various yarns and various types of construction

EXAMPLE A fibre rope can be a stranded rope consisting of three to eight strands, a parallel strand rope, a single or double-braided rope, etc.

Note 1 to entry: Each combination of yarn and type of construction normally results in different properties and characteristics.

[SOURCE: ISO 19901-6:2009, 3.30]

3.54

fibre rope grommet

FRG

endless loop-shaped sling made up from a single length of *fibre rope* (3.53)

Note 1 to entry: A fibre rope grommet is of similar construction to a *steel wire rope grommet* (3.150).

[SOURCE: ISO 19901-6:2009, 3.31]

3.55**fibre rope sling****FRS**

sling made from a single *fibre rope* (3.53), usually with spliced eye end terminations

[SOURCE: ISO 19901-6:2009, 3.32]

3.56**float-off**

offloading an object from a submersible transport vessel or *barge* (3.11) by means of submerging the vessel or barge deck to a depth that is sufficient to allow the object to float and be removed from the vessel/barge

[SOURCE: ISO 19901-6:2009, 3.34]

3.57**float-on**

loading an object onto a submersible transport vessel or *barge* (3.11) by means of submerging the vessel or barge deck to a depth that is sufficient to allow the floating object to be manoeuvred into position over the vessel/barge

Note 1 to entry: The object is then lifted from the water and onto the vessel/barge deck by deballasting the vessel/barge to its seagoing condition.

[SOURCE: ISO 19901-6:2009, 3.35]

3.58**float-out**

transfer of a floating *structure* (3.153) out of a flooded dry dock

[SOURCE: ISO 19901-6:2009, 3.36]

3.59**float-over**

transfer of a major *assembly* (3.8) supported on *barge(s)* (3.11) onto its temporary or permanent *structure* (3.153) by means of manoeuvring the major assembly over the structure and setting it down by means of ballasting the barge(s) supporting the assembly, deballasting the structure or lowering the supports of this assembly or combination thereof

[SOURCE: ISO 19901-6:2009, 3.37]

3.60**foundation**

offshore wind energy part of an offshore wind turbine *support structure* (3.155) which transfers the loads acting on the structure into the *seabed* (3.128)

EXAMPLE *Monopile* (3.93), *jacket* (3.73) structures, gravity-based structures or floating *foundations* (3.60) structures.

Note 1 to entry: Different foundation concepts are shown in [Figure 1](#) together with other parts of an offshore wind turbine.

Note 2 to entry: While [Figure 1](#) defines the foundation as the part below the substructure which is in the *seabed* (3.128), the term foundation as used in the offshore wind industry usually refers to the substructure and the foundation (terms as used in [Figure 1](#)). Thus, a foundation as usually referred to in the offshore wind industry would be e.g. a monopile or a piled jacket structure. Therefore, when talking about a lift or an installation of e.g. a monopile, this document uses the term “foundation” instead of talking about “foundation and substructure” to be lifted.

[SOURCE: IEC 61400-3: 2010; 3.11, Example modified for clarity.]

3.61

grillage

steel *structure* (3.153), secured to the deck of a *barge* (3.11) or vessel, designed to support the cargo and distribute the loads between the cargo and the barge or vessel

[SOURCE: ISO 19901-6:2009, 3.38]

3.62

grommet

endless loop-shaped sling made up from a single length of (fibre or steel wire) rope

Note 1 to entry: See also *fibre rope grommet* (3.54) and *steel wire rope grommet* (3.150).

[SOURCE: ISO 19901-6:2009, 3.39]

3.63

gross weight

calculated or weighed weight of the *structure* (3.153) being lifted, including a weight contingency factor

Note 1 to entry: Sometimes the gross weight is referred to as a *not-to-exceed (NTE) weight* (3.97).

[SOURCE: ISO 19901-6:2009, 3.40]

3.64

grouting

offshore construction process used to connect some elements by using a special concrete type of mixture which is being pumped into the void between the elements

3.65

guard vessel

special ship attending the *offshore installation site* (3.100) required to maintain a higher degree of readiness in order to enforce the safety zone around an offshore construction site for non-construction vessels

3.66

gust wind speed

maximum value of the wind speed of a gust averaged over a short (3 s to 60 s) specified duration within a longer (1 min to 1 h) specified duration and at a defined height

Note 1 to entry: For design purposes, the specified duration depends on the dimensions and natural period of the (part of the) *structure* (3.153) being designed such that the structure is designed for the most onerous conditions; thus, a small part of a structure is designed for a shorter gust wind speed duration (and hence a higher gust wind speed) than a larger (part of a) structure.

Note 2 to entry: In practice, for design purposes, the gust wind speeds for the different durations (e.g. 3 s, 5 s, 15 s, 60 s) are derived from the wind spectrum.

[SOURCE: ISO 19901-1:2005, 3.8, modified for clarity.]

3.67

health, safety, security and environment plan

HSSE plan

plan that includes activities on health, safety, security and environment during planning, design and execution of operations

3.68

heave compensation

system fitted to hoisting/lowering machinery on offshore construction vessels to enable the object being hoisted or lowered to maintain a constant vertical position when the vessel is oscillating in a vertical direction

[SOURCE: ISO 19901-6:2009, 3.41]

3.69**hook load**

sum of the *rigging weight* (3.123), including the *dynamic amplification factor* (3.45), and the nominal lift weight

Note 1 to entry: static hook load is the hook load of the *gross weight* (3.63) or *NTE weight* (3.97) plus the rigging weight; dynamic hook load is the static hook load times DAF; nominal hook load is maximum allowed weight [including *rigging* (3.122)] as per crane chart.

[SOURCE: ISO 19901-6:2009, 3.42]

3.70**hub**

part mounted to the *nacelle* (3.95) of a wind turbine in order to connect the *blades* (3.14) forming the rotor *assembly* (3.8)

3.71**indeterminate lift**

lift where the sling forces are not statically determinate

[SOURCE: ISO 19901-6:2009, 3.43]

3.72**intermediate storage**

area in the staging port where the components for an *offshore wind farm* (3.103) are temporarily stored before *pre-assembly* (3.113) and/or *loadout* (3.80) onto transport vessels

3.73**jacket**

foundation (3.60) type of an *offshore wind farm* (3.103) made of tubular steel members which are usually piled into the *seabed* (3.128)

3.74**J-tube**

tube being part of the *foundation* (3.60) appurtenance designed and to be used for support and protection of the *array cables* (3.6) or *export cable* (3.51) from the *seabed* (3.128) up to the top of the *transition piece* (3.163) or a *topside* (3.158)

3.75**launching**

offloading an object into the water from a *barge* (3.11), other floating unit or fixed infrastructure by means of sliding the object longitudinally, or less commonly, sideways along the floating unit or the fixed infrastructure

[SOURCE: ISO 19901-6:2009, 3.44, modified for clarity.]

3.76**lift point**

connection between the *rigging* (3.122) and the *structure* (3.153) being lifted

Note 1 to entry: Lift points include *padears* (3.108), *padeyes* (3.109) and *trunnions* (3.165).

[SOURCE: ISO 19901-6:2009, 3.45]

3.77**limit state**

state beyond which the *structure* (3.153) no longer fulfils the relevant *design criteria* (3.38)

[SOURCE: ISO 19900:2013, 3.28]

3.78

link beam

connecting beam between the quay and floating unit

Note 1 to entry: The link beam can provide a structural connection, or can solely provide a smooth path for skidding or *trailers* (3.161).

[SOURCE: ISO 19901-6:2009, 3.49, modified for clarity.]

3.79

load case

compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent *actions* (3.1) and fixed variable actions for a particular design or *verification* (3.169)

[SOURCE: ISO 19902:2007, 3.29]

3.80

loadout

transfer of a *foundation* (3.60) or a wind turbine component, cables, a *topside* (3.158) module of an *offshore substation* (3.102) or any other equipment or components from land onto a *barge* (3.11) or vessel by horizontal movement or by lifting devices

Note 1 to entry: The following types of loadout operation can be distinguished:

- floating: loadout from the quay onto a floating barge or vessel;
- grounded: loadout from the quay onto a grounded barge or jack-up;
- lifted: loadout performed by crane;
- skidded: loadout where the *structure* (3.153) is skidded, using a combination of *skidways* (3.139), *skidshoes* (3.138) or runners, propelled by towing engines, jacks or winches;
- trailer: loadout where the structure is wheeled onto the barge using *trailers* (3.161) or *self-propelled modular transporters* (3.133).

[SOURCE: ISO 19901-5:2016, 3.1.30, modified for clarity.]

3.81

location

one of many areas of an offshore construction site where a *foundation* (3.60) with a wind turbine, an *offshore substation* (3.102) or *offshore accommodation platform* (3.99) will be or is located

3.82

marine operation

planned and controlled vertical or horizontal movement of a *structure* (3.153) or component thereof over, in or on water

Note 1 to entry: Examples for marine operations cover *loadout* (3.80), *offshore transport* (3.105), installation, marine operations during *commissioning* (3.27) as well as operation and maintenance works, component exchange and repair or *decommissioning* (3.35) or redeployment.

[SOURCE: ISO 19903:2006, 3.36]

3.83

marine spread

fleet of vessels assembled to perform a *marine operation* (3.82)

[SOURCE: ISO 19901-6:2009, 3.53]

3.84**marine warranty surveyor
MWS**

independent expert acting on behalf of a construction-all-risk (CAR) insurance company for *third party* (3.157) review and approval of the planning, design and execution of the *loadout* (3.80), *offshore transport* (3.105) and installation

3.85**marshalling port**

harbour chosen to temporarily store components, to perform *loadout* (3.80) and start the *offshore transport* (3.105) before offshore installation

3.86**mating**

transfer of a major *assembly* (3.8) supported on *barge(s)* (3.11) or vessel(s) to a temporary or permanent *support structure* (3.155)

Note 1 to entry: The following types of mating operation can be distinguished:

- afloat: transfer of the barge supported major assembly to a floating structure by means of submerging the structure sufficiently to allow the assembly to be manoeuvred over it, then lifting the assembly off the barges by deballasting the structure;
- onto structure *foundation* (3.60): transfer of the barge supported major assembly to a foundation by means of manoeuvring it over the foundation, then ballasting the barge supporting the assembly or lowering the supports of this assembly in order to transfer the weight of the assembly onto the structure.

[SOURCE: ISO 19901-6:2009, 3.54]

3.87**maximum wave height**

$H_{\max}$

largest of all wave crests to adjacent trough values related to a certain time and area

3.88**mean wave period**

T_z

zero-crossing period of a wave

3.89**mean wind speed**

average velocity of wind commonly measured by anemometer at a defined height and averaged over a certain time frame

3.90**mechanical completion**

stage of the process when the *wind turbine generator* (3.176) (WTG) is firmly bolted to the *foundation* (3.60), before *commissioning* (3.27) and prior to commencing power generation

EXAMPLE Connection of ladders, WTG internal cabling, software installation required.

3.91**metocean reduction factor****alpha factor**

f_{MR}

maximum ratio of operational criteria/design environmental condition for weather restricted *marine operations* (3.82) to allow for weather forecasting inaccuracies

Note 1 to entry: See also 3.5.

Note 2 to entry: [SOURCE: Reference [56], modified for clarity.]

3.92
minimum breaking strength
MBS

certified *strength* ([3.152](#)) of a chain, wire rope, *fibre rope* ([3.53](#)) or accessories

[SOURCE: ISO 19901-6:2009, 3.55]

3.93
monopile

single pile to be penetrated into the *seabed* ([3.128](#))

3.94
mooring component

general class of component used in the mooring of floating *structures* ([3.153](#))

EXAMPLE Chain, *steel wire rope* ([3.149](#)), synthetic *fibre rope* ([3.53](#)), clump weight, buoy, winch/windlass or anchor.

[SOURCE: ISO 19901-6:2009, 3.56]

3.95
nacelle

housing which contains the drive-train and other elements on top of a horizontal axis wind turbine *tower* ([3.160](#))

[SOURCE: IEC 61400-3:2010, 3.34]

3.96
nominal value

value assigned to a *basic variable* ([3.12](#)) determined on a non-statistical basis, typically from acquired experience or physical conditions

[SOURCE: ISO 19900:2013, 3.29]

3.97
not-to-exceed weight
NTE weight

maximum acceptable weight of the *structure* ([3.153](#)), with an associated limiting centre of gravity (CoG) envelope

[SOURCE: ISO 19901-6:2009, 3.58]

3.98
offload

transfer of a major *assembly* ([3.8](#)) or a module from a *barge* ([3.11](#)) or transport vessel to land by horizontal movement or by lifting

[SOURCE: ISO 19901-6:2009, 3.59]

3.99
offshore accommodation platform

fixed *platform* ([3.111](#)) located inside an *offshore wind farm* ([3.103](#)) used for accommodation of personnel during operational phase from which personnel embarks via helicopter, crew transfer vessel or other vessels to the *wind turbine generator* ([3.176](#)) for conducting service and maintenance

3.100
offshore installation site

area where the *locations* ([3.81](#)) of the *foundations* ([3.60](#)) for the *wind turbine generators* ([3.176](#)) and the *offshore substation* ([3.102](#)) will be installed offshore

3.101**offshore installation vessel**

offshore construction and installation vessel(s) involved in the construction of the *offshore wind farm* (3.103)

3.102**offshore substation**

structure (3.153) in an *offshore wind farm* (3.103) which connects the *array cables* (3.6) and the *export cables* (3.51) and transforms the voltage level between both

3.103**offshore wind farm****OWF**

offshore site generating electricity from wind energy with the components such as *foundations* (3.60), *transition pieces* (3.163), *piles*, *towers* (3.160), *nacelles* (3.95), *hub* (3.70), *blades* (3.14), *array cables* (3.6) as well as *export cable* (3.51) and *offshore substation* (3.102) and/or *offshore accommodation platform* (3.99) where required

3.104**offshore transmission owner****OFTO**

entity which takes responsibility of the assets which usually link offshore generation to the onshore network

Note 1 to entry: In terms of physical assets, an OFTO will normally have the ownership of (i) offshore electricity transmission infrastructure such as *offshore substations* (3.102), the *export cable* (3.51) as well as the onshore cabling, (ii) any onshore substations, and (iii) the electrical equipment relating to the operation thereof. However, the ownership of the electricity transmission can be different depending on local regulation.

Note 2 to entry: OFTO differs from *owner* (3.107).

3.105**offshore transport**

offshore transportation of the components of an *offshore wind farm* (3.103) from designated *marshalling port* (3.85) or another fabrication yard to the *offshore installation site* (3.100)

3.106**operational duration**

planned duration of a port and *marine operation* (3.82), excluding a contingency period

Note 1 to entry: See also *weather window* (3.174).

Note 2 to entry: See also Reference [56].

3.107**owner**

representative of the company or companies which own an *offshore wind farm* (3.103) project

EXAMPLE An owner can be wind farm lease and permit holder, developer, employer of contractors which manufacture and install the components of an offshore wind farm and potential operator of the offshore wind farm.

Note 1 to entry: Owner differs from *OFTO* (3.104).

3.108**padear**

lift point (3.76) consisting of a central member of tubular or flat plate form with horizontal *trunnion* (3.165), or consisting of a solid casting, around which a sling or *grommet* (3.62) can be passed

[SOURCE: ISO 19901-6:2009, 3.62]

3.109

padeye

lift point (3.76) consisting essentially of a plate, reinforced by cheek plates if necessary, with a hole through which a shackle can be connected

[SOURCE: ISO 19901-6:2009, 3.63]

3.110

permit to access

permit issued by the construction management of an *offshore wind farm* (3.103) during construction when required to an *offshore installation vessel* (3.101) to allow entry into the safety zone of an *offshore installation site* (3.100) in order to conduct its designated works agreed by the construction management

3.111

platform

complete *assembly* (3.8) including *structure* (3.153), *topsides* (3.158) and, where applicable, *foundations* (3.60)

[SOURCE: ISO 19901-6:2009, 3.64]

3.112

point of no return

PNR

point during an operation or a geographical point along a route that represents the final opportunity to reverse, delay or abandon the operation and return to a *safe condition* (3.126)

[SOURCE: ISO 19901-6:2009, 3.65, modified for clarity.]

3.113

pre-assembly

stages of the process for the assembly of the *wind turbine generator* (3.176) (WTG) components at the staging port including works and parts of the WTG or other required components in order to commence *loadout* (3.80) of pre-assembled WTG components

3.114

pre-piling

activities in relation to installing piles in the *seabed* (3.128) where upon a *jacket* (3.73) or a similar deep *foundation* (3.60) is going to be installed

3.115

recognized organization

RO

organisation that has been assessed by a flag state, and found to comply with Part 2 of the Code for Recognized Organizations (RO Code) MSC.349(92) and IMO resolution MEPC.237(65)

[SOURCE: MSC.349(92)^[69], modified for clarity.]

3.116

risk assessment and method statements

RAMS

documents which detail the way a work task or process is to be completed outlining the hazards involved and the required safety precautions based on detailed risk assessments

3.117

remotely-operated vehicle

ROV

underwater vehicle operated remotely from a surface vessel or installation

[SOURCE: ISO 14723:2009, 4.32]

3.118**representative value**

value assigned to a *basic variable* (3.12) for *verification* (3.169) of a *limit state* (3.77)

[SOURCE: ISO 19900:2013, 3.38]

3.119**reserve buoyancy**

contingency buoyancy expressed in percentage of the nominal total intact buoyancy of *barges* (3.11) or vessels or floating *structures* (3.153)

[SOURCE: ISO 19901-6:2009, 3.68, modified for clarity.]

3.120**resistance**

capacity of a *structure* (3.153), component or a cross-section of a component to withstand *action* (3.1) effects without exceeding a *limit state* (3.77)

[SOURCE: ISO 19904-1:2006, 3.32]

3.121**return period**

average period between occurrences of an event or of a particular value being exceeded

Note 1 to entry: The offshore industry commonly uses a return period measured in years for environmental events. The return period in years is equal to the reciprocal of the annual probability of exceedance of the event.

[SOURCE: ISO 19901-1:2005, 3.23]

3.122**rigging**

slings, shackles and other devices including *spreader bars/frames* (3.145) used to connect the *structure* (3.153) being lifted to the crane

[SOURCE: ISO 19901-6:2009, 3.71]

3.123**rigging weight**

total weight of *rigging* (3.122), i.e. between the *lift points* (3.76) and the crane hook, including slings, *grommets* (3.62), shackles, lifting tools and *spreader bars or frames* (3.145) including contingency

[SOURCE: ISO 19901-6:2009, 3.72, modified for clarity.]

3.124**rotor-nacelle assembly**

part of an offshore wind turbine carried by the *support structure* (3.155)

Note 1 to entry: See Figure 1 for information.

[SOURCE: IEC 61400-3:2010; 3.35]

3.125**safe haven**

sheltered *location* (3.81) at which a *tow* (3.159) or transport can seek refuge from inclement weather

[SOURCE: ISO 19901-6:2009, 3.73]

3.126**safe condition**

condition where the object is considered to be exposed to a normal level of risk of damage or loss

3.127

scour protection

materials placed on the *seabed* (3.128) to prevent scour from developing around the *foundation* (3.60) where the foundation penetrates into the seabed

3.128

seabed

materials below the sea in which the *structure* (3.153) is founded, whether of soils such as sand, silt or clay, cemented material or of rock

Note 1 to entry: The seabed can be considered as the half-space below the *sea floor* (3.130).

[SOURCE: ISO 19901-6:2009, 3.74]

3.129

sea fastening

temporary fastening items which keep movable items in position during transportation at sea

[SOURCE: ISO 19901-6:2009, 3.75]

3.130

sea floor

interface between the sea and the *seabed* (3.128)

[SOURCE: ISO 19901-4:2003, 3.5]

3.131

search and rescue

SAR

operation to retrieve persons in distress, provide for their initial medical or other needs and deliver them to a place of safety

3.132

section of array cable

length of *array cable* (3.6) of a specific cable type between two *foundations* (3.60) or between a foundation and an *offshore substation* (3.102) or between a foundation and an onshore substation

3.133

self-propelled modular transporter

SPMT

platform (3.111) vehicle with a large array of steerable wheels, connected to a central spine beam by hydraulic suspension that can be raised or lowered

3.134

semi-submersible

floating *structure* (3.153) normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns connected to submerged pontoons

[SOURCE: ISO 19904-1:2006, 3.36]

3.135

significant wave height

H_s

mean wave height (crest to trough) of the one-third highest waves

3.136**site chart**

updated map of the *offshore installation site* (3.100) showing important information of e.g. all planned or existing *locations* (3.81), allowable jack-up positions, jack-up footprints, as as-built/as-laid information, safety zone, positions of all other equipment temporarily anchored in the offshore installation site such as measurement equipment, cardinal buoys, to allow the bridges of all *offshore installation vessels* (3.101) and other offshore spreads working in the offshore installation site to have the same information

3.137**skew load factor****SKL**

factor by which the load on any *lift point* (3.76), or pair of lift points, is multiplied to account for sling length mismatch in a statically *indeterminate lift* (3.71)

Note 1 to entry: The SKL distribution is applied for the design of the whole *structure* (3.153), the lifting points, the slings, the shackles and the *spreader bars or frames* (3.145).

[SOURCE: ISO 19901-6:2009, 3.78, modified - Note 1 to entry added.]

3.138**skidshoe**

bearing pad attached to the *structure* (3.153) that engages in the *skidway* (3.139) and carries a share of the vertical load

[SOURCE: ISO 19901-6:2009, 3.79]

3.139**skidway**

system of structural beams (concrete or steel) or rails, on the quay and on the floating unit, on which the *structure* (3.153) is loaded out via the *skidshoes* (3.138)

[SOURCE: ISO 19901-6:2009, 3.80]

3.140**skirt**

structure (3.153) constructed at or below the base of a structure that extends downwards from the bottom of the *foundation* (3.60) plate, penetrating into the *seabed* (3.128)

Note 1 to entry: Skirts are used to increase the capacity of the foundation to resist vertical and horizontal loads and improve erosion resistance.

[SOURCE: ISO 19901-6:2009, 3.81]

3.141**sling eye**

loop at each end of a sling, either formed by a *splice* (3.144) or by a mechanical termination

[SOURCE: ISO 19901-6:2009, 3.82]

3.142**special purpose vessel**

mechanically self-propelled vessel which, by reason of its function, might carry more than 12 special personnel

Note 1 to entry: A special purpose vessel fulfils various roles on *offshore wind farms* (3.103) including rock dumping vessel, fall pipe vessel, *unexploded ordnance* (3.168) survey, explosive ordnance disposal, and deployment and operation of bubble curtains for noise mitigation measures.

[SOURCE: Reference [41]]

3.143

splash zone

area of a *structure* (3.153) that is frequently wetted due to waves and tidal variations or during lift operations; also used during installation of *foundations* (3.60) when immersing the foundation components in the water

Note 1 to entry: Refers to the wave-affected zone of the water column surrounding a structure whether during installation phase or during operation.

[SOURCE: ISO 19901-6:2009, 3.83, modified – Note 1 to entry slightly reworded for clarity.]

3.144

splice

length of sling where the rope is connected back into itself by tucking the tails of the unit ropes back through the main body of the rope(s), after forming the *sling eye* (3.141)

[SOURCE: ISO 19901-6:2009, 3.84]

3.145

spreader bar

spreader frame

structure (3.153) designed to resist the bending and compression forces induced by angled slings by altering the line of action of the force on a *lift point* (3.76) into a vertical plane

Note 1 to entry: The usual purpose of a spreader bar or frame is to avoid a clash between the *rigging* (3.122) and the structure, which would result if the rigging were connected directly from the lift point to the hook.

[SOURCE: ISO 19901-6:2009, 3.85]

3.146

spud can

structure (3.153) which can be attached to the base of the jacking legs, normally a conical structure which provides stability to lateral forces on the jack-up when deployed into the sea-bed systems

3.147

squat effect

tendency of floating objects or vessels to undergo an increase in draught when underway in shallow water

[SOURCE: ISO 19901-6:2009, 3.86, modified for clarity.]

3.148

steel cable-laid sling

SCLS

assembly of several (usually six) round stranded *steel wire ropes* (3.149) (referred to as unit ropes), laid helically around a core (usually a seventh rope)

Note 1 to entry: The definition strictly applies to the type of steel wire rope construction. Cable-laid slings have hand-spliced eye end terminations by splicing the rope back on itself to form an eye termination.

Note 2 to entry: See IMCA LR 008, M 179 for guidance on the manufacture and safe use of cable-laid slings and *grommets* (3.62) amongst others for flemish eye resin filled sleeve termination (FERFS).

[SOURCE: ISO 19901-6:2009, 3.87, Note 2 to entry modified for clarity.]

3.149

steel wire rope

rope made of various types of steel wire construction

EXAMPLE A steel wire rope can be a stranded rope consisting of six or eight strands laid helically around a core (steel core, fibre core, IWRC), a spiral rope, etc.

Note 1 to entry: Each combination of material and type of construction normally results in different properties and characteristics.

[SOURCE: ISO 19901-6:2009, 3.88]

3.150**steel wire rope grommet****SWRG**

endless loop-shaped sling made up from a single length of round stranded *steel wire rope* (3.149)

Note 1 to entry: As for cable-laid slings, the steel wire rope used in a *grommet* (3.62) is also referred to as a unit rope.

Note 2 to entry: During the production of grommets, a temporary rigid core is used, which is replaced at the end of spiralling by the first half loop and the last half loop of the unit rope. When removing the temporary rigid core, the ends of the unit rope are tucked into the body of the grommet to form the core, with the tuck position diametrically opposite the core butt position.

Note 3 to entry: See IMCA LR 008, M 179 for guidance on the manufacture and safe use of cable-laid slings and grommets.

[SOURCE: ISO 19901-6:2009, 3.89 modified - Note 2 and 3 to entry reworded for clarity.]

3.151**steel wire rope sling****SWRS**

sling made from a single *steel wire rope* (3.149) with various possible end terminations

Note 1 to entry: Terminations include spliced eyes, flemish eye with swaged steel sleeve (also known as super loop), flemish eye resin filled sleeve (FERFS), spelter sockets, resin sockets, etc.

Note 2 to entry: See IMCA LR 008, M 179 for guidance on the manufacture and safe use of cable-laid slings and grommets (3.62).

[SOURCE: ISO 19901-6:2009, 3.90, modified – Note 2 to entry inserted for clarity.]

3.152**strength**

mechanical property of a material indicating its ability to resist *actions* (3.1), usually given in units of stress

[SOURCE: ISO 19902:2007, 3.49]

3.153**structure**

organized combination of connected parts designed to withstand *actions* (3.1) and provide adequate rigidity

[SOURCE: ISO 19900:2013, 3.49]

3.154**sub-structure**

part of an offshore wind turbine *support structure* (3.155) which extends upwards from the *seabed* (3.128) and connects the *foundation* (3.60) to the *tower* (3.160)

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3: 2010; 3.46]

3.155**support structure**

part of an offshore wind turbine consisting of the *tower* (3.160), *sub-structure* (3.154) and *foundation* (3.60)

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3:2010; 3.47]

3.156

termination efficiency factor

factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in *strength* (3.152) caused by a *splice* (3.144) or other end termination

[SOURCE: ISO 19901-6:2009, 3.93]

3.157

third party

person or body that is recognized as being independent of the parties involved, as concerns the issue in question

3.158

topside

structure (3.153) and equipment placed on a supporting *foundation* (3.60) such as a *tower* (3.160) including *nacelle* (3.95), *hub* (3.70) and *blades* (3.14) as well as topside for *offshore substations* (3.102) or *offshore accommodation platforms* (3.99)

Note 1 to entry: For a jack-up, the hull is not part of the topsides.

Note 2 to entry: A separate fabricated deck or module support frame is part of the topsides.

[SOURCE: ISO 19900:2013, 3.52, modified - Note 1 to entry slightly reworded for clarity.]

3.159

tow

marine transportation of an object or its supporting *barge* (3.11) by being pulled or pushed by tow vessel(s)

Note 1 to entry: A tow can be defined into the following types:

- dry: marine transportation of an object with the object located clear of the water aboard a barge or other unit;
- wet: marine transportation of an object with the object floating directly in the water.

[SOURCE: ISO 19901-6:2009, 3.95]

3.160

tower

tower constituting the part of a *support structure* (3.155) for the *wind turbine generator* (3.176) between the top flange of the *transition piece* (3.163) or top flange of the *foundation* (3.60) and the bottom flange of the *nacelle* (3.95) connecting the *sub-structure* (3.154) to the *rotor-nacelle assembly* (3.124)

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3]

3.161

trailer

unpowered vehicle towed by a powered vehicle used for transport

3.162

transport frames

steel *structure* (3.153) to support, if required, the onshore transport of the *wind turbine generator* (3.176) components which will be joined onto the corresponding steel structure at the vessel [i.e. *bolting* (3.16) frames or twistlocks] for seafastening

3.163

transition piece

part of the *foundation* (3.60) connecting the *foundation support structure* (3.155) to the *wind turbine generator* (3.176) *tower* (3.160)

3.164**tripod**

three-legged offshore *foundation* (3.60), normally fixed by piles to the *seabed* (3.128)

3.165**trunnion**

lift point (3.76) on a *structure* (3.153) consisting of a tubular member or cast cantilever with a stopping plate at the end, around which a sling or *grommet* (3.62) can be passed

Note 1 to entry: An upending trunnion is used to rotate a structure from horizontal to vertical, or vice versa, and the trunnion forms a bearing point around which the sling, grommet or another structure rotates.

[SOURCE: ISO 19901-6:2009, 3.97]

3.166**tugger line**

line between a winch and an object to control the orientation and position to prevent or reduce the motion, or to position a lifted object during an installation operation

[SOURCE: ISO 19901-6:2009, 3.98]

3.167**upending**

process of changing the orientation of an object in the water from the horizontal to the vertical by means of ballasting, flooding, by crane assistance or a combination of these techniques, or in air only by means of crane assistance

EXAMPLE Upending in air only by means of crane assistance, *monopile* (3.93) using upending tool or bucket.

[SOURCE: ISO 19901-6:2009, 3.99]

3.168**unexploded ordnance****UXO**

explosive weapons (bombs, naval mines, etc.) that did not explode when they were deployed mostly during wars in the sea and still pose a potential risk of detonation once touched during *marine operation* (3.82) by either jack-up vessels or equipment during *cable laying* (3.20) and *cable burial* (3.19) or *deburial*

Note 1 to entry: Explosive remnants of war that has been primed, fused, armed or otherwise prepared for use or used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction or design or for any other reason (jettison or dumping). UXOs laying on *seabed* (3.128) or buried pose a risk of blast or detonation once stimulated with sufficient energy during marine operations (geotechnical operations, cable laying with ploughing and trenching or piling operations).

3.169**verification**

examination made to confirm that an activity, product, or service is in accordance with specified requirements

[SOURCE: ISO 19901-6:2009, 3.100]

3.170**watertight**

capability of preventing the penetration of water into or through the *structure* (3.153) with a water pressure head corresponding to that for which the surrounding structure is designed

[SOURCE: ISO 19901-6:2009, 3.101]

3.171

weather-restricted operation

marine operation (3.82) that can take place safely within the limits of a favourable weather forecast

Note 1 to entry: It is not necessary that the design weather criteria reflect the statistical extremes for the area and season. A suitable factor should be applied between design weather criteria and operational weather limiting criteria.

[SOURCE: ISO 19901-6:2009, 3.102]

3.172

weathertight

capability of preventing the penetration of water into the *structure* (3.153) during temporary exposure to water

Note 1 to entry: A watertight closing appliance is also considered weathertight.

[SOURCE: ISO 19901-6:2009, 3.103]

3.173

weather-unrestricted operation

marine operation (3.82) that can take place safely in any weather condition that can be encountered during a season

Note 1 to entry: The statistical extremes for the area and seasons are considered in the design weather criteria.

[SOURCE: ISO 19901-6:2009, 3.104]

3.174

weather window

operational duration (3.106) including a contingency period determined with due allowance for the nature and criticality of the individual operations (safe to safe) and for which forecast environmental conditions remain below prescribed operational limits

3.175

50/50 weight estimate

value representing the median value in the probability distribution of weight estimates

Note 1 to entry: The actual weight is equally likely to be smaller or larger than the 50/50 weight estimate.

Note 2 to entry: The 50/50 weight estimate is used as the basis for weight budgeting.

[SOURCE: IEC 61400-3:2010, Figure 1]

3.176

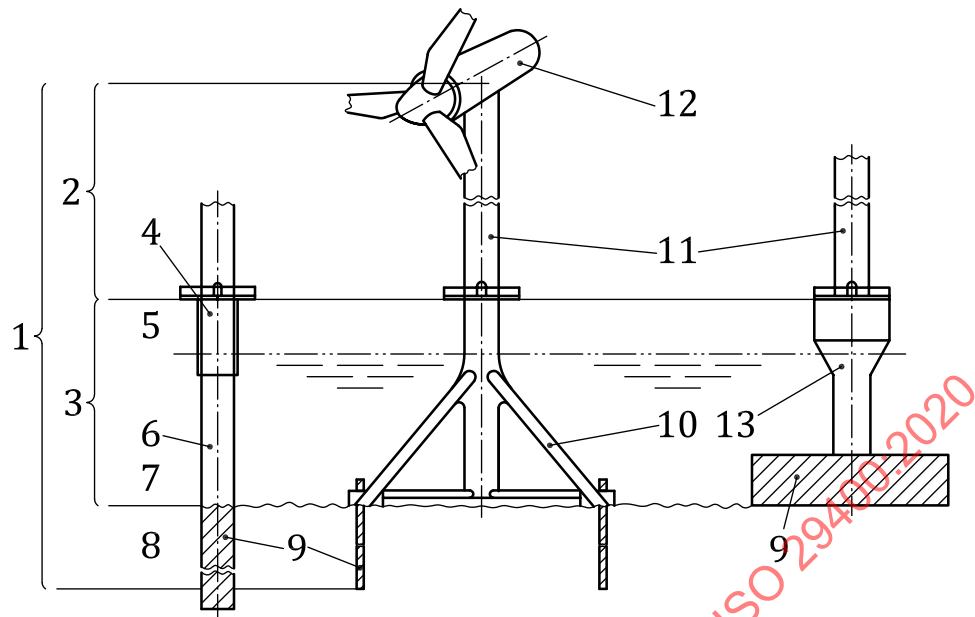
wind turbine generator

offshore wind turbine generator

WTG

turbine generator which converts the kinetic wind energy into electric energy, typically including the *tower* (3.160), the *nacelle* (3.95), the rotor, the *blades* (3.14) and the associated equipment

Note 1 to entry: See Figure 1 depicting all parts of an offshore wind turbine.



Key

1 support structure	6 pile	11 tower
2 tower	7 sea floor	12 rotor-nacelle assembly
3 sub-structure	8 seabed	13 GBS
4 transition piece with platform	9 foundation	
5 water level	10 jacket/tripod	

Figure 1 — Parts of an offshore wind turbine (SOURCE: IEC 61400-3:2009, Figure 1)

3.177

working load limit

WLL

maximum load that can safely be applied to a rope, sling, *grommet* (3.62), shackle or *lift point* (3.76) or lifting tool or *spreader bar or frame* (3.145)

[SOURCE: ISO 19901-6:2009, 3.106, modified for clarity.]

4 Symbols and abbreviated terms

4.1 Symbols

A_1, A_2, A_3 ,	areas under or between the wind heeling moment curve and the hydrostatic righting moment curve (see Figures 4 and 5)
B_0	total available buoyancy of the structure
B_r	reserve buoyancy, expressed in percent of B_0
d	nominal diameter of a rope, sling or leg of a grommet, expressed in millimetres
d_h	diameter of shackle pinhole, expressed in millimetres
d_p	diameter of shackle pin, expressed in millimetres
f_{fr}	calculated percentage friction force

f_{SF}	safety factor (in WSD method)
$f_{SF,FRS}$	safety factor for a fibre rope sling
$f_{SF,FRG}$	safety factor for a fibre rope grommet
$f_{SF,sh}$	safety factor for a shackle (in WSD method)
$f_{SF,Y}$	safety factor for component Y (in WSD method)
$F_{CS,FRS}$	corresponding breaking strength of a fibre rope sling
$F_{CS,FRG}$	corresponding breaking strength of a fibre rope grommet
F_{dgf}	design grommet force (for a complete grommet)
$F_{dgf,1}$	design force for one leg of a grommet
F_{dhl}	design hook load for a one-crane lift
$F_{dhl,i}$	design hook load on hook i for a two-hook lift
F_{dsf}	design sling force for a one-part sling
$F_{dsf,2\text{ parts}}$	design sling force for each part of a two-part sling
F_{hl}	“dynamic” or nominal hook load, expressed in kilonewtons
F_{rgf}	representative grommet force (for a complete grommet)
$F_{rgf,1}$	representative force for one leg of a grommet
F_{rhl}	representative hook load for a one-hook lift by a single crane
$F_{rhl,i}$	representative hook load on hook i for a two-hook lift ($i = 1, 2$)
F_{rsf}	representative sling force for a one-part sling
$F_{rsf,2\text{ parts}}$	representative sling force for each part of a two-part sling
$F_{srhl,i}$	nominal hook load, F_{hl} , statically resolved between hooks ($i = 1, 2$)
F_{BP}	continuous static bollard pull of each tug, expressed in kilonewtons
$F_{DS,FRS}$	design strength of a fibre rope sling, in force terms;
$F_{DS,FRG}$	design strength of a fibre rope grommet, in force terms;
$F_{DS,sh}$	design strength of a shackle in force terms
$F_{DS,Y}$	design strength of component Y in force terms, where Y is a sling or a grommet (in PFD method)
F_{min}	minimum value of the breaking strength of a steel wire rope, expressed in kilonewtons
f_{MR}	is the metocean reduction factor (alpha factor according to Reference [56] or as determined project-specifically);
F_{PR}	minimum towline pull required, expressed in kilonewtons
$F_{RS,sh}$	representative strength of a shackle in force terms
$F_{RS,FRS}$	representative strength of a fibre rope sling

$F_{RS,FRG}$	representative strength of a fibre rope grommet
$F_{RS,Y}$	representative strength of component Y in force terms, where Y is a sling or a grommet (see 19.6)
$F_{WLL,FRS}$	WLL of a fibre rope sling, in force terms
$F_{WLL,FRG}$	WLL of a fibre rope grommet, in force terms
$F_{WLL,sh}$	working load limit (WLL) of a shackle in force terms
$F_{WLL,Y}$	working load limit (WLL) of component Y in force terms, where Y is a sling or a grommet (in WSD method)
g	acceleration of gravity, equal to 9,81 m/s ²
H_c	height of cribbing above deck, expressed in millimetres
H_{max}	maximum anticipated wave height at the site during loadout, expressed in metres
H_s	significant wave height, expressed in metres
k_{be}	bending efficiency factor
k_{CoG}	CoG factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the lift weight between the lift points
k_{DAF}	dynamic amplification factor
k_{lf}	lateral force factor
k_{sf}	CoG shift factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the total hook load between the two hooks
k_{skl}	skew load factor, the value of which reflects unequal load sharing in an indeterminate lift between slings that differ in length as a result of manufacturing tolerances
k_{te}	termination efficiency factor
k_{tf}	tilt factor, the value of which reflects the effect of uneven heights of the crane hooks and/or uneven hoisting speeds when statically distributing the total hook load between the two hooks
k_{wcf}	weight contingency factor
k_{yaw}	yaw factor, the value of which reflects the effect of yawing during lifting with two cranes when statically distributing the lift weight between the lift points
l_{freebd}	effective freeboard, expressed in metres
L_{lim}	is the design operational limit (operational limiting criteria according to Reference [56]).
L_{WF}	is the forecasted operational limit (forecasted operation criteria according to Reference [56]);
P_{clf}	calculated lateral force on a lift point due to known misalignment between the orientation of the lift point and the sling direction (where applicable)
P_{dlf}	design lateral force on a lift point
P_{ddf}	design force on a lift point in line with the sling direction

P_{dvf}	design vertical force on a lift point
P_{rlf}	representative lateral force on a lift point
P_{rdf}	representative force on a lift point in line with the sling direction
P_{rvf}	representative vertical force on a lift point
T_C	is the estimated maximum contingency period.
T_{eff}	tug efficiency in the considered sea conditions, expressed in percent
T_{POP}	is the planned operation duration (or the duration required to stop the operation and go back to a safe condition);
T_R	is the weather window (operation reference period according to Reference [56]);
W	gross weight
W_c	cargo weight, expressed in kilo newtons (kN)
W_{cw}	calculated weight
W_{lw}	“dynamic” or nominal lift weight
$(W_{rlw})_{one\ crane}$	representative lift weight on a lift point for one-hook lifts by one crane
$(W_{rlw})_{two\ cranes}$	representative lift weight on a lift point for lifts by two cranes
W_{rw}	rigging weight
$W_{rw,i}$	rigging weight associated with crane hook i ($i = 1, 2$)
W_s	weight of the sling
W_{st}	static hook load
$W_{srlw,i}$	statically resolved lift weight for crane hook i ($i = 1, 2$)
$W_{srlw,j}$	statically resolved lift weight acting on lift point j
$W_{srlw,i,j}$	statically resolved lift weight for crane hook i acting on lift point j
W_{ww}	weighed weight
W_0	weight of the structure in air
Y	grommet types SWRG or FRG
$\gamma_{f,hl}$	partial action factor for hook load (in PFD method)
$\gamma_{f,lp}$	partial action factor for forces on a lift point when designing lift points and their attachment to the structure (in PFD method)
$\gamma_{f,mf}$	partial action factor for forces on a lift point when designing structural members directly supporting or framing into the lift points (in PFD method)
$\gamma_{f,m}$	partial action factor for forces on a lift point when designing other structural members (in PFD method)
$\gamma_{f,s}$	partial action factor for forces in slings, grommets and shackles (in PFD method)

γ_R	partial resistance factor (in PFD method)
$\gamma_{R,FRS}$	partial resistance factor for a fibre rope sling
$\gamma_{R,FRG}$	partial resistance factor for a fibre rope grommet
$\gamma_{R,sh}$	partial resistance factor for a shackle (in PFD method)
$\gamma_{R,Y}$	partial resistance factor for component Y (in PFD method) Y = SWRS; SCLS; FRS; SWRG or FRG
ϕ_{max}	maximum dynamic heeling angle due to wind and waves, expressed in degrees
θ	angle between the sling and the horizontal plane, expressed in degrees

4.2 Abbreviated terms

AAAA	Always afloat, always accessible
AIS	Automatic identification system
ALARP	As low as reasonably practicable
AMS	Anchor management system
ASD/WSD	Allowable stress design/working stress design
CAD	Computer aided design
CBRA	Cable burial risk assessment
CCTV	Closed circuit television
CGBL	Calculated grommet breaking load
CoG	Center of gravity
COLREGS	International regulations for preventing collisions at sea
COSHH	Control of substance hazardous to health
CPT	Cone penetration test
CRBL	Calculated rope breaking load
CTV	Crew transfer vessel
DAF	Dynamic amplification factor
DGPS	Differential global positioning system
DoC	Depth of cover
DoL	Depth of lowering
DP	Dynamic positioning
EPIRB	Emergency position indicating radio beacon
ERCoP	Emergency response cooperation plan

ETA	Estimated time of arrival
ETD	Estimated time of departure
FIFO	First-in-first-out
FMEA	Failure mode and effects analysis
FRG	Fibre rope grommet
FRS	Fibre rope sling
GA	General arrangement
GBS	Gravity base structure
GDB	Geo data base
GDPR	General protection regulation (EU)
GIS	Geographical information system
GM	Effective metacentric height
GNSS	Global navigation satellite system
GZ	Metacentric height
HAZID	Hazard identification study
HAZOP	Hazard and operability study
HDD	Horizontal direction drilling
HSSE	Health, safety, security and environment
ICPC	International cable protection committee
ID	Personal identification
IHO	International Hydrographic Organization
IMCA	International Marine Contractors Association
IMDG	International maritime dangerous goods
IMO	International Maritime Organization
ISM	International safety management
ISPS	International ship and port facility safety
LAN	Local area network
LAT	Lowest astronomical tide
LIFO	Last-in-last-out
LRFD	Load and resistance factor design
MBES	Multibeam echosounder

MBL	Minimum breaking load
MBR	Minimum bending radius
MBS	Minimum breaking strength
MC	Marine coordination
MRCC	Marine rescue coordination center
MSDS	Material safety data sheet
MWS	Marine warranty surveyor
NDT	Non-destructive test
NTE	Not-to-exceed
OHS	Occupational health and safety
OWF	Offshore wind farm
PFD	Partial factor design
PLGR	Pre lay grapnel run
PMS	Positioning monitoring system
PNR	Point of no return
PPE	Personal protective equipment
pUXO	Possible UXO
QRA	Quantified risk analysis
RAMS	Risk assessment and method statements
RCS	Recognized classification society
ROV	Remote operated vehicle
RPD	Rack phase difference
RPL	Route positioning list
RTK	Real time kinematic system
SAR	Search and rescue
SCLS	Steel cable-laid sling
SHL	Static hook load
SKL	Skew load factor
SOLAS	Safety of life at sea convention
SPMT	Self-propelled modular transporters
SWL	Safe working load

SWRG	Steel wire rope grommet
SWRS	Steel wire rope sling
TV	Television
ULS	Ultimate limit state
UXO	Unexploded ordnances
VIO	Vortex induced oscillations
WG84	World Geodetic System
WLL	Working load limits
WSD	Working stress design
WTG	Wind turbine generator

5 General considerations

5.1 Introduction

5.1.1 General

There are three categories of “port facility” when installing, maintaining, repairing and decommissioning offshore wind farms:

- almost all WTG components, foundations, topsides and cabling are manufactured in facilities adjacent to a loadout quay, and this constitutes the “manufacturer’s port”;
- most often the components are transported to a marshalling port, from where they are loaded out onto the installation vessel and taken to the offshore wind farm, but sometimes they are transferred directly from the manufactures to the OWF on board the installation vessel;
- during the operational phase and partially during installation, there can be maintenance issues that arise. Maintenance teams can be mobilised from a “maintenance port”.

In terms of activities at ports there are three distinct types:

- vessel operations associated with transportation which can be characterized as “project cargo logistics”;
- vessel operations associated with loadout and installation when components leave the marshalling port;
- vessel operations when components leave the maintenance port are associated with equipment that requires maintenance during marine operations.

Port operations include activities at the staging port in order to prepare the components for loadout as well as any preparations of the port areas for the construction, maintenance, repair or decommissioning. Such operations can include:

- pre-assembly of components;
- temporary storage;
- positioning components at the quayside for loadout;
- set-up of offices for construction;

- implementation of port security measures;
- offload of components from barge or vessel to shore;
- soil preparation and levelling of the marshalling port;
- seabed dredging and/or rock placement adjacent to the loadout quay.

Marine operations related to offshore wind farms include short-term marine movements and other activities where the structure(s) or the operation is at risk from the marine environment. Such operations include but are not limited to:

- loadout from shore to barge or vessel;
- launching from shore, or sheltered areas or barge to water, e.g. floating monopiles;
- float-out topsides from dry docks;
- wet or dry towage and other marine transportations;
- temporary anchoring and stationkeeping during construction;
- installation by means of launching or float-off, upending, lowering by ballasting, float-over or lifting;
- cable installation and cable repair;
- positioning, jacking and pre-loading jack-ups and leg stabilised units;
- unexploded ordnance survey;
- geophysical and geotechnical surveys;
- refuelling offshore substations and temporary generators used on WTG before full energization (if required);
- bunkering of offshore installation vessels;
- provisioning of vessels and structures in the offshore wind farm;
- paint repair works;
- scour protection;
- component exchange;
- decommissioning and total or partial removal of the structure including reinstatement of the environmental conditions prior to site development to the extent required.

General requirements and guidance on safety and emergency issues, and reference to applicable legislation, are contained in [5.1.2](#) to [5.10](#). Effective management of these issues requires full knowledge of applicable regulatory requirements.

General disclaimer to technical requirements on stability, crane and towline stated in these rules: if special purpose vessels are used, IMO rules apply in respect to these requirements.

5.1.2 Safety requirements

Personnel is the most valuable asset and protecting them should be at the forefront of any HSSE endeavour.

A system such as ISO 45001^[66], "Occupational health and safety (OHS) management system", or any other equally acceptable system should be used.

The overall objective of the safety of marine operations is to perform all operational activities at minimum risk of accidents or incidents to personnel, environment and property. This can be met if the following factors to minimize the risk are taken into consideration:

- the operation is designed taking into account the statistical weather extremes for the area and season;
- the operational weather conditions, chosen at values not exceeding the specified operational limits, are forecasted for a sufficiently long period to enable completion of the operation;
- the required equipment, vessels and other means are designed and checked for adequate performance with respect to their intended use;
- there is redundancy in the critical equipment provided to cover possible breakdown situations;
- the operations are planned, in nature and duration, such that accidental situations, breakdowns or delays have a very low probability of occurrence and are covered by detailed contingency plans;
- adequate documentation has been prepared for a safe, step-by-step execution of the operation, with clear indications of the organization and chain of command;
- the operations are conducted by competent personnel;
- safe systems of work are devised in light of a systematic risk assessment.

Special precautions shall be adhered to during jacking operations. Location specific assessment and procedures shall be provided by each of the respective offshore installation vessels for each jacking location in a vessel approach plan and, where appropriate, reviewed by the marine warranty surveyor before jacking operations take place. Marine coordination during construction works shall issue a site chart (showing the locations of the structures and cables, etc. in the offshore site) which shall be used by all offshore installation vessels in planning their vessel movements. The approval of the vessel approach plan by a marine warranty surveyor (MWS) can be a precondition for obtaining a permit to access the location in question.

Each of the respective offshore installation vessels shall take full account of the exact locations where vessels have previously jacked and the positions of proposed and/or installed subsea cables and scour protection.

In case of anchoring, the respective offshore installation vessel shall provide detailed anchor plans taking full account of project plan, subsea cables, etc. for approval by the MWS. Actual anchor positions shall be documented by the offshore installation vessel when deployed and again when recovered. Each of the respective offshore installation vessel safety zones shall take into account anchor positions.

5.2 Jurisdiction

5.2.1 Introduction

Installation of offshore wind farms and related port and marine operations are subject to approval by appropriate parties in due time before actual activities commence. Thus, national and international regulations and guidelines on personnel safety and protection of the environment are the governing requirements. It should also be noted that marine operations can involve more than one nation's area of jurisdiction and that, for barges and vessels, while the flag state jurisdiction is primary, additional requirements can be imposed by the coastal or port state.

5.2.2 Safety of life at sea

In order to respect the safety of life at sea, information with respect to conventions, codes and guidelines is required. The information is subdivided into separate provisions with respect to vessels on international voyages and vessels on domestic voyages, and is further subdivided to separately address mandatory instruments (i.e. conventions) and recommended instruments (i.e. codes and recommendations).

For vessels on international voyages, the vessel's flag state generally requires the vessel's compliance with the international conventions and mandatory codes identified in References [22] to [28], [39] and [44]. Such compliance is generally demonstrated by the issuance of the relevant certificate mandated by the convention.

Before selection of any vessel where the vessel's flag state is not party to the most recent protocols or amendments to the instruments referenced above, careful consideration should be exercised.

The international conventions identified in References [22] to [28] do not apply to domestic voyages. In such cases, national standards offering equivalent levels of safety should be applied.

References [34], [38], [40] to [42], and [45] to [48] provide recommendations that the flag state can adopt and apply as mandatory requirements, as applicable, to vessels under their jurisdiction. Where these are not adopted and applied by the flag state, national standards offering equivalent levels of safety should be applied.

5.2.3 Environment

A system such as the suit of standards ISO 14000^[64], "Environmental management", or any other equally acceptable system should be used.

The legislation for the protection of the environment is evolutionary and covers various aspects. It is embodied in a number of instruments of broad scope, from the law of the sea and general practices covering natural resources exploitation, protection of marine environment, pollution and dumping of waste, through to international conventions, regional conventions and national rules.

Applicable international conventions can be found in References [32] to [34].

5.3 HSSE plan

A health, safety, security and environment (HSSE) plan shall be established. The objectives of the plan shall be:

- to protect the health of the workforce;
- to document the HSSE standards, processes and procedures that apply to the work;
- to identify, assess and manage hazards and risks arising during the work, reducing the risks to as low as reasonably practicable (ALARP);
- to ensure that safety is inherent in planning and design of the work;
- to ensure minimal impact on the environment;
- to ensure the security of the work site, particularly the port facilities including components and access procedures.

The HSSE plan shall identify the allocation of responsibilities and interfaces during each phase of the project, together with the specific procedures, methods and work instructions to be applied, including risks from simultaneous operations at the construction site.

Selected issues to be taken up in the HSSE plan are described in 5.4 to 5.10.

5.4 Risk management

5.4.1 Introduction

For risk management, a recognized standard shall be used, such as ISO 31000^[65] or ISO 17776^[3]. In any case, the provisions of 5.4 and 5.5 apply.

It is good industry practice that no major activity is carried out on a site without an approved method statement, describing all performed activities in detail. The risk assessment process shall be part of that approval procedure. The risk assessment resulting in RAMS to be provided, shall analyse the activities performed in the method statement.

A mandatory interface shall be defined to ensure that there is extensive and adequate communication with all parties involved in the project. All relevant parties on project (internal or external) shall contribute to the RAMS assessment (including engineering and installation design). As a consequence, all design phase documents related to the installation shall be cross referenced in the method statements.

The overall responsibility for risk management shall be clearly defined when planning marine operations.

Risk management shall be applied to the project to reduce the effects of hazards and to limit the overall risk. This objective can be achieved by addressing the following functions in turn:

- identification of potential hazards;
- assessment of risk potential;
- prevention of hazards wherever possible;
- control to reduce the potential consequences of unavoidable hazards;
- measures to reduce the probabilities of occurrence of an incident, or to mitigate the consequences of an incident, should one occur.

Each port and marine operation, including each major system that is essential to the performance and safety of port and marine operations, e.g. lifting procedures, power generation and supply systems, ballast and compressed air systems, shall be subjected to a documented hazard study.

Personnel and organisations involved in port and marine operations, as well as those involved in the design and operation of the systems, shall take part in the hazard studies.

It is recommended that consequence assessment be used to rank the probabilities and consequences of various events, to form a basis for further investigation if necessary.

5.4.2 Techniques to evaluate risks

Appropriate techniques to evaluate risks include, but are not limited to:

- design and execution: HAZOP, HAZID, and scenario based risk assessments;
- execution implementation: job safety analyses, safety campaigns and drills, hazard hunts and tool box talks, which can be applied at field supervision level.

QRA techniques can be used:

- to compare levels of risk between alternative proposals or between known and novel methods;
- to enable rational choices to be made between alternatives.

5.5 Job safety analysis

Job safety analysis should be performed to detail the:

- sequence of the operation;
- equipment to be used at each stage;
- hazards to be controlled;

- precautions to take and the responsibilities of persons involved.

The analysis should be performed and documented by the port contractor as well as the marine contractor for their respective field of work. When completed, the results of the job safety analysis should be communicated to personnel involved in the various operation activities through kick-off meetings and tool-box talks resulting in officially issued permit-to-work documents.

5.6 Environmental impact study

An environmental impact study shall be carried out to identify and deal with risks to the environment (e.g. waste management, disposal at sea, hazardous materials), to people and wildlife (e.g. toxicity, explosives, noise, vibrations and other disturbances).

5.7 Manning, qualifications, job and safety training

Personnel shall be appropriately qualified, trained and should be assessed for the work they are expected to undertake so as to ensure that they can undertake that work competently. Communication should be agreed to be conducted in a language commonly shared by all key personnel. Supervisors shall possess a thorough knowledge of the entire operation under their control and have prior experience with similar operations. Other key personnel shall have knowledge and experience within their area of responsibility.

Qualification and competence requirements for job categories critical to safe operations shall be specified. Special care and training shall be given to all repetitive offshore operations such as installation of foundations, cable laying and burial, WTC-tower installation as well as nacelle and blade installation. Before commencement of an operation, personnel involved shall be briefed by the supervisors regarding responsibilities, communication, work procedures and safety, as well as given a step-by-step run-through of the operation for example by means of a toolbox talk.

Job-specific training shall be carried out and should cover the following topics:

- general and specific site regulations;
- legal obligations;
- instructions regarding the operation in question and any associated activities;
- instructions regarding the use of the components of the offshore wind farm and equipment used for marine operations.

Computer simulations, model tests and simulator training of the operation can give valuable information for the personnel carrying out the operation.

Personnel shall receive safety training which shall include general safety requirements, emergency training and drills, as appropriate to the job requirements and to the locations in which work is to be performed and considering applicable national and international conventions, codes and guidelines.

Fire and evacuation alarms and drills shall be respectively periodically tested and carried out as required by applicable safety legislation. Where more than one manned platform or vessel is affected by the construction activities, consideration should be given to joint emergency drills.

An up-to-date list with information of next of kin should be maintained.

5.8 Daily progress and incident reporting

During port and marine operations, daily progress reports shall be provided once in 24 h. They can include:

- time of operational and stand-by activities over 24 h;
- fuel consumption;

- main crew on board;
- incident, accident and near-miss accident reports;
- pollution or substantial threat of pollution reports.

Specific requirements on incident reporting, investigation and loss adjusting could apply in case of incidents related to the construction-all-risk insurance (where in place). Incident reporting depends on the contract requirements and governmental regulations and should preferably be provided as soon as possible after the incident occurred. Content of incident reporting including root-cause-analysis as well as communication path should be determined before start of operations

5.9 Personnel tracking

A suitable security and tracking system corresponding to the requirements as stated in the HSSE plan where allowed by government regulations/legislation should be in use to:

- record the presence of personnel on the port premises and the installation and supporting vessels;
- track their whereabouts;
- restrict access to certain areas to authorized personnel only, if required.

Recording for each individual shall include information such as name, address, telephone number, NOK information, date and expiry of training and health certificates, records of site inductions, etc. including facilities to register PPE with inspection intervals. Where nationally applicable, use of this data can be subject to existing regulations, such as the EU General Data Protection Regulation (GDPR).

Each person shall receive his/her personal identification (ID) card or equivalent which shall always be verifiable when on the site. Whenever a person is scheduled to go offshore, the database shall be checked by construction management to investigate if all training, inductions, etc. are in place for the person and fits the task to be performed; The ID card or equivalent can be used for electronic tracking of personnel movement by presenting the card to a terminal on the vessels when a vessel or installation is boarded or left. In this case the ID and location is automatically recorded in the people tracking system. If the electronic system is not used, the system shall be kept up to date semi manually by the owner's construction management based on e-mail and voice communication.

During the installation of an offshore wind farm, multiple installation and commissioning works are likely to simultaneously take place at various locations, e.g. commissioning of foundations, array cables, and mechanical and electrical completion of WTG as well as contractual taking-over between owner's contractors and owners. Due to these works, high traffic via crew transfer vessels, accommodation vessels or helicopters is likely during the construction phase which require an effective personnel tracking system.

NOTE Requirements of the ISPS Code^[21] can apply.

5.10 Approval by national authorities

National authorities can decide to survey and approve the operations, or parts thereof.

6 Organization, documentation and planning

6.1 Introduction

The organization, documentation and planning that shall be set up for the performance of port and marine operations are outlined in 6.2 to 6.8. The extent and detail of documentation shall suit the complexity and risks involved in the operation.

6.2 Organization and communication

6.2.1 Project organization

An appropriate organization shall be set up to govern how the port and marine operations integrate with the rest of the project. Key responsibilities shall be clearly defined. The responsibilities and reporting lines shown on the organization chart shall include but not be limited to:

- owner's organization and project management for the project;
- contractor's project management for the project;
- engineering design;
- procurement;
- manufacturing;
- port operations;
- marine operations;
- marine coordination;
- HSSE management;
- project controls;
- quality management;
- interface management;
- document management.

6.2.2 Operational organization

Separate organization charts shall be drawn up for each port and marine operation, showing the reporting line into the project organization. The details of the organization charts and their overall setup should be consistent with the size or complexity of the project and should be limited to the parties actually involved. Each operational organization chart should indicate, as appropriate, the functional links among the following entities:

- owner's representative;
- overall project management;
- operational management;
- port management;
- marine coordination;
- towing vessels;
- mooring and anchoring systems;
- marine spread;
- ballast system operation;
- weather forecasting;
- support services;

- marine warranty services;
- certification services;
- advisory panel providing expertise as required;
- HSSE management;
- statutory, regulatory and approving bodies.

In each case, the responsibilities and duties of each function should be clearly defined and published to minimize uncertainties and overlapping responsibilities.

Where transfer of responsibility is involved, the hand-over point from one organization to another (e.g. fabrication to marine operations, or onshore to offshore operations) should be identified.

During on-going marine operations, the selection of site team members shall be limited to those persons with defined roles during the operation. Any organisational changes that are part of an emergency response should be clearly identified. Back-up services, including emergency services, contingency assistance and technical advisory services, shall be identified and appropriately located.

Communication systems, including radio channels, telephone, telefax, internet, e-mail and out-of-hours numbers, shall be identified.

Personnel changes that occur during the course of an operation as a result of shift changes should be identified. Every effort should be made to avoid changes of personnel during critical stages of the operation.

Key personnel participating in port and/or marine operations shall communicate in one language.

For preparation of appropriate operational manuals, information on operational organization should also be included, see [6.5.2](#) to [6.5.6](#).

6.3 Quality assurance and administrative procedures

An acceptable quality management system shall be in place and all activities shall be managed through it. A system such as the ISO 9000- series^{[16], [17]}, or any other equally acceptable system, may be used.

The ISM Code^[39] requires that operators of vessels have a management system verified by valid ISM certificates; see [6.6.2](#). This does not apply to operators of those vessels that are exempted under national or flag state regulations.

6.4 Technical procedures

Technical procedures shall be set up to control the design and engineering related to port and marine operations. They shall be documented in RAMS.

These procedures shall define the use of applicable technical standards and ensure agreement and uniformity on matters such as:

- the use of international and national standards;
- the use of certifying authority/regulatory body standards;
- project information and conditions;
- design briefs and design basis;
- metocean criteria;
- calculation procedures;

- method statements;
- risk assessments.

Design briefs are defined as the fundamental principles and philosophy upon which the design basis and detailed design of port and marine operations are based. Design briefs include, among others, design criteria, methods of analysis, acceptance criteria and a description of software used.

Port and marine operations involving procedures that are not proven by past experience shall require analysis and/or the performance of simulations and/or model tests to demonstrate the adequacy of the planned procedures. Such analyses, simulations or model tests shall be used primarily to investigate the anticipated motions and the stability of the structure during any critical phases of port and marine operations.

6.5 Technical documentation

6.5.1 Document numbering system

The document numbering system used for RAMS for ports and marine operations should normally follow and comply with the overall numbering system already in place for the project. As an alternative, a specific document numbering system and document register may be used.

Documents describing RAMS for port and marine operations shall be clearly identified by number, revision and date, type of document, discipline involved and review status as defined by the document numbering system managed by the document control organization implemented by the project.

6.5.2 RAMS for port and marine operations

6.5.2.1 Documents describing RAMS for port and marine operations should be grouped, for example:

- design basis and criteria documents;
- structural weight control reports including weighing procedures if applicable and weighing reports;
- port operations procedure documents (pre-assembly, intermediate storage, transport of components to the quayside, loadout including mooring arrangements or jacking procedures);
- marine operations procedures documents (transport including towing where applicable and installations of all components of the offshore wind farm);
- supporting documents, including definitions of actions, structural and naval architectural calculations, systems operational manuals, equipment specifications and decommissioning reports.

RAMS and procedural documents that are intended for use as an active tool during port and marine operations should include a section that clearly shows their reference to higher and lower level documents and should list interrelated documents. They should be written with the end user in mind providing consistent and accurate information while avoiding unnecessary duplications.

RAMS for port or marine operations should be available and accessible on board or on-site close to the operation for reference by anyone that is involved.

All technical drawings should be provided in draughting form to an acceptable standard, such as ISO 128-1.

6.5.2.2 Elements that are considered essential and that should be included in or referred to by RAMS for port and marine operations are the following:

- project system management:
 - project organization, responsibilities and lines of command;

- job descriptions for key personnel;
- organisational chart;
- offshore installation site and marking;
- contractual approvals and hand-over;
- appendices listing more detailed information, such as drawings, equipment specifications, site information, dimensional control, operational monitoring and control systems, logging of operational control parameters, communication systems, ROV procedures, check lists;
- operational schedule (programme) as bar chart, showing the anticipated operational duration of each activity split into single steps, defined contingency durations, adverse weather durations, indicating interrelated activities and accounting for anticipated learning curves during the operations;
- preparations, surveys and outline check lists;
- specific step-by-step instructions for each phase of the operation, including sequence, timing, resources, key decision points and hold points;
- calculations showing the acceptability/limits of the planned operations;
- principles for transport and transfer of personnel:
 - access for personnel to the offshore site;
 - personnel database;
 - procedures for offshore transfer of personnel;
 - night transfers, transfers in reduced visibility and bad weather;
- principles for project related vessel traffic and access to the site:
 - vessel requirements for weekly traffic information;
 - guard vessel;
 - principles for accessing the site;
 - restricted areas and exclusion zones;
 - trespassing traffic;
 - results of related calculations, e.g. environmental actions, moorings, ballast, stability, bollard pull;
 - HSSE plan: safety plan, including a description of safety equipment, the location and signalization of safety routes, and requirements for personnel training, contingency plans;
 - emergency response cooperation plan (ERCoP);
 - information on authorities and permits, including notification requirements;
 - environmental criteria, including design and operational limits.

6.5.3 Operational schedule/programme

A detailed activity schedule should be established showing how port and marine operations are planned. The schedule should be presented as an operational bar chart, showing the duration of each repetitive and non-repetitive activity, interrelated activities, key decision points and hold points.

For weather-restricted activities, the operational schedule/programme shall be set equal to the following items:

- operational duration for a specific operation plus a certain time contingency determined with due allowance for the nature and criticality of the individual operations (safe to safe). The operational duration plus the time contingency result in the required weather window for the operation;
- estimated weather downtime covering the time for waiting on weather usually based on site-specific long-term weather statistics;
- estimated technical downtime related contingency covering the time for e.g. technical breakdowns and maintenance;
- time for learning curves at the start of all repetitive processes.

Due to the interdependence of installation processes during installation of all components of an offshore wind farm, reasonable buffer time between each sequence should be included in the operational schedule. Site specific conditions as well as seasonal influences should be driving factors for establishing sufficient buffer time.

Risk analysis should be used as a tool to assist in establishing realistic contingency times.

6.5.4 Contingency philosophy

Port and marine operations shall include contingency and back-up plans.

These contingency and backup plans shall be included within the RAMS for the operation to which they relate. Risk assessments shall be a natural part of the approval process for the method statement.

Where there are limits on an operation, the operation shall either be completed within the limits or aborted. In the latter case, the vessel(s) should be able to return to a safe condition or safe haven within the available time.

To be able to meet such requirements, essential systems, parts of systems or equipment should have redundancy systems, back-up systems or back-up system alternatives.

Back-up systems may be an integrated part of the primary system when feasible.

For systems consisting of several units or requiring repetitive processes, back-up or redundancy can be provided by having a sufficient number of spare units available on-site. The time required for the transfer of operations to back-up or redundancy systems shall be assessed.

Spare parts and key service personnel should be available on-site or on stand-by. If key parts and service personnel are on stand-by, then the time taken to mobilize them to the site should be assessed in order to check the effectiveness of the contingency arrangements.

6.5.5 Contingency planning and emergency procedures

For emergency procedures and response, ISO 15544, and the provisions of [6.5.5](#) and [6.5.6](#) should be followed.

Contingency and emergency planning shall form part of the general operational procedures. Plans for responding to foreseeable emergencies that can be identified by a risk assessment shall be developed. These can include, but are not limited to:

- occurrence of severe weather or sea states in excess of allowable metocean criteria;
- planned precautionary action in the event of forecast severe weather;
- structural or stability parameters approaching pre-set limits;
- failure of ballast system;

- failure of equipment, such as lift or hammer system;
- failure of grouting system (if applicable);
- loss of communication;
- loss of vessel or barge control;
- loss of electrical power;
- fire;
- collision;
- pollution;
- leakage;
- structural failure;
- anchor line failure;
- man overboard;
- personnel accidents or medical emergencies;
- medical evacuation from remote locations;
- grounding;
- unexpected water depth limitations or sea floor hazards;
- unexploded ordnance (UXO);
- geohazards;
- wrecks;
- piracy, mutiny, terrorism, or other unauthorized intervention.

Emergency procedures for all phases of port and marine operations shall be prepared to cover foreseeable hazards, including those due to adverse weather conditions, human errors, technical failures and associated changes of the configuration of the operations underway.

The procedures shall include details on alarm signals, reporting, communication, organization and required equipment, for instance personnel rescue means and fire-fighting equipment.

The project operational organization shall be prepared to manage, as contingency measures, any changes to an agreed procedure arising from an emergency situation not previously identified in hazard studies. The management of such an unforeseen situation shall support any decision made by means of adequate risk and safety assessment tools as described in [5.4](#) and [5.5](#).

6.5.6 Emergency response coordination plan

Emergency procedures issued by parties involved in marine operations for offshore wind farms should be compatible with each other, and gathered in an emergency response cooperation plan (ERCoP). The ERCoP shall be aligned with the marine rescue coordination center (MRCC) or other official emergency agencies of the specific country or region.

In the event of an emergency situation, the ERCoP should define who is the on-scene commander, their role, and the interfaces between the various parties involved.

The ERCoP should also include a flow chart outlining the responsibility for notifying a maritime rescue coordination centre and, if necessary, onshore base organisations, the owner and public relations.

The extent of any onshore support required depends on the nature and scale of the emergency situation. Should onshore support be required, the ERCoP should define which emergency response organization among the involved parties takes primacy in the organization of the onshore support.

6.5.7 As-built documentation/Post construction file

6.5.7.1 Introduction

As-built-data can consist of foundation and scour protection locations, anchor patterns, array cable and export cable route position lists, cable crossings, mattresses, offshore substations and other topsides, etc.

Preliminary as-built/as-laid-data following the construction/lay down of either foundations, export and array cables, anchors or other offshore structures shall be delivered to the construction management of the owner as soon as possible as some of this data has to be made available to subsequent installation operators. All preliminary as-built-data relevant for any marine operations shall be inserted into the site chart which shall be updated regularly and provided to all operators active in the offshore wind farm during these marine operations. Once final as-built/as-laid data is made available, the site chart shall be updated accordingly. Delivery of final as-built/as-laid data to appropriate national maritime authorities shall consider national requirements.

In case of simultaneous operations at one location or in the vicinity of one location, the construction management shall ensure that any newly available (preliminary and/or final) as-built-data are verbally communicated and exclusion zones are clearly defined in order to avoid any incidents.

Additional information assisting future marine operations during the operational and decommissioning phase should be included in a post construction file.

6.5.7.2 Position data of foundation and other offshore structures

Recommended delivery time of as-built-data shall be:

- preliminary position data: within 24 h after the operation;
- final approved data: as soon as possible according to project-specific requirements after the actual operation.

As-built-data shall consist of:

- foundations/offshore structure: installation date, preliminary, final or decommissioned;
- water depth related to chart datum (usually related to LAT);
- coordinates of position of foundation/offshore structure including specification of coordinate system;
- coordinates of spudcan footprints of jack-up vessels in the vicinity of the foundations including their extent.

6.5.7.3 As-laid-data of cable

Recommended delivery time of as-built-data of foundation/offshore structures shall be:

- preliminary position data: within 24 h after the operation;
- final approved data: as soon as possible according to project-specific requirements after the actual operation.

As-built-data of foundation/offshore structures shall consist of:

- export and array cable: connection between WTG locations, between WTG location and offshore substation, between offshore substation and other connecting substations, between offshore substation and onshore connection point;

- export and array cable: installation date;
- export and array cable: water depth relevant to chart datum;
- export and array cable: burial depth from seabed and burial depth from chart datum at each coordinate;
- export and array cable: if applicable, protection thickness/burial depth [depth of lowering (DoL) and depth of cover (DoC)], from chart datum at each coordinate;
- coordinates of position of cable turning points for every 10 m or as specified;
- coordinates and type of cable protection system, if applicable.

6.5.7.4 Post construction file

Additional information should be provided as a post construction file to comply with either any legal obligation or project-specific requirements. This file should include information relevant to future maintenance and repair works as well as any expected marine operations including decommissioning. It is recommended to also include results of lessons learned workshops conducted after finalization of construction works and all RAMS and procedures for documentation purposes.

6.5.8 Standards for data transfer to CAD systems

6.5.8.1 Introduction

During the design, manufacturing, construction and operation and maintenance phase of a wind farm certain CAD and GIS files are transferred between contractors and owner, which is essential information for all parties.

Particularly during the construction phase, the site chart shall be set up and continuously updated by the construction management.

Requirements regarding geographical data that is exchanged between contractors and the owner are specified in [6.5.8.2](#) to align the coordination systems used by all parties during the operations.

6.5.8.2 Geographical data

This clause summarizes the key geographical data requirements. If these requirements cannot be met for any reason, then an alternative approach taking site-specific requirements into account shall be proposed.

- horizontal datum: The preferred geodetic datum for use offshore is World Geodetic System 1984 (WGS84);
- spheroid: WGS1984;
- geodetic reference system, offshore: The preferred geodetic reference system for use in European offshore wind farms is ETRS89 (European Terrestrial Reference System 1989) used as part of the geodetic coordinate reference system (EPSG 4258);
- horizontal projection, e.g. for the North Sea: Universal Transversal Mercator Zone 32 North, Central Meridian 9° East (UTM32N);
- vertical datum, offshore: The preferred vertical datum for use offshore is lowest astronomical tide (LAT) – where applicable. Adjustments between all vertical datums shall be carried out using the appropriate method;
- all soundings shall be reduced to LAT using the relevant tidal information from relevant national publications or preferably use calibrated tide gauges for data on tidal heights that is not found in published tidal predictions;

- vertical datum, onshore: The preferred vertical datum for use onshore is to be determined according to national standards;
- geoid: The reduction of the ellipsoid heights measured on the WGS84-ellipsoid requires an undulation (separation of the geoid), which are available as geoid models. The relevant ellipsoid of reference has to be determined according to national specifics;
- where appropriate such as near shore land/sea interfaces both vertical datums should be referenced;
- all constituent data that has been used to compile the submitted data shall be stored in its original format and made available at the request of the owner;
- raw data, e.g. from side-scan-sonar and similar data, shall be passed to the owner.

6.5.8.3 Presentation of coordinates

6.5.8.3.1 Geodetic coordinates

Coordinates shall be expressed as decimal degrees. The position of coordinates relative to the prime meridian shall be expressed using sign notations (i.e. coordinates west of the prime meridian shall be negative and coordinates east of the prime meridian shall be positive). The position of latitude coordinates relative to the equator shall also be expressed using sign notations (i.e. coordinates north of the equator are positive). In Europe, the preferred geodetic datum for use offshore should be European Terrestrial Reference System 1989 (ETRS89) (EPSG: 6258), used as part of the ETRS89 geodetic coordinate reference system (EPSG: 4258). For non-European projects, the preferred datum should be World Geodetic System 1984 (WGS84) (EPSG: 6326), used as part of the WGS84 geodetic coordinate reference system (EPSG: 4258). The applied geodetic datum should be aligned with project-specific requirements.

An example of compliant coordinates is provided in [Table 1](#).

Table 1 — Format of geodetic coordinates (example)

Latitude	Longitude
55,207 083 33	-3,596 250 00

6.5.8.3.2 Projected coordinates

Where appropriate, projected coordinates referenced to a projected coordinate reference system may be used. The preferred projection for use offshore is the Universal Transverse Mercator (UTM).

Projected coordinates shall be presented in numeric eastings and northings as shown in the example in [Table 2](#).

Table 2 — Format of projected coordinates (example)

Easting	Northing
568 300,00	236 500,00

6.5.8.4 Site chart and drawing requirements

All site charts or drawings provided as part of any deliverable (e.g. within reports, etc.) shall include the following:

- coordinate reference system definition by EPSG code or a minimum set of defining parameters including vertical reference system (where applicable). Reference [61] should be consulted;
- chart datum;

- scale bar;
- scale ratio stating the paper size at which the ratio is valid;
- north arrow;
- appropriate grid or graticule;
- drawing units shall be metric;
- a title appropriate for the contents of the map;
- a unique figure number which to be referred to in any written report;
- a drawing number which corresponds to a source map document such that the data used in the map can later be identified if required;
- drawing version number or revision identifier (i.e. rev A or rev 2);
- appropriate copyright notices/information;
- contact details (an address as a minimum);
- in the case of multiple maps being produced, for consistency each map should be produced to the same style;
- chart revision date including name or abbreviation of the author.

6.5.8.5 Meta data

All data, including but not limited to GIS and CAD, should be accompanied by metadata conforming to, as a minimum, ISO 19115-1 and the INSPIRE profile of ISO 19115-1 and ISO 19119. ISO 19139, on XML encoding, should be used to encode metadata (these standards are options in the ArcCatalog Metadata editor). If coordinates in a dataset have undergone a coordinate transformation, this fact shall be recorded in the lineage statement of metadata. The coordinate transformation shall be identified by reference to the EPSG database.

6.5.8.6 Geospatial images

All photographs should be supplied in JPEG format. All images (maps, aerial images, interpreted images, etc.) shall be georeferenced to the correct coordinate reference system.

Side-scan-sonar and similar data shall be provided as tiled GeoTIFF files or as ECW compressed wavelet images.

Where colours are used to represent discrete values or ranges of values and it is applicable for these images to be tiled, then a consistent stretch shall be applied across all tiles/images such that the data appears as a single coherent data set when displayed.

6.5.8.7 Vector data

Final deliverables that include electronic mapping shall be created following the format of the project defined GIS specifications.

6.6 Certification and documentation

6.6.1 Introduction

Statutory obligations for documentation and certification requirements for any particular structure, vessel or operation shall be determined in advance. For each document required, the issuing authority and the applicable rules shall be identified.

A project assurance plan should be established, defining the minimum requirements for vessel certification and for the reports from inspection and maintenance condition surveys.

A complete and updated list of certificates and documents that is required to carry on board ships is given in Reference [51]. The certification, documentation and all correspondence should be in English. Where the original certification, documentation or correspondence is not in English, a reliable translation into English or another agreed working language should be provided.

6.6.2 Required or recommended documentation

Documentation that is either required or recommended for transportation using various types of vessels must reflect national and international legislation and standards. Specialist advice should be obtained regarding required documentation.

The ISM Code^[39] requires that vessels involved in the performance of marine operations be in possession of a certificate of compliance with the Code, demonstrating that the company owning the vessel(s) has developed and put into effect a vessel safety management system in line therewith. This does not apply to operators of vessels that are exempted under national or flag state regulations.

In addition, vessels carrying crew and passengers are expected to carry an international ship security certificate indicating that they comply with the requirements of the ISPS Code.

6.7 Marine warranty survey

6.7.1 Introduction

This clause only applies to offshore wind farms holding a construction-all-risks (CAR) insurance. In case a CAR insurance is in place, the insurers usually request that (i) documentation for the marine operations related to the components is reviewed by a MWS, (ii) the MWS conducts vessel and equipment suitability surveys before the start of marine operations and (iii) attends a reasonable number of marine operations to ensure compliance with planned procedures while issuing certificates of approval.

This clause provides information for the planning of offshore wind farms in respect to CAR insurance and employment of MWS. It does not intend to state that a CAR insurance or the employment of a MWS is mandatory.

6.7.2 Role of the marine warranty surveyor

An insurance warranty is a clause in the insurance policy for a particular marine project or a vessel requiring the approval of one or more marine operations by marine warranty surveyors from a specified independent survey house. In most cases the insured employs the survey house though occasionally an insurance broker or insurance underwriter may do so.

The warranty clause can include coverage from as early as the factory gate. This involves inland temporary stages as well as offshore marine operations. Normally the insurer or insuring consortium prepares a list of trusted MWSs. The insured then chooses from tendering offers.

The warranty requirements are normally satisfied by the issue of one or more certificates of approval. Responsibility for interpreting the terms of the warranty so that an appropriate scope of work can be defined rests with the assured who may be the operator, owner or its contractor.

The MWS service besides issuing certificates of approval for marine activities, delivers reports for surveyed equipment and vessels, project-based acceptance of tools and technical expertise in developing manuals and procedures. The scope of work is based on the marine warranty clause in the insurance policy.

The surveyor may also decide during an operation to monitor the operations and agree any changes in procedures. In this case it has no executive authority on the project but when necessary it can submit

recommendations to the assured's representative in order to ensure that the project is run in a safe and proper manner.

6.7.3 MWS scope of work

Details of scopes of work, including surveys, reviews and calculations required, are specific to the warranted operation and usually part of the overall design package.

Early involvement of the MWS in agreeing criteria at an early or planning design stage is recommended as it often saves time and expense in changing designs shortly before or after construction has started. Similarly, alternative criteria may be agreed during the project to give a better or similar level of risk.

Project-specific release notes can be required for some projects. Third party certification has normally three components:

- design approval (finalized with statement of acceptability);
- inspection during construction (inspection reports);
- final release (release note issued only after design was approved, tool was constructed and tested).

6.7.4 Certificate of approval

A certificate of approval is the formal document issued by the warranty surveyor when, in their judgement and opinion, all reasonable checks, preparations and precautions have been taken to keep risks within acceptable limits, and an operation can proceed. It is the main deliverable of the approval process.

The certificate of approval for a marine operation such as load out, transport, towage or installation normally should be issued when:

- all preparations including engineering reviews, acceptance of procedures/manuals, seafastening and ballasting are complete;
- marine equipment such as tugs, jack-ups, vessels or barges and towing connections have been inspected and accepted;
- a readiness meeting has been held;
- the actual and forecast weather are suitable for the operation to begin.

In extreme cases, a warranty surveyor is unable to issue a certificate of approval due to inadequate procedures or equipment for the likely conditions. Similarly, failure to follow the procedures and conditions in the certificate of approval could lead to it being withdrawn. In the event of a loss, the lack of a valid certificate of approval could invalidate the insurance warranty and prevent or reduce payment by underwriters for any covered loss.

A certificate of approval is issued for a particular towage, voyage or operation only or for a set of repetitive operations. It is issued based on external conditions observed by the attending surveyor of the jacket, hull(s), machinery and equipment, without removal, exposure or testing of parts.

Any alterations in the surveyed items or agreed procedures after issue of the certificate of approval can render the certificate void unless approved by the MWS.

Fatigue damage is excluded from a transportation certificate as this is usually provided by certification of structural integrity design which includes load cases for transport and lifting of the components.

A certificate of approval for transportation does not cover any moorings prior to the start of transportation, or at any intermediate shelter port or arrival port, unless specifically approved by the MWS.

A certificate of approval for installation applies to the safety of the structure and associated equipment during the defined installation period. It does not imply that the completed jacket, platform or other installation is fit for purpose. The safety of personnel is not specifically addressed by the MWS.

6.8 Systems and equipment

6.8.1 Introduction

Operational systems and equipment should be tested and commissioned prior to the operation.

Vessels, systems and equipment required for marine operations shall be in good condition with appropriate documentation and fit for the purpose for which they are intended. They shall have the capability and capacity to operate effectively under the environment and actions for which the operation is designed. They shall be used in accordance with manufacturer's instructions and procedures. Where possible, they should be designed to be fail-safe and should possess an adequate level of reliability and redundancy.

6.8.2 Marine vessels

Marine vessels and their equipment should be inspected prior to the operation to confirm their suitability including seaworthiness and validity of certification, as applicable for the type of vessel and voyage planned; see [6.6](#) and [6.7](#).

Vessel stability should be in accordance with [Clause 13](#) throughout all stages of the operation, unless it can be shown that reduced stability requirements can be accepted. For example, during phases of deck mating, taking account of the reduced environmental conditions and the partial restraints of the structure to the vessel, reduced stability criteria may be considered.

6.8.3 Major equipment

Repetitive marine operations during installation of offshore wind farms apply various types of major equipment, such as e.g. cranes, hammers for piling, spreader bars as well as specific custom-made lifting equipment for blades, transitions pieces and piles or equipment used for cable installation.

In principle all such major equipment shall be certified by a recognized organization. For exceptions for lifting equipment refer to chapter [19.19.2](#). Further exception related to load-testing are made for hammers. An as-built fabrication dossier should be provided similar at listed under [19.19.2](#).

Other major equipment like slings, grommets and shackles used during lifting shall have standard certificates.

7 Metocean requirements

7.1 Introduction

It is often impractical and/or uneconomical to design marine operations for performance in extreme environmental conditions (i.e. for unrestricted operation). Consequently, most operations related to the installation of offshore wind farms are generally treated as weather-restricted operations, requiring specifications of weather windows of minimum duration and operational limits related to the metocean parameters during which the marine operations can be performed. Setting the operational limits too high can lead to unacceptable risk, whereas setting the limits too low can lead to excessive waiting on weather or weather downtimes. Thus, the limits should be appropriate to the installation method and means used, and to the expected duration in line with the location and with the season.

Operational limits for marine operations are defined based on technical constraints, e.g. tool usage, vessel motions, personnel safety and may be adapted to site-specific conditions when possible. These limits are a major step to ensuring the safe execution of a marine operation.

A set of operational limits that is dependent on the type and duration of the operation shall be established and documented in the relevant RAMS. Such criteria shall include, but not be limited to:

- wind speed and direction;
- wave height, period, and direction;
- current speed, profile (where applicable), and direction;
- swell height, period and direction.

Operations can be defined as weather-restricted or weather-unrestricted; see [7.2](#).

Appropriate procedures shall be established and documented to secure a good prospect of personnel survival in the event of evacuation, escape and rescue.

7.2 Weather-restricted/weather-unrestricted operations

7.2.1 Weather-restricted operations

Weather restricted operations are characterized by:

- an operational limit specific for the operation based on design criteria (see [7.4.1](#));
- a required weather window specific for the operation and including a time contingency (see [7.5](#)).

The reliability of weather forecasts is such that weather-restricted operations should generally be completed within 72 h.

In areas with consistent weather patterns, the duration of a weather-restricted operation may be extended beyond three days, if such an extension can be justified by appropriate documentation.

Weather-restricted operations that can be stopped and brought into a safe condition within the maximum allowable period for a weather restricted operation (for instance many WTG maintenance and commissioning works, soil preparation, cable burial), can have a longer total duration.

Furthermore, a continuous surveillance of actual and forecasted weather conditions should be implemented.

7.2.2 Weather-unrestricted operations

Weather-unrestricted operations can safely take place in any weather condition that can be encountered during a season in the area of the planned marine operation. The environmental criteria for these operations shall be based on the statistical extremes for the area and season concerned. Guidance on the return periods to be used for determining the relevant environmental criteria can be found in section 3.4.3 of Reference [\[56\]](#).

With increasing development in areas experiencing tropical cyclones and tsunamis, it would be of value to also check the risk levels of tropical cyclones and tsunamis events, and to seek out the relevant local codes of practice for all relevant extreme weather hazards identified, where the probability of occurrence and the severity of such an event is assessed as a risk requiring some level of mitigation.

7.3 Metocean conditions

7.3.1 Wind

Wind conditions shall be considered in the planning and engineering of marine operations. For the description of the wind parameters, reference shall be made to ISO 19901-1.

For the wind conditions, the time reference shall be defined (e.g. 10 min average or 1 min average, etc.).

7.3.2 Wave, wave period and swell conditions

Wave conditions as well as any wave periods limiting the operations, e.g. during jacking operations shall be considered in the planning and engineering of marine operations. For the description of the wave, wave period and swell parameters, reference shall be made to ISO 19901-1.

If swell has a noticeable effect on the operation, the response of the vessel to combined wind-driven seas and swell should be evaluated. In shallow water, sway and surge motions due to shoaling swell and second order wave drift actions should be considered.

For operation phases that are sensitive to large or extreme wave heights, such as temporary on-bottom stability, maximum or significant wave height (as appropriate) and range of associated periods should be considered in the analysis.

For operations that are sensitive to small fluctuations of the sea level, even under calm sea state conditions, the occurrence of long period, small amplitude swell on the site should be checked, with a maximum wave period of 30 s.

Attention should also be paid to current acting against the waves, which can amplify wave steepness.

7.3.3 Current

Current conditions shall be considered in the planning and engineering of marine operations including any operations involving divers. For the description of the current parameters, reference shall be made to ISO 19901-1.

For marine operations, data and forecasts should be provided for current speed and direction including, as appropriate, current profiles (if available) from the surface to the sea floor.

During jacking operations, possible rates of scour around spud cans induced by currents shall be considered. In conditions where excessive scour potentially endangers leg stability and/or the foundation and hence jack-up vessel stability, provisions should be made for scour monitoring and scour management including contingency plans.

To be able to forecast current with the required reliability, the following is normally necessary:

- for sites where tidal current dominates, currents can be forecasted with models calibrated on in situ measurements. The use of a recently measured dataset is recommended for this modelling;
- for sites where the complexity of the bathymetry (topographical current) can generate unstable flow, current measurements with devices that record the current velocity and direction should be used, including readouts at various depths; an example is the shedding of current stream around land obstacles that can introduce macro vortices in the main current flow.

7.3.4 Other metocean factors

Other factors and combinations of factors that can be critical and shall be considered if relevant in the planning and engineering of marine operations, include:

- joint occurrence of wind, wave, current and water level, including tide and surge;
- tide;
- water levels;
- restricted visibility;
- sea ice, icebergs, snow and ice accretion on topsides and structure, exceptionally low temperatures;
- tropical cyclones, dust storms and wind squalls;
- water density and salinity;

- precipitation;
- air temperature;
- water temperature.

Additional guidance and recommendations for operations in ice-affected waters for certain geographic areas can be found in Reference [55].

7.3.5 Temperature

The occurrence of extreme high and low environmental temperatures shall be considered for their effect on equipment, operations and personnel, particularly regarding grouting operations (where applicable). Very low or high temperature can adversely affect hydraulic, pneumatic, ballasting, mechanical and safety systems. Changes in operational fluids can be required and auxiliary heating or cooling systems can be necessary. Personnel activities can be affected by temperature.

Ice accretion can potentially affect the accessibility to assets via boat-landings or the ability of certain safety equipment to function during extreme winter conditions. All lifeboat davits, inflatable life-raft quick-release mechanisms, hinges and locks of life-jacket storage lockers on decks, lift-ring and EPIRB beacon mountings, etc. shall be suitable for deployment in the extreme conditions prevalent in the area of operation. The SOLAS requirements are applicable.

7.3.6 Marine growth

The effect of marine growth on the submerged and splash-zone affected parts of the wind farm components shall be considered during marine operations and access of personnel to these components. Marine growth can result in changes in weight, effective diameter and surface roughness of the components.

7.4 Metocean criteria

7.4.1 Design criteria and operational limits

For each specific phase of a marine operation, the design criteria and operational limits shall be defined as follows:

- the design criteria are that set of values of metocean parameters (such as wind, wave, current, water level, visibility, water density, water salinity, water temperature, marine growth and icing), for which design calculations are carried out, and against which the structure and/or operation is checked;
- for the design criteria, the directionality of waves, wind and current may be considered;
- to determine design criteria, return periods shall be used. The return periods shall be related to the weather window (referred to in Reference [56] as operational reference period). Guidance on the return periods to be used for determining the relevant design environmental criteria can be found in section 3.4.3 of Reference [56];
- for weather-unrestricted operations, the operational limits are the same as the design criteria, although lower values can be set for practical reasons;
- for weather-restricted operations, the operational limits are that set of values of metocean parameters (such as wind, wave, current, water level, visibility, water density, water salinity, water temperature, marine growth and icing), which are not exceeded at the start of the operation and which are forecasted not to be exceeded for the required weather window, (see 7.5). The "operational limits" are more stringent than the "design criteria" (otherwise the operation can be weather-unrestricted).

During the design stage of the marine operation, the following shall be considered:

- ways to make the operation more time-efficient and to reduce the required weather windows;
- redesign of the operation to tolerate higher metocean parameters (higher waves, current and wind conditions), if possible;
- possible contingency situations, and back-up and stand-by measures;
- possible delays to previous activities, which can push the operation into an unfavourable season.

7.4.2 Return periods

Metocean parameters used as design criteria for marine operations are related to the planned duration of the operation including contingency.

The site-specific return period shall be used for determining the environmental design criteria for weather unrestricted marine operations. The same criteria shall also be used for determining if an operation is restricted or unrestricted. Return periods can depend on location and should be determined in each sea area.

It is noted for clarification that the reference to the return periods is a means of quantifying risk and relates to the potential for damage to the structure during a marine operation (such as installation or transport). There is no relation to the design life time of the structure itself.

Guidance for applying the return periods can be found in Reference [56].

7.4.3 Vessel response-based analysis

For marine operations at offshore windfarms where wind, sea, swell and currents are all significant, an analysis of the vessel responses should be conducted. Through numerical simulations, statistical estimates of the vessel or component behaviour can be directly characterized. This technique is especially important when more than a single directional parameter can dictate the response and, therefore, the sensitivity of the operation.

7.4.4 Probability distributions of sea state parameters

In order to understand the relationship of sea state parameters, such as the significant wave height and peak period, the uni- and bi-variable distributions should be examined. This includes the joint probability distributions of significant wave height and period, and wind speed, wave height and current speed versus direction. For those parameters that dictate operability, weather windows should be computed.

7.5 Operational duration, contingency and weather window

This [section 7.5](#) applies to weather-restricted operations.

7.5.1 Planned operational duration

The conduct of marine operations requires that a procedure document (RAMS) shall be in place containing details of the proposed work schedule with particular reference to the anticipated planned operation duration T_{POP} of each operation, and the time needed to suspend operations and to reach a safe condition e.g. by moving to the nearest safe haven, or to reaching a safe location and positioning, jacking, preloading and elevating to the minimum safe air gap (where applicable) at that location. It is recommended that the total time estimated for suspension of operations, removal, transport and installation in a safe location (including the time for jacking, preloading and elevation to the minimum safe air gap (if required) should not exceed 48 h including contingency for delay (see References [56] and [58]).

7.5.2 Weather window and contingency

The weather window (referred to in Reference [56] as operational reference period) shall include a contingency period determined with due allowance for the nature and criticality of the individual operations in the weather window (safe to safe).

The weather windows (typically expressed in minutes or in hours) should be determined as follows:

$$T_R = T_{POP} + T_C \quad (1)$$

where

- T_R is the weather window (operational reference period according to Reference [56]);
- T_{POP} is the planned operation duration (or the duration required to stop the operation and go back to a safe condition);
- T_C is the estimated maximum contingency period.

The weather window shall include the necessary contingencies for:

- inaccuracy in operational duration;
- technical or operational delays, causes of delay include leg extraction problems (if jack-ups are used), waiting for slack water, breakdown, etc.;
- uncertainty in the environmental statistics;
- extra allowance for operations with vulnerable or critical equipment;
- reduced allowance for operations with a time schedule based on previous similar operations;
- extra allowance for operations in geographical areas and/or seasons where conditions are difficult to predict.

Further specifications on weather windows and contingency for weather restricted operations can be found in Reference [56].

7.5.3 Point of no return

Weather-restricted operations shall be divided into a series of phases where the operation can be aborted and brought to a safe condition within the remainder of the existing weather window. The weather window in which conditions remain below operational limits shall be of sufficient duration to reach a safe condition before proceeding beyond the point of no return (PNR).

The reliability of the weather window is crucial for the critical period during an operation between any PNR and the structure reaching a safe situation.

The planned duration of a weather-restricted operation should not normally exceed 72 h. However, the duration may be indefinitely extended in prolonged periods of benign weather under the following provisions (as per Reference [58]):

- the limits for the restricted mode are never exceeded;
- a required weather window suitable for moving e.g. a jack-up or a floating vessel to the safe location is clearly and consistently identified with a high level of confidence in each weather forecast.

In case these provisions are not fulfilled and risk of continued severe weather is deemed to follow this weather window such that the limits for the restricted mode could be exceeded, then the jack-up or the vessel used for floating installation operations should be moved to shelter immediately before the limits

for jacking down, jacking to survival height, lifting anchors, moving off location, transport, jacking up and preloading or anchoring at the safe location are approached or exceeded (as per Reference [56]).

7.5.4 Forecasted and monitored operational limits, metocean reduction factor

Due to the fact, that a weather forecast as well as weather monitoring results during operations show varying uncertainties for different weather windows, a metocean reduction factor also called “alpha factor” shall be considered for application to the operational limits.

The forecasted operational limits should be determined as follows:

$$L_{WF} = f_{MR} \times L_{lim} \quad (2)$$

where

- L_{WF} is the forecasted operational limit (forecasted operation criteria according to Reference [56]);
- f_{MR} is the metocean reduction factor (alpha factor according to Reference [56] or as determined project-specifically);
- L_{lim} is the design operational limit (operational limiting criteria according to Reference [56]).

The metocean reduction factor should be determined as a function of the duration of the operation (or of the weather window), the number of data sources and the quality of the available data and depending on the area and season, the delicacy of the operation, and the typical reliability of the forecast(s). Guidance can be found in Reference [56].

Weather-restricted operations shall be planned using reliable historical/hindcast data provided with weather forecasts that indicate not only the probability of not exceeding the limiting criteria but also the persistence of such conditions for the season and the weather windows considered for the particular operations.

For project-specific weather forecasts and weather windows typical for repetitive operations during construction of offshore wind farms, example of specific metocean reduction factors, i.e. alpha factors are provided in Reference [56]. However, the metocean reduction factors may depend on the location of the project (which may have more or less foreseeable weather), on the competence of the forecaster(s) and on the level of agreement between measured sea-states and forecasted values.

The following simplified example clarifies the principle that could be applied for a restricted operation based on values provided in Reference [56]:

- operation: offshore transport of foundations;
- weather window: 22 h (including contingency);
- design criteria: $H_s = 4$ m;
- weather forecast provisions: two independent, project-specific weather forecasts plus infield wind and wave monitoring plus availability of offshore meteorologist;
- applicable metocean reduction factor based on weather window < 24 h: 0,87;
- resulting in forecasted operational limit for planned operation: $H_s = 4 \text{ m} \times 0,87 = 3,5 \text{ m}$.

7.6 Weather forecasts

7.6.1 Introduction

Forecasts shall be obtained before and during marine operations. The forecast shall be issued at suitable regular intervals dependent on the operation, with the intervals not exceeding 12 h. The forecast should be made by a competent forecaster who has the necessary data at his disposal to make a highly specific recommendation for the particular operation. Wherever possible, a second forecast should be obtained from an independent source before critical operations.

For weather-restricted operations, regular contact with experienced forecaster(s) should be made available to check the local situation and provide regular weather briefing based on forecasts from two independent sources. This applies to marine operations such as:

- offshore lifting operations for installation, component exchange/repair and decommissioning;
- pile driving;
- cable laying and burial;
- float-over topsides;
- foundation float-out/tow out;
- towing of barges loaded with major wind farm components.

7.6.2 Forecast parameters

The forecast should cover short- and medium-term and outlook periods, and should include:

- synopsis;
- barometric pressure, temperature;
- wind direction and speed, where the speed should be given for 10 m and 50 m and hub heights above sea level; the wind speed should indicate 10 min means and also indicate wind gusts at predefined intervals;
- waves and swell, including significant and maximum height, direction and period;
- surface and (if relevant) depth averaged currents;
- loop currents and wind squalls;
- visibility, rain, snow, sleet, icing and sea ice;
- lightning;
- confidence level of the forecast.

In addition, weather maps showing the synopsis (24 h) and prognosis (48 h) should be made available.

7.7 On-site monitoring

Where operations are sensitive to local (near-site or on-site) environmental conditions or to changes in these, real-time measurement, both prior to start and during operations, shall be considered. This can include wave measurements as well as wind measurement from various levels of the crane boom or from LIDAR equipment during infield operations.

8 Onshore transport and nearshore transport

8.1 Introduction

Transports of components to a base port are organized as an onshore or a nearshore transport as well as also offshore transport. For offshore transport see [Clause 16](#).

Onshore and nearshore transports include:

- land-based transports;
- transports via roads;
- transport via railways;
- inland water transport via inland waterways;
- nearshore transport via vessels or barges.

Depending on the transport mode different recommendations occur. These requirements are explained in the following clauses.

8.2 Structural integrity calculations

Components shall be proven to withstand the static and dynamic forces to be expected during inland transport. These forces include but are not limited to wind forces and vessel/barge motions.

In the case that a seafastening of components is required, load case calculations for structure, seafastening and barge/vessel shall be performed for the respective component and/or group of components.

8.3 Transport by road

Transport by road of components and sub-assemblies can be performed by different vehicles. These transport vehicles include, but are not limited to:

- trucks;
- SPMTs;
- low-loader trailer.

For all transport vehicles certified lashing points have to be used for lashing the load. The lashing can be covered by national regulation and safety standards. Lashing points of the components shall be clearly marked and certified.

The requirement of a transport permit shall be checked before starting the transport. If a transport permit is required, the transport operations shall consider the particular transport permit provided by responsible authorities.

8.4 Transport via inland waterways

Transport via inland waterways refers to transports of components with inland vessels or barges on inland waterway (e.g. rivers). Seafastening requirements shall be adapted to the sheltered character of inland waterway. It has to be proven that components and vessels withstand dynamic forces to be expected during inland transport. All operations and process steps during the transport can be covered by national regulations.

8.5 Transport via nearshore waterways

The transport via nearshore waterways addresses transports with vessels or barges in coastal areas. In particular, nearshore transports are defined as transports in coastal areas and sheltered areas close to the coastline for a short distance or, if for a longer distance, with sufficient accessible shelter ports in close vicinity.

For nearshore transport a specific seafastening of components is required. The requirements for the seafastening depend on the particular nearshore area. Factors which influence the dimensioning of the seafastening are the expected:

- significant wave heights;
- wind speed.

Restrictions for the seafastening can differ in dependence of the nearshore route. Usually the requirements of the seafastening for nearshore transports are less restrictive than the seafastening for offshore transports.

8.6 Transport via railways

All transports via railways shall consider the requirements of the railway operator. In particular, the components have to meet the requirements of the minimum clearance outline, structure gauge and the kinematic gauge. The minimum clearance outline profile can vary depending on the particular railway system used. Accordingly, if multiple railway systems should be used for the transport of components (e.g. across country borders), the requirements of the minimum clearance outline have to be checked for each railway system used for the transport.

8.7 Transport frames and equipment

Equipment and transport frames which are solely used for inland transport shall be suitable for the respective tasks. National regulations can apply. All transport frames and equipment used for inland and offshore transport shall be built and certified for offshore use.

Transport frames should normally be certified as suitable for multi-trip usage and consider fatigue cases. Before storing components, the transport frame shall be inspected visually and inspection records shall be kept for later checking. If the inspection reveals any areas of concern or there are areas that could be subject to laminar tearing, then NDT inspection shall be carried out considering them as second-hand equipment. In addition, critical areas should be subject to suitable NDT every 3 to 5 uses (depending on fatigue and/or likely maximum stress levels). Normally the transport frames are also used as lifting frames so the lifting points should also be thoroughly inspected. Design of these frames should also have compatible lifting points.

Before storing components, the equipment and storage frames shall be inspected visually. Damaged storage frames or frames with plastic deformations shall not be used for storing or transporting components.

The design of transport frames should aim for multiple use in different transport steps of the supply chain. This avoids additional handling steps for the change of transport frames. Ideally, transport frames and transport units have compatible lashing points and a compatible system for the seafastening.

9 Intermediate storage areas

9.1 Introduction

Intermediate storage is done between different transportation operations. It includes storage processes at the component manufacturers and their suppliers as well as the storage of components in marshalling ports. Components have to be stored at defined storage areas with suitable equipment (e.g. storage

frames), which allow a secure storage for the durations required by the project. This leads to different requirements for:

- general infrastructure (e.g. accessibility of components, security measures);
- surface configuration and the ground load-bearing capacity;
- equipment for storage and the protection of components during the storage phase.

In this context, the provision of components for next transportation operations (e.g. provision at quayside for installation vessels) is defined as an intermediate storage process.

9.2 Infrastructure requirements

The design of storage areas shall provide sufficient manoeuvring areas. Accordingly, additional areas have to be included in the planned storage areas. As a general rule, the storage area should have at least a size of a minimum 1,4 times the square meters required for the simultaneous storage of the before scheduled components. If specified storage concepts are applied, these additional manoeuvring areas can be reduced. These concepts should prove that the layout of storage areas meet minimal turning curves of used transport vehicles (e.g. SPMTs) and lifting equipment (e.g. stacker and mobile crane).

Furthermore, the underlying accessibility concept of components can reduce the requirement of additional manoeuvring areas. Storing components with a FIFO (first-in-first-out) or a LIFO (last-in-first-out) concept allows concentrating more components on a smaller area. However, these storage concepts do not allow single access of components. Accordingly, changes in the provision order are not possible. The underlying storage concept shall prove that the concentration of components does not violate load bearing restrictions.

9.2.1 Load bearing

For storage areas used for the storage of WTG components or other major parts such as foundations, a load bearing certificate shall be provided and the maximum load bearing capacity on the storage yard shall be clearly stated. At the major areas of the storage yard such as transport routes, quay side and storage access, the maximum load bearing capacity shall be at least the highest load bearing capacity required by the components stored on the storage area.

If not all parts of the storage area have the same load bearing capacity, then it shall be clearly marked in the statement and also marked directly on the specific areas of the storage yard.

9.2.2 Surface

The surface of the storage area shall be plane and no obstacles should hinder the transport and storage of the components. A statement shall be provided showing the surface inclination, the connection points for water and electricity including the voltage and ampere at connection point, the position of light mast and the distribution of luminous intensity in lux. The intensity of the illumination should meet the requirements mentioned in CIE S 015/E:2005 for the application in ports. The intensity of the illumination can be covered by national safety regulations.

9.3 Storage frames and equipment

Storage frames and other storage related equipment have to be suitable for storing components for a period of e.g. at least six months. National regulations can apply. It should be certified that used storage frames are able to bear the load of the respective components. The load shall be transmitted correctly to the surface and the ground. Before storing components on specified storage frames, the equipment and storage frames have to be inspected visually. Damaged storage frames or frames with plastic deformations shall not be used for storing components.

The design of storage frames should aim for multiple use in the supply chain. Ideally, storage frames can also be used for transport activities.

9.4 Requirements of components for storage

Components have to provide clearly marked attachment points for storage and transport frames or other storage equipment. Manufacturers shall provide statements comprising requirements for the storage of their components. These requirements can include, but are not limited to:

- provision of electrical current during the storage phase;
- specific environmental conditions during storage (e.g. humidity, temperature, etc.);
- maintenance routines during storage;
- additional protection measures against environmental conditions.

All measures provided in this statement should allow a secure storage phase of e.g. at least six months.

9.5 Protection of components against environmental conditions

The outside structure of the main components is constructed to be exposed to natural influences. Due to this reason, only the connection points have to be protected against wind, water, etc.

The connection points of the main components should be covered either with tarpaulin, a wooden cover or equivalent covers and be designed according to the different connection points. The chosen cover shall ensure that the connection points are totally covered and secured for the whole supply chain process. The connection of lifting pads/devices shall be possible without removal of covers. The manufacturer of the component should state requirements for the protection of the components.

Ideally, the protection measures can be used during the entire supply chain. Covering lifting points or connecting points of storage and transport frames should be avoided.

9.6 Structural integrity calculations

9.6.1 Introduction

All major components shall have a statement where it is clearly shown that the components can be stored over a longer period of e.g. at least six months. The statement shall include the storing position e.g. towers upright or horizontal, a general description of the component, the storing position, the stack ability and the required securing measures.

9.6.2 Vortex shedding

Wind, current or any fluid flow past a structural component may cause unsteady flow patterns due to vortex shedding. This may lead to oscillations of slender elements normal to their longitudinal axis. Such vortex induced oscillations (VIO) should be analysed to evaluate the risk for the structure and the seafastening and grillage.

Wind-induced VIO could be a design issue effecting e.g. fully mounted towers standing at the quayside or being transported on board of the installation vessels. Mitigation measures could be the use of aerodynamic devices to change the shape of the structure, e.g. applying helical strakes around the towers. Other means could be dampening devices inside the towers or other protections to reduce the risk of vibrations.

Similar checks for VIO should be conducted for jacket foundations placed on the quayside and transported on board the installation vessels.

For further information, see Reference [56] as well as DNVGL RP C205 (chapter 9) where applicable for offshore wind farm structures.

9.7 Security measures

For the security of the operations, the ISPS code, legal harbour, national and/or international regulations can be applicable.

10 Pre-assembly

10.1 Introduction

Pre-assembly of components refers to assembly-processes which are not part of the manufacturing process of the components at the site of the manufacturer. Pre-assembly processes can occur for example in ports, e.g. WTG towers, blades mounted to hubs, or transition pieces as part of the foundations. Before and during the pre-assembly of components, different requirements concerning the working area, lifting activities, operational conditions and the used equipment arise. For pre-assembly activities, the operator of the assembly area can differ from the operator of the assembly activities (e.g. pre-assembly of foundations by the manufacturer in the port area). Accordingly, different responsibilities of the involved parties shall be taken into account.

10.2 Pre-assembly area requirements

The general requirements of intermediate storage of components apply (see 9.2). Surfaces and the load bearing capacity shall be sufficient for the components that should be assembled. As appropriate, additional areas shall be planned for cranes and other equipment for the assembly. Further requirements for the assembly (e.g. access to electric current, water or compressed air) have to be stated by the operator of the assembly activities.

10.3 Pre-assembly activities

A proven concept for pre-assembly activities/quality assurance shall be provided. This concept has to cover all assembly activities such as:

- incoming inspections;
- storage positions and securing of components;
- pre-assembly of nacelle including:
 - mounting of hub including hydraulic and electrical connections;
 - installation of heli-hoist platform;
 - mounting of aviation light;
- pre-assembly of trafo and power units;
- pre-assembly of tower sections including:
 - preparation, lifting and mounting of tower sections;
 - electrical installations and cable routing;
 - mounting of staircase platforms and service lift;
 - mounting of helical strakes (if required);
- ground enforcement for placing nacelle and tower at quayside (if required);
- ID and logo marking;
- pre-commissioning;

- final inspections;
- rectification and verifications of rectification works.

Furthermore, the concept has to provide protection measures for other goods which are stored near the assembly area (e.g. protection against contamination with flush rust induced by the assembly activities). A suitable countermeasure in this context can be housing of the working area with tarpaulin.

Health and security aspects shall be included. The assembly operator shall define which dangerous substances are used and indicate quantities of these substances. The operator of the assembly activities is responsible for the safe storage of these substances. The handling and disposal of hazardous substances can be covered by national regulations.

10.4 Pre-assembly equipment

All equipment and machinery used during pre-assembly shall be certified; this can be covered by local or national regulations.

10.5 Structural integrity calculations

For requirements, see [8.2](#).

10.6 Vortex shedding

For requirements, see [9.6.2](#).

10.7 Security measures

For requirements, see [9.7](#).

11 Port activities

11.1 Introduction

Port activities comprise the exchange of WTG components, foundations, cables or other units of an offshore wind farm between different transport units and the port. Activities performed within the port, e.g. intermediate storage, pre-assembly, provision of components, are addressed by [Clauses 9, 10](#) and [11](#). Specific requirements concerning the quayside, the access to harbour areas, soil requirements in the harbour and the vessel management are addressed in this clause.

11.2 Accessibility of harbour areas

11.2.1 Water access

Vessels operating at offshore harbours usually require an always afloat, always accessible (AAAA) status, which means that vessels shall not have ground contact during their laytime. Any exceptions regarding particularly loadout operations from jack-up vessels whether semi-jacked or fully jacked conditions require that the vessel is first preloaded. A site-specific jack-up assessment in accordance with ISO 19905-1 shall be carried out for all loadout operations conducted in semi-jacked or elevated mode. In addition, a geotechnical assessment of spudcan/dock wall and spudcan/soil interaction shall be conducted.

Agreement with the port authorities for jacking or semi-jacking operations in ports usually is required.

Furthermore, the port infrastructure shall be suitable for basic manoeuvres (e.g. turning manoeuvres) of the vessel. Factors which mainly determine this status are:

- tidal restrictions;
- draught of the vessel;
- loaded draught of the vessel;
- under-keel clearance;
- overall length and beam of vessel;
- length of the quayside;
- dock wall and dock furniture clearances for overhanging cradles, racks and cargo components;
- restrictions to navigation by jack-ups caused by port activities such as container cranes with booms lowered in the service position;
- general geometry of the harbour basin;
- width and length of locks;
- air draught in locks and under bridges;
- overhead power lines;
- other harbour traffic.

11.2.2 Inland access

For the inland transport of components, all recommendations of [Clause 8](#) apply. The surface and the load-bearing capacity have to be sufficient for the respective components.

11.3 Storage areas of quayside

The party responsible for the area shall provide detailed descriptions of the operational limits of the quayside, as well as information on availability of electricity, freshwater, as well as any other appropriate requested information.

See also [11.6](#).

11.4 Security measures

For requirements, see [9.7](#).

11.5 Quayside requirements

The party responsible for the port area shall provide detailed information about tide and current conditions as well as quayside structure analysis, including maximum pressure loads close to the quay, safety distance between the quay wall and cranes/components, quay bollard and fender capacity. This information shall be considered during the planning of handling operations.

11.6 Port subsea soil requirements for jacking activities

As a pre-requisite of jacking activities, the seabed and the subsurface shall be analysed with regard to load bearing by the jack-up legs.

If the load bearing capabilities are not sufficient, the sea bed shall be strengthened up to desired load bearing capabilities.

The load bearing quality of the sea bed shall be documented and provided and analysed for specific jack-up vessels and loading situations.

The jack-up procedure shall include all relevant information (specifications of the jack-up vessel, type and dimensions of jack-up-legs including spudcan, weights and forces during loading/unloading).

Most common risks should have sufficient mitigation measures to allow comfortable margins in terms of soil capacity and prevention of uncontrolled movement of jack-up's legs. The risks with highest consequences considered in common practice are the following:

- punch-through;
- bearing failure and settlement;
- sliding failure;
- footprints;
- rack phase difference (RPD);
- scour;
- layered soils;
- foundation fixity;
- jack-up spudcan and jacket leg interaction;
- jack-up spudcan interaction with the quay's foundation;
- cyclic loading;
- debris, boulders, UXO, etc.;
- shallow gas;
- seafloor instability;
- soil liquefaction.

See also [18.8](#) (jack-up soil assessment) in respect to punch-through during loadout and during offshore installation operations.

12 Weight control

12.1 Introduction

Weight control and related weight measurements are crucial for the verification of the RAMS and included lifting calculations. WTG components as well as foundation components are lifted during repetitive operations. For these operations it is usually sufficient to provide weighing proof of the maximum weight of these components. WTG components and foundation components weight control are considered to have the same level of importance. Single lifts such as jacket and topsides for offshore substations and offshore accommodations platforms should be weighed before start of loadout or any lifting operations. It is advisable to conduct all planning with a “not-to-exceed”-weight and confirm this by weighing before start of operations. Particularly for single lifts of jackets and topsides, contingency planning should be conducted to allow for feasible lowering of weight in case the total weight exceeds the maximum allowable weights for loadout, lifting or transport. If weighing is not feasible/performed, a contingency factor shall be applied.

Weight control shall be documented with a weight control procedure , such as that described in ISO 19901-5^[11].

Weight control procedures shall be in operation throughout construction and outfitting when afloat. In the weight control documentation, SI units should be used.

12.2 Weight control classes

In relation to weight control classes, ISO 19901-5^[11] as well as Reference ^[56] state that:

- “Class A weight control shall apply if the project is weight or CoG sensitive for lifting and marine operations or during marine operations (with the addition of temporaries), or has many contractors with which to interface. Projects can also require this high definition if risk gives cause for concern.”
- “Class B weight control shall apply to projects where the focus on weight and CoG is less critical for lifting and marine operations than for projects where Class A is applicable.”
- “Class C weight control shall apply to projects where the requirements for weight and CoG data are not critical.”

Unless it can be shown that a particular structure and specific lift operation are not weight or CoG sensitive, class A weight control shall apply using the following weight contingencies:

- Calculated weights: If the 50/50 weight estimate as defined in ISO 19901-5^[11] is derived, an appropriate weight contingency factor no less than 1,05 shall be applied. The extreme of the CoG envelope (if applicable) shall be used^[56].
- Weighed weights: A weight contingency factor of no less than 1,03 shall be applied to the final weighed weight. This may be reduced if it can be demonstrated, for the specific case in question, that the overall accuracy of the weighing method and equipment is better than 3 %.

The level of contingencies shall conform to project weight control report according to ISO 19901-5 for the considered phase if not otherwise specified.

The application of weight contingency factors for lift purposes is given in [19.4](#).

Weight and CoG evaluation for combination of components (nacelle and hub, hub and blades, etc.) should be documented into an explanatory report.

12.3 Weight and CoG constraints

For the purpose of planning marine operations, the 50/50 weight estimate method as described in ISO 19901-5^[11] is not always used. Instead, not-to-exceed (NTE) weights with associated CoG envelopes are developed. In cases where minimum values of weight and CoG govern, these minimum values (not-to-go-under values) should be used. COG envelopes should consider 5 % in all directions before weighing, reduced to 1 % after weighing.

Upon receipt of the as-built weight and CoG, normally obtained by direct measurement, these as-built data are compared against the values used in the analyses. If needed, the analysis should be re-run using the as-built values with the selected weight contingency.

12.4 Weight control monitoring

When afloat, periodic draught measurements, weight control audits (of the construction and installation status, temporary item status and of the completeness of the weight reporting system) and appropriate inclining tests shall be carried out. Inclining tests shall only be carried out if subsequent operations require an accurate position of the CoG and if it is practical to do so.

For a description of the execution of an inclining test, see [13.12](#).

Alternatively, a deadweight survey and displacement test may be carried out to determine the weight and the horizontal position of the CoG. If the indicated weight and/or CoG does not fall within some pre-

agreed accuracy of the projected values (normally 1 %), a conservative penalty shall be applied for CoG determination by calculations. For more information, see [13.12](#).

12.5 Dimensional control

Where the balance between weight and buoyancy is critical to the draught, stability or floating behaviour, the dimensional control and monitoring shall be maintained, updated monthly and reviewed by relevant parties.

12.6 Serial items

When a large number of virtually identical items are built with quality control and management system (such as ISO 9001[\[47\]](#)), weighing of each item is not required. A reduced weight contingency factor may be agreed based on the standard deviation from weighing, of initial items with random subsequent weighing used to confirm consistency of manufacture. The manufacturer shall also supply a weight statement with tolerance and CoG envelope for all weight-sensitive items. Weighing of each item is not required if the quality control and predictions of final weights in initial weighings are shown to be good enough and a reduced requirement for weighing may then be agreed.

12.7 Weight determinations

The below information offers guidance in preparing weight determinations related to OWF components by physical weighing.

For weight determination, the following items should be engineered:

- weight control report containing components and contingency;
- weighing procedure/RAMS;
- structural integrity assessment for weighing load case;
- weighing results report.

13 Stability

13.1 Introduction

This clause does not cover the case of floating turbines moored to the seabed. Stability in this clause is referring (i) to vessels and barges, whether self-propelled or towed, or (ii) to self-floating structures, such as topsides of offshore substations or offshore accommodation platforms which are floated to the offshore location for installation by jacking up, or any structures towed during transport for further installation at the offshore location.

In addition to the above current requirements, the stability and global strength of all vessels are covered:

- by IMO criteria and registration authorities' requirements, applicable to vessels subject to IMO rules and regulations, or;
- by criteria set out by competent authorities, applicable to vessels that are subject to local requirements established by such authorities.

The general stability requirements for floating objects (e.g. wind turbine foundations, substation topsides), with comments on the stability criteria for particular types of structure where they differ from the general requirements, are set out in [13.2](#) to [13.12](#).

Special consideration is given for structures designed for one time voyage from construction site to installation site (floating topsides, floating foundations, etc.) which in addition to below specified criteria can also need to follow operational specific requirements.

Reference should be made to the IMO rules for special purpose vessels and work vessels operating in the offshore wind farms and near other structures.

13.2 General requirements

Intact stability and damage stability in accordance with the criteria established for the project shall be documented.

The general requirements for intact and damage stability given in [13.4](#) and [13.5](#) shall be applied to vessels and floating structures. Exceptions and alternatives are dealt with separately.

Vessels and barges used in marine operations shall consider the stability requirements dictated by the flag state of the vessel.

13.3 Stability calculations

The purpose of carrying out stability calculations it is to verify that the vessel/floating structure fulfils the requirements set out in the applicable rules and regulations. Thus, for all floating structures and vessels to which this document applies, stability calculations shall be carried out.

The results of the weight determinations (see [Clause 12](#)) shall be taken into account in these stability calculations.

If motion responses in various floating stages (such as construction afloat, towage and installation) that relate to the marine operations can cause loss of stability or can become critical for other considerations, dynamic analyses shall be used to verify adequate reserves in stability for safe marine operation, as per chart in [Figure 2](#).

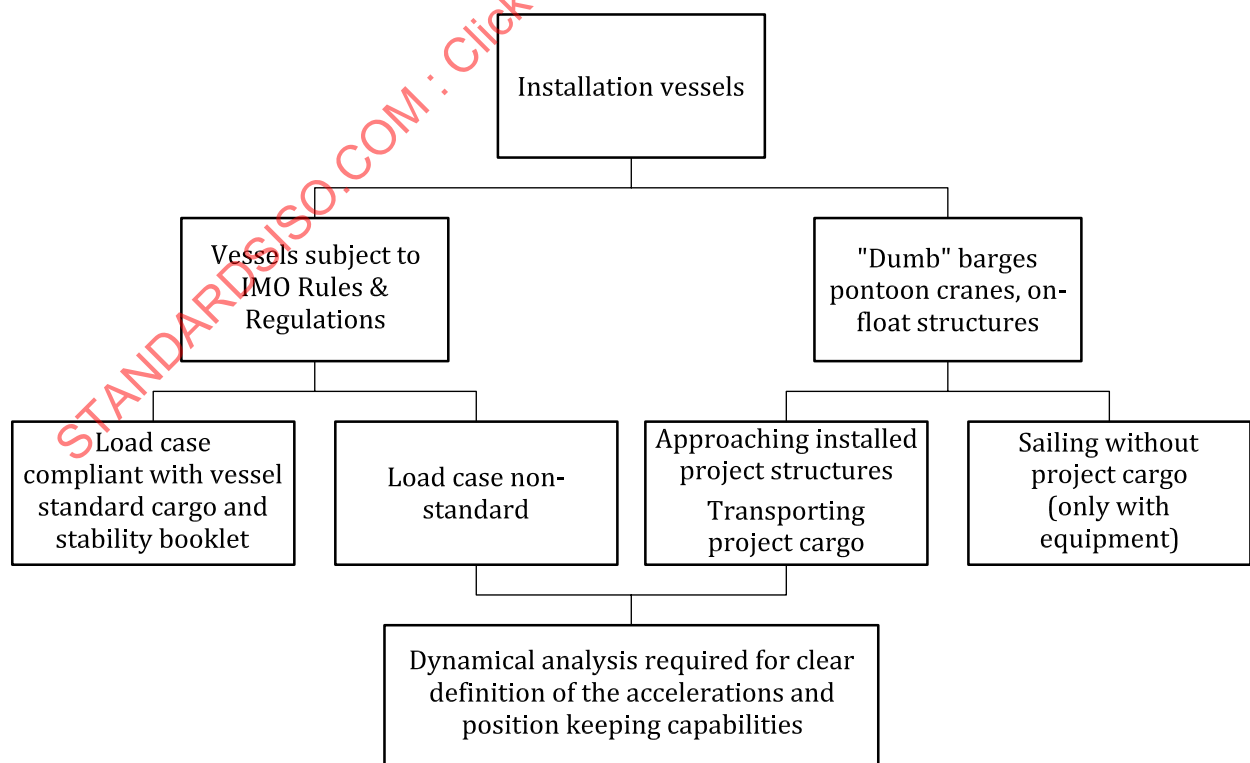


Figure 2 — Chart for dynamic analysis

The effective metacentric height (GM) together with the displacement and added mass and the moment of inertia determine the natural roll period. By employing the effect of free surface in cargo and ballast tanks, the natural periods can be shifted out of the region of spectral peak periods. This can avoid dynamic amplification. However, free surface effects at larger roll angles are limited by the tank shape and filling grades. The reduction in initial GM due to free surface shall be supported by adequate theoretical or experimental justification.

If the object considered is not essentially symmetrical about both a longitudinal and a transverse plane, then free-trimming calculations shall be carried out.

NOTE For some self-floating structures, longitudinal stability can be more critical than transverse stability.

The cargo (such as overhanging legs of structures and hulls of transformer platforms) can contribute to the intact stability (see 13.4) and thus shall be included in the calculations.

Allowance for ice accumulation on exposed structures should be taken into account as well.

In case project-specific reasons require deviation from the use of methods described in Figure 2 to allow quasi static or standard methods for evaluating positioning ability, methods as described in chapter 11.4 of Reference [56] or 12.2.5 of ISO 19901-6:2009^[8] should be used.

13.4 Intact stability

13.4.1 Introduction

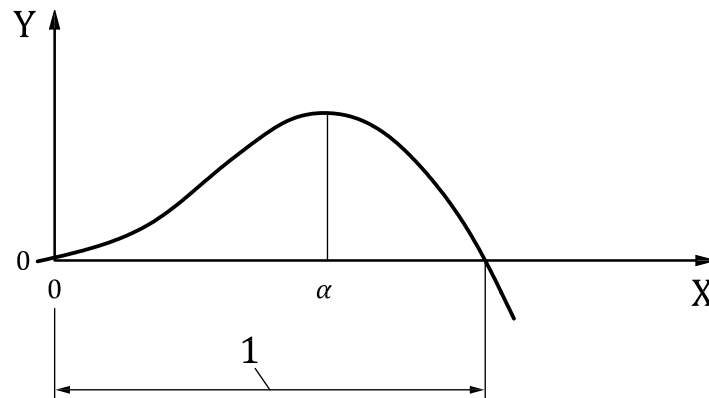
The intact stability range is the range between 0° heel or trim and the heeling angle at which the righting arm (GZ) becomes negative, as indicated in Figure 3.

NOTE External actions other than wind heeling, such as current actions, mooring and towing line tensions, actions from propulsion units, either main or azimuthing, can also have impact on stability.

Figure 3 shows both the initial linear and the subsequent nonlinear relationship between the heeling angle and the righting arm. The heeling angle, α , indicates the angle where the maximum hydrostatic righting moment occurs.

The maximum amplitudes of motion and associated stability criteria for a specific towage or voyage can be derived from motion response calculations or model tests. In addition, a further limiting heeling angle shall be determined to account for structural design limitations of, for instance, the topsides modules and their attachments to the hull at both the fit-out and welded out stages. In other words, if the integrity of equipment foundations or topsides-to-hull attachments are compromised at 10°, it is irrelevant if the hull can heel to 15°.

In general, the stability criteria of the applicable flag state and class approved requirements shall be considered, unless satisfying other safe stability criteria can be demonstrated and proven as equal.

**Key**

- X heeling angle, expressed in degrees
 Y righting arm, expressed in metres
 1 intact stability range

Figure 3 — Illustration of stability terms**13.4.2 Intact stability criteria**

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see [Figure 4](#)) shall be calculated up to a heeling angle which is the smallest of:

- the angle corresponding to the second intercept of the two curves;
- the angle at which the progressive flooding occurs;
- the angle at which overloading of a structural member occurs, including grillage and sea fastening components.

Guidance on how to derive the wind heeling moment curve is given in Reference [\[44\]](#).

The area under the righting moment curve shall not be less than 1,3 times the area under the wind heeling moment curve for column-stabilized floating structures (wet tow of semi-submersibles) and shall not be less than 1,4 times the area under the wind heeling moment curve for other types of floating structures (including dry tow of semi-submersibles) as given in the relationships in [Formula \(3\)](#) for column-stabilized structures and [Formula \(4\)](#) for other structures:

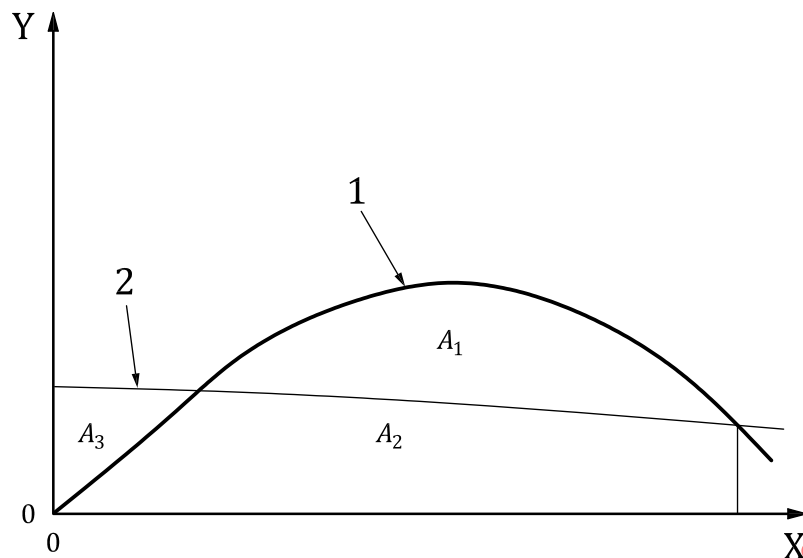
$$(A_1 + A_2) \geq 1,3 (A_2 + A_3) \quad (3)$$

$$(A_1 + A_2) \geq 1,4 (A_2 + A_3) \quad (4)$$

where A_1 , A_2 and A_3 are the areas defined as indicated in [Figure 4](#).

The wind speed used to compute the wind heeling moment curve shall be the 1 min sustained wind at an elevation of 10 m above sea level during the operation with return periods as defined in [7.4.2](#).

NOTE A 36 m/s wind speed is typically checked for normal operational conditions.



Key

- X heeling angle, expressed in degrees
- Y moment, expressed in kilonewton-metres
- 1 righting moment
- 2 wind overturning moment

Figure 4 — Intact stability requirement

The stability range should not be less than $20 + 0,8 \beta$, where β is the sum of the static wind heeling angle and the maximum roll angle in degrees.

Where cargo overhangs are immersed as a result of heeling due to a 15 m/s beam wind in still water conditions, it shall be demonstrated that vessel controllability is not seriously impaired, and that no structural damage to the cargo can occur; see also sea fastening requirements as given in [16.17.3](#).

For marine operations of very short duration in sheltered waters (for instance harbour moves and out-of-dock operations) that are covered by a reliable weather forecast, an exemption from the intact stability requirements may be considered. However, the range of positive stability shall never be less than 15° .

13.5 Damage stability

13.5.1 Introduction

Damage stability shall be evaluated by considering the operational procedures and duration, environmental actions and responses, and the consequences of possible damage. Reference should be made to Reference [\[56\]](#). Distinction is made between requirements on damage stability for non-jack-up vessel (see [13.5.2.1](#)) and for jack-up vessels (see [13.5.2.2](#)).

Evaluation of damage stability shall be based on damage scenarios according to previously identified contingency situations. Collision, leakage and operational failure situations shall be evaluated. Damage cases shall include flooding of any one compartment located below the maximum subdivision waterline that is either adjacent to the sea or capable of being flooded by ballast water, sea water service or bilge piping passing through the compartment.

As a minimum, the floating object shall have sufficient stability and reserve buoyancy to remain floating at a waterline below any opening where progressive flooding can occur with any one compartment undergoing flooding.

Attention shall be paid to ingress of water caused by, for example:

- impacts from vessels, dropped objects, etc.;
- mechanical system failure;
- operational errors;
- vessel dynamics and variations of wave height in defined sea states;
- downflooding points.

In the case of collision, the following parameters shall be considered:

- compartments separated by a watertight deck within ± 5 m of the maximum subdivision waterline shall be considered as one compartment;
- transverse penetration of not less than 1,5 m, unless it can be demonstrated that such penetration is unlikely to occur;
- longitudinal damage of 3 m of horizontal extent, or one eighth of column perimeter of exposed areas in the worst region;
- piping ventilation systems, trunks, etc. within the extent of damage shall be assumed to be damaged.

Damage to compartments above the maximum subdivision waterline, including, for instance, caissons or cargo compartments, the buoyancy of which is required to meet the intact stability requirements of [13.4](#), should be taken into account in damage case definition.

The emptying of a full compartment to the waterline in damaged condition shall be considered if it gives a more severe result than the flooding of an empty compartment. The loss of air from any air cushion compartment shall also be considered.

Where it is impractical to comply with damage stability requirements in [13.5.2.1](#) and/or [13.5.2.2](#), a risk assessment shall be carried out, and the following precautions for the prevention of damage/collision impact shall be taken:

- reinforce or fender vulnerable areas to withstand collision from the largest towing or attending vessel, at a speed of typically 2 m/s;
- protect offshore wind farm components against collision or damage from towing and handling lines;
- provide emergency towlines with trailing pick-up lines to minimize the need for vessels to approach the structure closely during the tow;
- provide emergency pumping equipment;
- minimize the potential for leaks via ballast or other systems;
- protect ballast intakes, discharges and any other penetrations through the skin of the vessel or object by means of a double barrier system or blanking off;
- conspicuously mark vulnerable areas and make masters of all towing or attending vessels aware of these;
- provide a guard vessel to warn off other approaching vessels.

13.5.2 Damage stability criteria

13.5.2.1 Damage stability criteria for non-jack-up vessels

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see [Figure 5](#)) shall be calculated from the equilibrium heeling angle up to a heel angle, which is the smallest of:

- the angle corresponding to the second intercept of the two curves;
- the angle at which progressive flooding occurs;
- the angle at which overloading of a structural member occurs, including grillage and sea fastening elements.

Guidance on how to derive the wind heeling moment curve is given in Reference [\[44\]](#).

The area under the righting moment curve shall not be less than 1,4 times the area under the wind heeling moment curve as given by [Formula \(5\)](#):

$$(A_1 + A_2) \geq 1,4(A_2 + A_3) \quad (5)$$

where A_1 , A_2 and A_3 are the areas defined as indicated in [Figure 5](#).

NOTE This criterion has been found inadequate for jack-ups, and is likely to be inadequate also for barges with limited freeboard carrying cargoes[\[59\]](#).

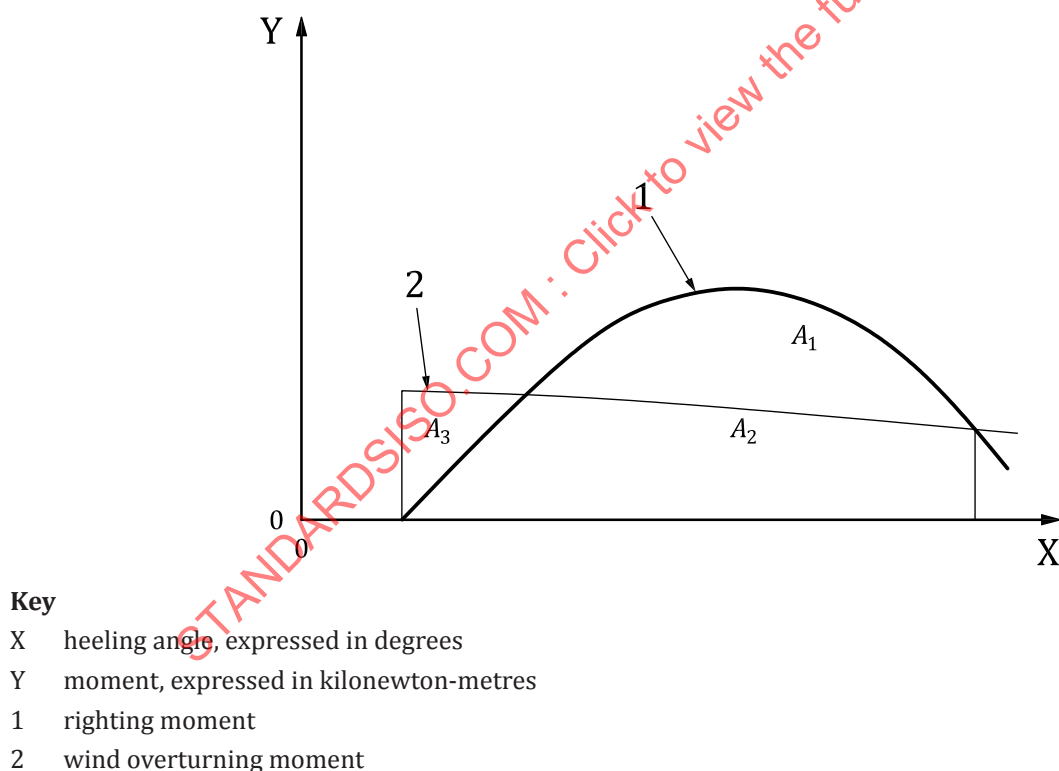


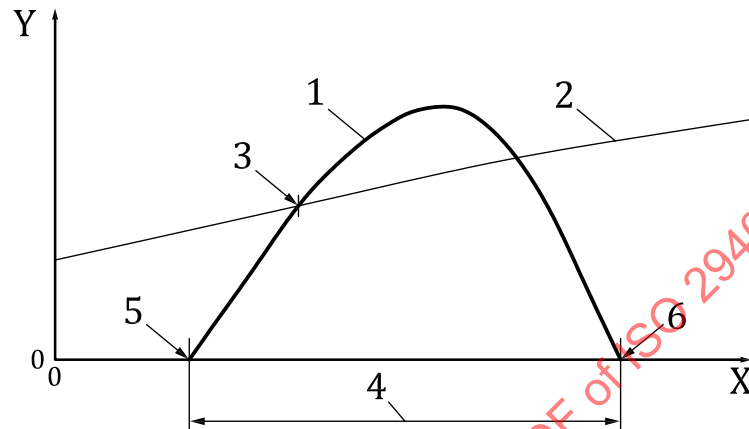
Figure 5 — Damage stability requirements for non-jack-up vessels^[8]

13.5.2.2 Damage stability criteria for jack-up vessels

Jack-ups shall have positive stability about any horizontal axis with any one compartment flooded or breached.

The residual range of damage stability, see [Figure 6](#), (ignoring downflooding and wind inclination) about any axis from the static heel angle (after flooding) to the maximum heel angle of positive stability shall be not less than $7^\circ + 1,5 \times \text{heel angle without wind}$, with a minimum of 10° .

The downflooding angle shall be greater than the first intercept (the static heel angle plus wind heel). The wind velocity used for overturning moment calculations in the damage condition shall be 26 m/s (50 knots) or the wind used for the intact calculation if less. It shall be applied in the most critical direction (see Reference [\[56\]](#)).



Key

- X heeling angle, expressed in degrees
- Y moment, expressed in kilonewton-metres
- 1 righting moment
- 2 wind overturning moment
- 3 1st intercept (static heel angle plus wind heel)
- 4 range of damage stability
- 5 heel angle without wind
- 6 maximum heel angle of positive stability

Figure 6 — Damage stability requirements for jack-up[\[56\]](#)

13.6 Single-barge transports

Single-barge transports should conform to the requirements set out in [13.4](#) and [13.5](#).

13.7 Multi-barge transports

Multi-barge transports are transports where the cargo is supported by more than one barge, or by one or more barges supported in turn by additional barge(s).

Multi-barge transports shall conform to the requirements of [13.4](#) and [13.5](#), with the following additional recommendations:

- barges that are totally immersed in the intact condition should be classed as submersible barges;
- it should be demonstrated that the flooding of any one compartment of any barge cannot cause the damaged barge to change its heeling or trim angle relative to the overall heeling or trim of the combined barge assembly. The damaged barge should not pivot around any of the reaction points between it and the cargo or between it and another barge, thus losing contact at any other reaction point.

13.8 Classed vessels

The requirements of [13.4](#) also apply to classed vessels.

For vessels that carry offshore or similar cargoes, reference should be made to the IMO instruments in References [\[44\]](#) and [\[27\]](#).

The damage stability requirements in [Clause 13](#) do not apply to the transport of cargoes on registered and classed trading vessels sailing at the assigned “B” freeboard or greater.

NOTE 2 The “B” freeboard is the minimum freeboard assigned to a type B vessel, which is generally defined as any vessel that is not carrying a bulk liquid cargo. Reduced freeboards can be assigned to a type B vessel that is over 100 m in length, depending on the arrangements for protection of crew, freeing arrangements, strength, sealing and security of hatch covers, and damage stability characteristics, see IMO instruments in Reference [\[52\]](#) for further details.

13.9 Self-floating structures

13.9.1 Introduction

Self-floating structures are objects that are supported by their own buoyancy during construction afloat, towage and installation (such as GBSs with or without topsides, floating monopiles, topside structures for offshore substations).

Because of the diversity of self-floating structures, where compliance with the general requirements and guidance in [Clause 13](#) is not applicable or practical, a risk assessment shall be carried out (see [13.5.2](#)).

13.9.2 Intact and damage stability

13.9.2.1 The requirements of [13.4](#) and [13.5](#) shall apply with the additional criteria specified in this subclause.

The initial intact GM, after correction for free surface and air cushion effects, shall not be less than 1 m.

Where the intact stability range required by [13.4](#) cannot be achieved, it shall be demonstrated that

- $\phi_{\max}$, the value of the maximum dynamic heeling angle due to wind and waves, expressed in degrees, is at most half that of the heeling angle, α , expressed in degrees, where the maximum hydrostatic righting moment occurs, see [Figure 3](#);
- the area ratio required in [13.4.2](#) can be achieved.

During construction afloat, particular attention shall be paid to any internal or external openings to sea that can vary as construction proceeds. After damage, when subjected to the design wind and wave for the operation, an adequate freeboard shall remain.

A risk assessment shall be carried out for operations where, at any stage, stability and/or reserve buoyancy is critical. The duration of the critical condition shall be minimized. Requirements for back-up systems and their availability shall be assessed.

13.9.2.2 For some floating structures, applying damage stability requirements is impractical at some stages of construction or towage. In such cases alternative measures shall be considered, which can include the following:

- providing local structural reinforcements or fenders within the area bounded by two horizontal planes positioned e.g. 5 m above and 3 m below the maximum subdivision waterline, in order to minimize effects of a collision from the largest towing or attending vessel;

- developing operational procedures and risk assessment with appropriate measures such as exclusion zone and tow line minimum length to ensure that flooding does not occur; this includes consideration of collision, leakage through the ballast or other systems, reliability and redundancy in pumping arrangements and redundancy of power supplies;
- carrying out a risk assessment for flooding.

13.9.3 Upending and installation of self-floating and launched structures

The following apply for the upending and installation of self-floating and launched structures:

- intact and damage conditions shall take into account the most severe combination of tolerances on structure weight, CoG, buoyancy, centre of buoyancy and water density;
- a FMEA or similar study should be carried out on the ballast and buoyancy systems to ensure that any single failure of a component or system does not lead to an unsafe condition either during or after marine operations;
- reserve buoyancy (the remaining buoyancy that can be mobilized before flooding can occur) should not be less than that shown in [Table 3](#);
- the minimum GM after launch and during upending should not be less than that shown in [Table 4](#).

Reserve buoyancy, B_r , as a percentage of the total available buoyancy, is calculated using [Formula \(6\)](#):

$$B_r = 100(B_0 - W_0)/B_0 \quad (6)$$

where

B_0 is the total available buoyancy of the structure;

W_0 is the weight of the structure in air; generally, this should be the upper bound design jacket weight.

For operations with crane assistance, the reserve buoyancy shall be based on nominal total intact buoyancy, when the weight is that of the jacket minus

- 90 % of the crane capacity at that radius, or
- total of 80 % of each crane capacity for a two-crane lift at the relevant lift radii.

Table 3 — Recommended reserve buoyancy based on nominal total intact buoyancy

Case	Intact %	Damage %
Structure after launch or lifted jacket if required to be re-rigged before upend. Also applicable where jacket is to be upended using ballast both with and without crane assistance and to self-upending jackets in free floating position.	10	5
During upending by ballasting	8	4
Absolute minimum, subject to agreed risk assessment results	5	2,5
^a Contingency procedures shall be in place to allow for corrective action should the static hook load exceed the expected static loads. ^b For all conditions, the effect of the maximum possible load on the lift points and jacket at each position analysed shall be considered in the design of these items.		

Table 3 (continued)

Case	Intact %	Damage %
Lifted jacket, with static and dynamic analysis carried out and contingency procedures in place ^{a,b}	8	4
Lifted jacket, with only static analysis carried out ^{a,b}	12	6
^a Contingency procedures shall be in place to allow for corrective action should the static hook load exceed the expected static loads.		
^b For all conditions, the effect of the maximum possible load on the lift points and jacket at each position analysed shall be considered in the design of these items.		

EXAMPLE Among other things, damage can be due to the unintended flooding of compartments during upending caused by tearing/breakage of rubber diaphragms on skirt pile sleeves.

Table 4 — Recommended minimum GM after launch and during upending

Case	Intact m	Damage m
During towage to field (self-floating only)	As agreed, damaged range is generally more critical than GM	
Before launch	^a	^a
During launch	>0,0 ^b	n/a
After launch, transverse and longitudinal	0,5	0,2
During upending, transverse	0,5	0,2
During upending, longitudinal ^c	>0,0	>0
After upending, before final positioning, both directions	0,5	0,2
^a Minimum range of static stability, ignoring any buoyancy contribution from the jacket, shall be not less than 15 + (10/GM) degrees or 20°, whichever is higher, with GM in metres.		
^b The angle of heel caused by 1,5 times the limiting launch wind speed shall be shown to be acceptable.		
^c A limited period during upending, when the structure is metastable or unstable longitudinally, can be acceptable, provided the behaviour has been investigated and all interested parties are aware of it. Practical problems that can be encountered with attending vessels, or rigging and handling lines, should be resolved.		

Documents should be prepared to show the calculations of the minimum GM after launch and during upending with the top of structures immersed, if applicable.

As it is not practical to provide either damage stability or reinforcement against collision over the full range of waterlines, planning and risk assessment as mentioned in [13.9.2](#) should also include:

- a clear statement of the draughts, times, durations and operational sequences when damage stability is not available, or the reinforcement cannot be carried out;
- a procedure to return to a waterline that is reinforced against collision should the installation operation be aborted.

13.10 Loadout operations

The stability requirements for loadouts of objects onto barges or vessels (see [Clause 15](#)) can also be applied to a float-on to or a float-off of a buoyant cargo from a submersible barge or vessel.

Loadout operations from the quay onto a floating barge or vessel shall be performed with a GM adequate for the operation and shall take into account the CoG changes as the cargo crosses the quay edge. Normally, GM should be greater than 1 m, unless a smaller value can be justified.

The free surface effects of slack tanks or ballast tanks on GM during the loadout operation should be considered.

The area ratio requirements of 13.4.2 shall apply.

Except for a float-on onto a submersible barge or vessel, the effective freeboard, l_{freebd} , (the minimum vertical distance from the water surface to any opening, e.g. an open manhole) should satisfy Formula (7), expressed in meters:

$$l_{\text{freebd}} \geq 0,5 + H_{\text{max}} / 2 \quad (7)$$

where H_{max} is the maximum anticipated wave height at the site during the loadout, expressed in metres.

The maximum possible tide level and any possible heel or trim should be taken into account. Coamings can be installed at openings to increase the effective freeboard.

During float-on operations, when loading a buoyant cargo onto a submersible barge or vessel, the stability of the combined vessel and cargo can at times be minimal. The slope of the righting arm versus the heeling angle curve can be very sensitive to a small change in ballast condition. Care should be taken to ensure that a small change in ballast does not cause an unforeseen change in trim or heel (in floating condition). A sensitivity check should be undertaken, taking into account tolerances in cargo weight and CoG, and ballast quantity and position.

For additional information on the stability requirements during float-on onto submersible barges and vessels, see 15.12.

13.11 Watertight integrity and temporary closures

The number of openings in watertight bulkheads and decks shall be kept to a minimum.

Temporary closing devices, such as hatches, blind flanges and access openings shall be watertight. closing devices, which can be submerged or exposed to slamming or sloshing, should be designed for such actions and suitably verified as fit for purpose. These temporary closing devices should be marked "CLOSED AT SEA". Type and securing of seals and gaskets should be carefully considered.

Openings between buoyant compartments that can contribute to progressive flooding should be closed during operations. If the above closings are temporary, they should be marked "CLOSED AT SEA".

Where practical, regular inspections or gauging of water level, draught, heel, trim and air pressure should be carried out during operations.

13.12 Inclining tests

The provisions for the execution and analysis of the measurements of inclining tests given below shall be followed. Additional information on inclining tests can be found in Reference [44].

Inclining tests shall be carried out on structures where knowledge of the precise position of the vertical CoG is critical to the safety or feasibility of subsequent operations. The necessity for such tests should be determined by the sensitivity of the planned operation, the accuracy of the calculated GM and weight control, and on whether previous tests have been performed.

A detailed procedure for the test shall be prepared.

The effects of external actions due to wind, waves, moorings, anchors, tugs and cranes should be considered and monitored.

Before the test, a sensitivity analysis of the parameters affecting the test results should be performed. Sensitivity analysis shall demonstrate the feasibility and safety of the inclining test in the external conditions described and agreed by the relevant parties.

NOTE Such parameters include draught, heel angle, sea water density, inclining weights and distance moved, wind actions, dimensional control of the structure and accuracy of the measuring equipment.

The floating structure or vessel should be completed as much as possible to ensure accuracy of the results of the structure or vessel in operation. For floating objects with a large GM, an inclining test does not always give sufficiently accurate results. In this case, the stability calculations shall be based on the calculated weight and CoG, derived from the weight control and dimensional control systems.

For adding major components to a floating structure that cannot be inclined, weight and horizontal CoG confirmation may be obtained by direct measurement (i.e. displacement test or dry weighing).

Where the indicated weight and/or CoG is not within a prescribed accuracy of the projected weight (normally 1 %), a penalty shall be applied to the vertical position of the CoG. This penalty shall take the form of the full difference between the measured and projected weight applied at a conservative location so as to force the vertical position of the CoG upwards.

14 Ballasting operations

14.1 Introduction

In this clause, the ballasting operations of offshore structures are considered, including steel structures, GBSs, vessel, barges, and, in particular, temporary or one-off ballasting requirements for transient marine operations rather than routine service life operations.

Regulations or requirements relating to the transfer and/or treatment of ballast water, locally and at destination, can be applicable.

Ballasting operations typically control the following:

- the draught, heel and trim of floating structures;
- the stability of floating structures;
- the deflection of, and/or the load distribution in, floating structures;
- the rate of immersion of floating structures;
- the ground reaction and distribution of reactions on seabed supported structures.

Ballasting is usually effected using sea water and distributed by pumping, gravity, air pressure or differential hydrostatic pressure through a system of pipes and valves into either open tanks or closed tanks that are vented.

Ballast systems using liquids can sometimes incorporate air cushions, typically to effect a decrease in draught. Air cushions can also be used to control the quantity of floodwater entering a compartment.

Less commonly, solid ballast can be used, typically in the form of heavy granular material, concrete or steel in the case of permanent ballast.

Ballast systems are typically used during transient phases in the following marine operations:

- lift-off or float-out from construction docks;
- immersion, trim and stability control during construction while afloat;
- load transfers from shore to barges (float-out operations);
- mating operations;
- launching operations;
- upending operations;
- structure setting operations;

- gravity structure installation operations;
- subsea immersion operations;
- float-on and float-off operations;
- decommissioning.

14.2 Ballast calculations for different stages

Ballast calculations have the purpose to fulfil the requirements set out in the applicable rules and regulations. Thus, for all floating structures and vessels to which this document applies, ballasting calculations shall be carried out. In case an automatic ballasting systems exists, potential load cases shall be analysed using the ballasting/load-computer. In case potentially unsafe transient conditions cannot be ruled out, detailed calculations and a procedure to return to safe ballast condition shall be established in accordance with an FMEA of the ballast system.

14.3 In ballast system

14.3.1 Operational aspects

During planning of marine operations, aspects for consideration relative to the operation of the ballast system shall be documented, as a minimum, with amongst others:

- arrangement drawings;
- line diagram(s) for the ballast piping or distribution system, identifying the system components, including its control mechanisms and power sources;
- line diagram(s) for the venting system, identifying the system components, including its control mechanisms and power sources;
- line diagram(s) for the compressed air system, identifying the system components, including its control mechanisms, safety devices and power sources;
- line diagram(s) for the hydraulic system, identifying the system components, including its control mechanisms, safety devices and power sources;
- system and equipment specifications to facilitate the measurement/monitoring of installed ballast;
- specification of system commissioning requirements and testing and trial parameters;
- ballast calculations for the planned operations;
- ballast calculations for contingency situations, including recovery from accidental flooding situations;
- drawings showing potential vulnerability of pipework passing through machinery spaces;
- certificates showing that checks have been completed on low-pressure pipework to ensure it does not become a downflooding conduit in a foreseeable event;
- drawings showing the location of a second station from which valves can be controlled in any foreseeable accidental event;
- associated stability, strength and deflection calculations for load cases, as appropriate;
- FMEA.

The ballast system should operate according to fail-safe principles so that the structure remains in a stable and controlled condition in the event of the failure of any single component. The definition of component should cover, at the very least, active components.

The ballast system shall have the capability to bring the structure back to a safe condition or interrupt the operations in the case of a possible failure.

Safe conditions for operations after passing a PNR should be defined.

Ballast and deballast systems should have sufficient capacity to complete the operation or to achieve a safe condition within the time limitations determined by weather forecasting periods, tidal cycles and any other constraints, with adequate contingency.

The ballast system should operate safely at feasible draughts and floating attitudes of the structure, including recovery from damaged conditions.

The ballast system should operate with adequate allowance for possible variations in the weight and in the position of the CoG of the structure; see [Clause 12](#).

A FMEA study should be implemented to demonstrate that control of operations is not compromised by the failure of any single component, particularly where the component plays an important role in the performance of any stage of the operation.

14.3.2 Other operational considerations

Where the functions of the ballast system include compensation for weight transfer when affected by the tide, then wherever possible, certain tanks should be solely dedicated to the tidal compensation measures and other separate tanks should be solely dedicated to the weight transfer compensation measures.

A risk analysis should be carried out to verify the ability of the ballast system to function in accordance with the design parameters.

NOTE The risk analysis typically takes the form of a FMEA.

Back-up facilities should be arranged for ballasting or deballasting of each independent compartment.

Where relevant, the strength, function and workmanship of the components of the ballast system should satisfy the requirements of the recognized organization rules.

The transfer of sea water (or fresh water) between any tank and the sea should be through two independently controlled valves to provide double barriers against water ingress.

Consideration should be given to internal pressurizing with air and remote monitoring of air pressure in nominally dry compartments for the purpose of detecting damage or leakage, for example on launched structures.

Compartments that are vulnerable to flooding from either penetration damage or from internal leakages should be fitted with a pumped bilge drainage system. Where appropriate, the bilge system should comply with RCS rules.

The design life of the system components should be considered for future decommissioning and removal requirements.

14.4 Protection against damage and deterioration

14.4.1 Introduction

Internal and external sea water inlets, vent piping and valves shall be protected against blockage or malfunction by the ingress of debris.

Control and indicating piping and cabling systems shall be protected against damage, for example from impacts during operations. Where appropriate, such systems should be routed to avoid areas that are vulnerable to penetration damage to the hull.

Sea water ballast systems shall consider the addition of a corrosion inhibitor and biocide, which can be covered in environmental regulations, if the ballast is either permanent or is to remain in the system for a prolonged period of time.

Regulatory authorities should be consulted regarding products that are accepted for discharge in areas under their jurisdiction.

Loose solid ballast, where submerged, should be protected against dispersal by wave or current action.

14.4.2 Freezing

When low temperatures are expected, measures shall be taken to prevent or minimize the effect of the freezing of ballast water contained in exposed compartments, and exposed tank vents should be checked and cleared of ice accumulation prior to ballasting operations.

14.5 Prevention of progressive flooding in damage condition

Ballast piping and vent lines shall be routed to avoid areas that are vulnerable to penetration damage to the hull. Where this arrangement is not practical, piping systems should be provided with shut-off valves that are located in the compartment containing the open end of the pipe or in a suitable position such that the compartment can be isolated in the event of damage to the piping system.

Piping systems and valves shall be designed to prevent accidental cross-flooding and uncontrolled ingress of water in likely operational conditions and in the designed damage cases.

14.6 Control and indicating systems

Where appropriate, a central ballast control station shall be provided. It shall be located above the worst damaged waterline, adequately protected from weather and accessible in any conceivable floating condition. Where applicable, it should be provided with the following control and indicating systems:

- ballast pump control system;
- ballast pump status-indicating system;
- air compressor control system;
- air compressor status-indicating system;
- ballast valve control system;
- ballast valve status-indicating system;
- vent valve control system;
- vent valve status-indicating system;
- tank level indicating system;
- draught indicating system;
- heel and trim indicating system;
- power availability indicating system;
- ballast system hydraulic/pneumatic pressure-indicating system;
- air cushion pressures;
- air cushion water seal levels;
- air leakage rates.

Both the ballast control system and the ballast indicating system should be provided with uninterruptible power supplies (i.e. battery or diesel generator set or external power source). The minimum required duration for the uninterruptible power supply shall be determined based on risk assessment.

Valves and operational controls shall be clearly marked to identify the function they serve.

Means to indicate whether a valve is open or closed shall be provided at each location from which the valve is controlled. The indication shall rely on positive movement of the valve spindle. Remotely operated valves shall have some local or other secondary means of determining its open or closed status.

The ballast control system and the ballast indicating system should function independently of each other so that a failure in any one system does not jeopardize the operation of the other systems.

The accuracy of electronic tank level soundings should be periodically verified against manual soundings to ensure accuracy.

Wherever practical, ballast tanks should be provided with a direct means to indicate their individual filling levels. Where tanks that are used for ballast have no means of indication, they should be designed to resist the loading from filling the compartment 100 % plus the greater of 66 % of its vent line height or the maximum pressure head that the tank can be subjected to by any pump used to fill it, whichever is the greater.

Ballasting operations shall be documented in an appropriate manner.

14.7 Pumps

14.7.1 Introduction

Ballast pumps should be self-priming unless it can be demonstrated that this is unnecessary for the intended application in the intact and damaged (inclined) condition.

14.7.2 Specification and layout

Rules and regulations can apply to the specification and layout of the ballasting system.

Rules and regulations can apply to the schematics and details of manifolds and valves.

14.7.3 Pump performance curves and functional limitations

Pump performance curves shall be documented and fed into the ballasting system, as appropriate, so that the operator can judge the performance and limit of the system. If necessary, the operations shall be laid down in a suitable operations manual.

14.8 Valve arrangements

Where remote controlled powered valves are fitted, a secondary means of operation, which can be manual control, shall be provided. Any automatic or radio-controlled system shall be provided with a manual override system.

The valve system shall be arranged to prevent the inadvertent transfer of ballast from one compartment to another in the event of failure of any single valve.

Valves that fail set (open) shall be provided with an independent secondary means of closure. Sea inlet and submerged ballast discharge valves shall automatically fail to the closed position upon loss of control or activating power, unless overriding considerations require a valve to fail set.

Consideration should be given to the requirement for non-return valves where there is a danger of unwanted siphoning between compartments, or between compartments and the sea.

The closing speed of power-operated valves should be limited where necessary to prevent excessive pressure surges. The actuators of control valves and the valves themselves shall be designed to operate against the highest flow velocities operationally possible.

Valves that can permit ingress of sea water, but also the transfer of sea water between tanks in case of loss of power or control, shall be of the “fail closed” type.

14.9 Vent systems

Ballast tanks shall be provided with air vents. The size of the vent pipes shall be sufficient to prevent excess overpressure of the tanks from rapid filling.

Vent openings that can become intermittently immersed in a damaged condition shall be self-closing in the event of immersion, or the vent system shall be designed to withstand flooding of the vented compartments concerned.

Closing appliances that are fitted to ballast tank air vent pipes should be of an automatic opening type that allows the free passage of air or liquid to prevent the tank from being subjected to a pressure or vacuum greater than that for which it is designed.

14.10 Air cushion system capacity

Air cushion systems should be designed for:

- redundancy in compression;
- active control and top-up;
- loss of any cushion section, which should be manageable.

14.11 System testing

Pumps and/or compressor systems should be delivered with a type approval certificate and function test shall be performed prior to be used. Where there is no type approval certificate, capacity trials should simulate realistic values of suction head, delivery head and backpressure, as appropriate.

Where systems have no redundancy, the commissioning and testing prior to operation shall be sufficient to prove reliability for in-service conditions.

The operability risks associated with the flushing and cleaning of hydraulic and pneumatic control systems shall be evaluated before a decision is made as to whether such systems should be flushed and cleaned as part of the testing process or after testing has been carried out.

15 Loadout

15.1 Introduction

This clause applies to the loadout of various types of structure, including, but not limited to, steel and concrete structures, jacket foundations, transformer substations, other WTG foundations, modules, components onto floating or grounded barges and ships. Loadout (float-on) of floating cargoes onto submersible barges and ships is covered in [15.12](#).

Due to the wide range of structures, loadout methods and transport vessels, this clause cannot cover all aspects of every loadout scheme. Alternative proposals and methods should be considered on their own merits in order to show that the operations are performed within defined and recognized safety/confidence levels.

The requirement of RAMSs for the loading, unloading and associated lifting processes depends on national regulations, the transport medium used and specific contract appointments between owner

and transport service provider. If certified RAMS for the loadout and lifting process is required, this statement has to address the specific component type, the transport medium and related processes. Annexes A.3 to A.6 of this document and Reference [56] provide an example for RAMS template which can be used as a guidance.

This clause applies particularly to skidded and trailer-transported floating loadouts in tidal waters. Recommendations for grounded loadouts or loadouts accomplished by lifting (see also [Clause 19](#)) are also included.

Loadouts involve the use of a system made of an assemblage of commercially manufactured equipment and sometimes a fabricator's own purpose-built devices and specially fabricated components that are designed for a range of operational conditions. It is important to document these operational parameters and ensure that the planned loadout procedures stay within these conditions. Analytical and operational checks should be made to ensure the integrity of the system.

Some of the more common checks are described in the remainder of this clause.

The following practices should be considered:

- use of contractors familiar with specialized equipment;
- performance of simulated tests prior to actual loadout, where practical, such as:
 - for skidded loadouts: perform a pre-skid (of a few metres only) to break friction and test equipment;
 - for trailered loadouts: perform a pre-lift and similar short movement.

The principles outlined in this clause also apply to the offloading of structures from a barge to shore. Barge-to-barge transfers should be considered on a case-by-case basis.

NOTE Reference to a “barge” includes a “ship” or “vessel” or vice versa, as applicable.

15.2 Categories of loadout

15.2.1 Introduction

The loadout operation can be categorized according to tidal conditions as indicated in [Table 5](#). The category does not reflect local weather conditions. For restricted and unrestricted operations refer to [7.2](#). Recommendations for design, reserves, and redundancy of mechanical systems can vary according to the category of loadout.

Table 5 – Categories of loadout operation according to tidal conditions^[8]

Category	Tidal limitations
1	The tidal range is such that, regardless of the pumping capacity provided, it is not possible to maintain the barge level with the quay throughout the full tidal cycle, and the loadout should be completed within a defined tidal window, generally on a rising tide.
2	The tidal range is such that, provided sufficient pumping capacity is available, it is possible to maintain the barge level with the quay during the full tidal cycle, and for at least 24 h thereafter.
3	The tidal range is negligible or zero, and there are no tidal constraints. Pumping should be employed only to compensate for weight changes as the loadout operation proceeds.
4	Grounded loadout employing sufficient pumping to compensate for tidal range to maintain ground reaction and/or actions on the barge within acceptable limits.
5	Grounded loadout where no pumping is necessary to maintain ground reaction and/or actions on the barge within acceptable limits.

15.2.2 Design: structural analysis during all loadout phases

The item to be loaded, hereafter called the "structure", shall be designed taking into account static and dynamic loads, support conditions, SPMT (loadout trailer) loads, environmental loads and loads due to misalignment of the barge and shore skidways or uneven ballasting.

For skidded loadouts, analyses which account for the structure and skidways should be presented which consider the elasticity, alignment and as-built dimensions of the shore and barge skidways for each stage of loadout. In the absence of detailed information, a 75/25 percent distribution of load across either diagonal may be considered, as appropriate.

The structure and supports shall be demonstrated as being capable of withstanding the subsidence of any single support with respect to the others by at least 25 mm.

Consideration shall also be given to lifting off construction supports or lifting onto seafastening supports.

The primary structure shall be of high-quality structural steelwork with full material certification and NDT inspection certificates showing appropriate levels of inspection. It shall be assessed using the methodology of a recognized and applicable offshore code including the associated loads and resistance factors for LRFD codes or safety factors for ASD/working stress design (WSD) codes.

15.2.3 Loadout planning

Normally, the owner of the structure has the overall responsibility for the planning and execution of the construction and marine operations, and hence also for the safety of personnel, facilities and the environment. The owner may delegate the execution and follow-up of these issues to the contractor.

Technical procedures shall be in place to control engineering related to the marine activities.

The objective of these procedures is to define applicable technical standards, to ensure agreement and uniformity with bridging documents where necessary, on matters such as:

- international and national standards and legislation;
- certifying authority/regulatory body standards;
- marine warranty surveyor guidelines;
- project criteria;
- design basis;
- metocean criteria;
- calculation notes;
- change management;
- document verification (essential as a quality assurance element in marine operations). The purpose of such verification is to avoid design or planning errors that can lead to unsuccessful marine operations;
- in case loadout is conducted from a jack-up vessel being jacked up during loadout, reference shall be made to [11.6](#) stating risks aligned with uncontrolled movement of jack-up legs and punch-through. Thorough investigation of the location for jacking during loadout is required.

15.2.4 Cargo weight details and CoG information

Generally, weight investigation and control measures, as well as CoG position accuracy requirements, shall comply with the provisions expressed in [Clause 12](#).

For calculation purposes conservative values of weight and CoG should be used. It should be noted that some calculation results, e.g. transportation motions, can be more critical with a lower value of weight and lower CoG.

Where an operation is likely to be CoG sensitive, the extremes of the CoG envelope shall be considered in calculations.

15.2.5 Deck loading plan

The deck strength shall be determined adequately for loadout and transportation loads including stiffener, frame and bulkhead spacing and capacity.

"Footprint" pressure on the quayside linkbeam and barge deck shall be shown to be within the allowable values.

Linkbeam capacity shall be demonstrated by calculation and these calculations shall form part of the loadout procedure.

The reactions onto the barge and the quay from the linkbeam should also be checked as this can impart highly concentrated loads into the barge and quay.

15.3 Structure being loaded

The structure being loaded shall be designed taking into account static and dynamic actions, support conditions, environmental actions, actions due to misalignment of the barge or vessel and shore skidways, or uneven ballasting.

For skidded loadouts, results of analysis that consider the elasticity, alignment and as-built dimensions of the shore and barge skidways for each stage of loadout shall be presented.

For arrangements of trailers or SPMT loadouts, the reactions imposed by the trailer configuration should be considered.

For lifted loadouts see [Clause 19](#).

Weight control and CoG shifts shall conform to the requirements of [Clause 12](#).

If weighing takes place shortly before loadout, the effect on the loadout procedures of any weight changes should be assessed in order to determine if planned weight contingencies are exceeded.

15.4 Site and quay

The quay, quay approaches, wall and foundations shall be adequate for the loadout and documented accordingly.

The capacity of mooring bollards, winches and other attachments shall be adequate for the loadout and documented accordingly. The bollard capacity may be documented by means of load test certificates or calculations.

Compatibility between quay strength and elasticity, and the support conditions used for analysis of the structure, should be demonstrated, where appropriate.

Recent (3 months maximum) and up-to-date bathymetric and height clearance information for the area covered or crossed by the barge during loadout operations, post-loadout operations and sail-away, should be supplied.

Under-keel clearance should not be less than 1,0 m during the period in which the barge is in position for loadout. This may be reduced to 0,5 m, provided a recent check of the loadout area has been made by bar sweep or divers' inspection, and subject to confidence in the lowest predicted tide and surge water levels and in agreement with relevant parties.

For tidal loadouts, an easily readable tide gauge shall be provided adjacent to the loadout quay. The water line level should be monitored prior to, during, and after loadout.

The necessary approval of port and coastal state authorities shall be obtained for the operation and for the institution of any necessary controls on marine traffic.

15.5 Barge

The barge shall be classed by a recognized organization. All certificates shall be made available for checking.

A check shall be made that the actions induced during loadout, including longitudinal bending moments, loads on internal structure and local loads, are within the approved design strengths.

Some loadout operations can temporarily invalidate the class or load line certificate, and it is necessary for these to be reinstated after loadout. This can apply if, for instance, structural changes have been made, including holes cut in the deck for ballasting, if towing or mooring connections or vent pipes have been removed, or, in some instances, after grounding on a pad.

The adequacy of the barge stability should be shown at all stages of loadout, as recommended in [13.10](#).

Suitable survey shall be performed prior to loadout, to check the integrity of the barge with respect to ballast system, navigation aids, condition of shells, towing gear, etc.

15.6 Link beams, skidways and skidshoes

The strength of the link beams, skidways and skidshoes shall be adequate and documented accordingly.

Link beams shall be checked for actions induced by barge moorings, barge movements and pull-on/pull-back actions.

Tolerances on link beam movement shall be suitable for anticipated movements of the barge during the operation.

Suitable lateral guides shall be provided along the full length of skidways.

Sufficient articulation of skidshoes shall be provided to compensate for level and slope changes when crossing from shore to barge.

15.7 Moorings

15.7.1 Weather-restricted operation

A loadout should be considered a weather-restricted operation as defined in [7.2.1](#). Design and operational weather conditions for the loadout operation shall be defined, taking into account:

- the forecast reliability for the area;
- the duration of the operation after the PNR, including a suitable contingency period;
- the exposure of the site;
- the time necessary for any operations before or after the loadout operation, including barge movements and moorings, ballasting, system testing, final positioning and initial sea fastening;
- currents during and following the operation.

For weather-restricted operations, the maximum forecast operational limits shall be lower than the design criteria; see [7.4](#).

15.7.2 Temporary mooring system

The design of the loadout mooring system shall be consistent with the requirements and recommendations in [Clause 13](#), with the following additional considerations. Moorings for the loadout operation should be designed for the weather conditions defined in accordance with [Clause 7](#). The design should also take into account potential loading from unplanned events such as SPMT breaking, contact forces from floating cranes, skidding forces, etc.

In cases where existing yard loadout mooring equipment is used, the wires and winches provided by the yard can sometimes have a breaking strength greater than the barge equipment to which they are connected. In such situations, great care should be exercised, and the forces should be controlled and monitored.

In cases where the propulsion system (see [15.11](#)) induces a reaction between the barge and the quay, the possible effects of this reaction shall be considered, including “hang-up” and sudden release.

The consequences of mooring line failure should be evaluated, and suitable measures taken to mitigate any risk (e.g. during skidding, a mooring line failure can result in high movement of the barge).

Mooring prior to, and after loadout should be considered a weather-unrestricted operation and should be designed for return periods in accordance with [7.4.2](#).

Consideration should be given to adjustable moorings, depending on the loadout method adopted and site condition (e.g. adjusting the tension in the mooring lines immediately before, during and after the loadout operation).

15.8 Grounded loadouts

A bathymetric and debris survey of the area covered by the bottom of the vessel/barge including specific safety zone shall be carried out, showing suitable support conditions for the vessel/barge.

A survey shall be made shortly before the vessel/barge is positioned to ensure that no debris is located where it can damage the bottom plating of the vessel/barge.

The plan area of the grounding pad with respect to the vessel keel/bottom plating of the barge should be of sufficient extent to ensure the edges of the grounding pad contain the “footprint” of the vessel/barge. If evenly distributed support over the bottom plating of the vessel/barge cannot be achieved, either geotechnical site investigation data shall be submitted, together with calculations demonstrating the capacity of the grounding pad and showing that no overstress can occur, or the sea floor shall be levelled.

Sufficient ballast capacity shall be available to provide ground reaction to withstand the loadings from the return periods as defined in [7.4.2](#) prior to and after loadout, coincident with mean high water on spring tides (MHWS) plus storm surge, and the corresponding mean low water on spring tides (MLWS) and negative surge, without lift-off, sliding or overstress. It is recommended that a 10-year return period be used [\[36\]](#).

Care should be taken when ballasting before grounded loadouts, or for floating loadouts with small under-keel clearances, to prevent seabed soil blocking the pumps or pipework. The highest possible water intakes should be used, and other precautions should be taken if there is significant suspended matter in the water.

If soils are soft and consolidation or settlement is expected to be significant, this shall be considered during the loadout. Where environmental conditions allow this, the barge can be placed on location in advance and preloaded with ballast in an attempt to induce the settlement prior to loadout. The designer is cautioned that consolidation of marine clays can take a long time. In any event, grounding on soft clay should be viewed with caution, considering the implications of adhesion and suction during removal of the vessel/barge.

Final skidway levels shall be compatible with the requirements of [15.3](#).

The ballast shall be adjusted during loadout, where necessary, to avoid vessel/barge settlement or overstress.

The plan for refloating of the vessel/barge shall be updated and, if necessary, revised in line with any changes in vessel/barge orientation not fully anticipated before the loadout. The plan for refloating the vessel/barge should include consideration of the moorings that are required, verification that the vessel/barge is undamaged and inspections or actions necessary to ensure that the vessel/barge remains in class following the grounding.

15.9 Pumping and ballasting

15.9.1 Pump capacity

Available pump capacity shall be based on the published pump performance curves, or verified by trial, taking account of the maximum head for the operational losses.

15.9.2 Recommended pump capacity

Pump capacity shall be documented onboard and depending on the category of loadout should satisfy the following points:

- the nominal maximum pump capacity computed for the loadout as planned, to compensate for tidal changes and weight transfer, with no contingencies;
- the computed pump capacity required, as a contingency, to hold the barge level with the quay, at the maximum rate of a rising or falling tide, assuming horizontal movement of the structure is halted;
- the computed pump capacity required, as a contingency, should be based on a $N+1$ philosophy, where N is the number of pumps to achieve the required maximum throughput. Where two or more pumps are supplied from a common power source, this shall count as a single system.

Primary ballasting is generally performed using external ballast pumps. For loadout on cargo barges, the barge's internal ballast system can be used as a back-up system. If the barge pumping system is used as part of the main or back-up pump system, a barge engineer familiar with the system shall be in attendance throughout the operation and the loadout communication system should include the pump room.

Pumps and systems shall be tested and shown to be operational within 24 h of the start of the loadout operation. A verification of pump capacity can be required.

Pumps that are necessary to reverse in order to function as part of the back-up capacity shall be capable of such reversal within a reasonable time defined by the risk assessment, and adequate resources shall be made available to perform this operation.

When barge internal pumps plan to be used as primary ballasting system, a full pump test should be carried out, checking the pump function and pump capacity. In case one pump fails, the other pump shall be able to provide ballasting for the all requested ballast tanks to maintain barge in even keel condition.

Responsiveness test described above could also be undertaken into a ballast system FMEA analysis.

Pumps that are portable in order to function as part of the back-up capacity shall be easily transportable, and may be considered only if free access is provided at all stages of loadout between the stations at which they can be required. Adequate resources shall be made available to perform the operation.

Ballast and barge levels shall be monitored during loadout, and shown to be within the limits of movements of any link beams, and the structural limitations of the barge and structure.

Where a compressed air system is used, the time lag required to pressurize or depressurize a tank should be considered, as should any limitations of the barge and structure.

Where a safe loadout plan is demonstrated, with reserve pumping capacity, this reserve capacity may be used to enable the loadout to proceed faster, provided it can also be demonstrated that this is safe.

The requirement for contingency pump capacity may be relaxed for weather and tidal unrestricted operations.

15.10 Loadouts by trailers, SPMTs or hydraulic skidshoes

15.10.1 Introduction

Where trailers or SPMTs are used to move the structure, the provisions of this subclause apply. When appropriate, the recommendations for trailers and SPMTs also apply to hydraulically operated skidshoes.

Maximum axle loading shall be shown to be within the trailer manufacturer's allowable values.

Footprint pressures on the quayside, link beam and barge deck shall be shown to be within the allowable values.

Shear force and bending moment curves should be prepared for the trailer spine structure, and maximum values shall be shown to be within the manufacturer's allowable figures.

SPMTs are normally arranged so that sets of axles are hydraulically interlinked, thus providing the same reaction at each support point within a set. Normally a layout with three sets of axles, thus giving a three-point support condition for the object, i.e. a statically determinate system, is recommended. However, it should be noted that a 3-point support system is generally less stable than a 4-point support system.

The hydraulic suspension layout (linking) should be thoroughly considered when undertaking a structural analysis. The planned hydraulic linkage and the associated load distribution shall be modelled in the analysis. The SPMT positions and linkage arrangements can be adjusted to optimise the resulting load distribution and deflections. The resulting deflections and stresses shall be compared against the allowable limits.

NOTE The resulting load distribution and structure deflections can differ significantly from that due to unlinked simple supports, especially for long structures.

In general, hydraulic systems should be linked or balanced to minimize torsion on the structure. In any event, the arrangement shall be compatible with the support assumptions considered for structural analysis. A contingency plan should be presented to cover hydraulic leakage or power-pack failure.

Vertical alignment of the barge, link beam and quay, including the effects of any change of slope and any movement of the barge due to wave action, should be within approximately one third of the maximum travel of the axles relative to the trailer spine.

15.10.2 Structural capacity

Documentation, including a statement showing the strength of the skidways, link beams and skid shoes, shall demonstrate compatibility with the statements made and assumptions used for the structural analysis.

The line and level of the skidways and skidshoes shall be documented by dimensional control surveys and reports. The line and level shall be within the tolerances defined for the loadout operation and skidway/skidshoe design.

For floating loadouts, care shall be taken to ensure that minimum friction exists between the barge and quay face. Where the quay has a rendered face, steel plates shall be installed in way of the barge fendering system.

15.10.3 Load equalization and stability

Hydraulic systems should be linked or balanced as a three-point hydraulically linked system to provide a statically determinate support system, thus minimising torsion on the structure. In any event the arrangement shall be compatible with the support assumptions considered for structural analysis of the structure being loaded out.

Stability of the hydraulic system to resist overturning shall be shown to be adequate, particularly when a 3-point hydraulic linkage system is proposed. The centre of action of the structure CoG shall remain within the middle quarter of the trailer support base, taking into account any uncertainty in:

- the horizontal and vertical centre of gravity (CoG);
- the design wind;
- any inclination of the structure/trailer assembly on shore;
- the predicted inclination of the barge under the design wind;
- possible change of heel or trim due to release of hang-up between the barge and the quay;
- any free surface liquids within the structure.

15.10.4 Vertical alignment

Vertical alignment of barge, linkbeam and quay, including the effects of any change of slope and any movement of the barge due to wave or swell action, should generally be within approximately one third of the maximum travel of the axles relative to the trailer spine.

Due to the particularities of those loadouts, vertical movement of the barge due to environmental condition should be limited as much as possible.

15.10.5 Skidshoes

Loadout operations involving skidding of cargo on the transportation vessel/barge shall take into account the following aspects:

- a statement showing the strength of the skidways, link beams and skid shoes shall be developed, demonstrating compatibility with the statements made and assumptions used for the structural analysis;
- link beams shall be checked for loads induced by barge moorings, barge movements and pull on/pull back forces;
- suitable lateral guides shall be provided along the full length of skidways;
- for floating loadouts, care shall be taken to ensure that minimum friction exists between the barge and quay face;
- the interface between the barge and barge fendering shall be liberally lubricated with a grease or other substitute, the use of which can be covered by local environmental rules.

15.11 Propulsion system design, redundancy and back-up

15.11.1 Propulsion system

The propulsion system, including back-up and contingency systems, shall be designed according to the category of loadout as defined in [15.2](#), and as shown in [Table 6](#). Recommendations for skidded loadouts include propulsion by wire and winch, hydraulic jacks or strand jacks. Recommendations for non-propelled trailer loadouts include propulsion by wire and winch or tractors.

If tractors provide motive power or if the trailers are self-propelled, the reversibility of motion should be demonstrated.

15.11.2 Redundancy and recommendations

For system redundancy, adequate back-up systems shall be provided so that the loadout can still proceed in the event of failure of any one mechanical component, hydraulic system, control system, prime mover or power source.

Where a system requirement is built-in, it shall be demonstrated that it is operational.

Where [Table 6](#) states that system redundancy is “recommended”, this shall be taken to read “required” if a conceivable failure can extend the operation outside the planned weather window. If it is not planned to provide this requirement, a risk assessment should be carried out.

Care should be taken to ensure that non-propelled trailers have a braking system as this is not always built-in.

The recommendation for a braking system may be relaxed provided it can be demonstrated that excessive inclination and runaway of the structure cannot occur; for example if a retrieval winch is employed as part of the contingencies, and this winch is paid out as the structure is loaded out, the winch can be employed as a hold-back system.

The coefficients of friction used for design and sizing of the propulsion system shall not be less than the maximum values shown in [Table 7](#), unless justification for a lower value can be provided.

Table 6 — Propulsion system design based on Reference [56]

Category ^a	System requirement	Skidded loadouts	Trailer loadouts	
			Non-propelled	SPMT
1	Slope capacity	Actual slope 3 %	Actual slope 3 %	Actual slope 3 %
	System redundancy	Required	Required	Required
	Braking system	Required	Built-in	Built-in
	Pull-back system	Required	Required	Built-in
2	Slope capacity	Actual slope 2 %	Actual slope 2 %	Actual slope 2 %
	System redundancy	Recommended	Recommended	Recommended
	Braking system	Required	Built-in	Built-in
	Pull-back system	Recommended	Built-in	Built-in
3	Slope capacity	Actual slope 1 %	Actual slope 1 %	Actual slope 1 %
	System redundancy	Not required	Not required	Not required
	Braking system	Required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in
4	Slope capacity	Actual slope	Actual slope	Actual slope
	System redundancy	Not required	Not required	Not required
	Braking system	Not required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in
5	Slope capacity	Actual slope	Actual slope	Actual slope
	System redundancy	Not required	Not required	Not required
	Braking system	Not required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in

^a See [Table 5](#).

Table 7 — Coefficients of friction for the design and sizing of the propulsion system based on Reference [56]

Level surfaces	Static		Moving	
	Typ.	Max.	Typ.	Max.
Sliding				
Steel on steel	0,15	0,30	0,12	0,20
Steel on Polytetrafluoroethylene (PTFE)	0,12	0,25	0,05	0,10
Stainless steel on Polytetrafluoroethylene (PTFE)	0,10	0,20	0,05	0,07
Polytetrafluoroethylene (PTFE) on waxed wood	0,14	0,25	0,06	0,08
Steel on waxed wood	0,10	0,28	0,06	0,15
Rolling				
Steel wheels on steel	0,01	0,02	0,01	0,02
Rubber tyres on steel	—	0,02	—	0,02
Rubber tyres on asphalt	—	0,03	—	0,03
Rubber tyres on compacted gravel	0,03	0,05	0,03	0,05

The design action on winching systems shall not exceed the certified safe working load (SWL), after allowance for splices, bending and sheave losses. If no certified SWL is available, the design action shall not exceed one-third of the breaking strength of any part of the system.

The winching system should be capable of moving the structure from fully on the shore to fully on the barge without re-rigging. If re-rigging cannot be avoided, this should be included in the operational procedures; adequate resources should be made available and the structure secured in a safe condition during re-rigging.

For skidded loadouts, the structure may be moved closer to the quay edge prior to the commencement of the loadout. Breakout friction is generally higher than the values given in [Table 7](#).

15.12 Float-on onto submersible barges or vessels

Floating transfers onto submerged barges or vessels should be accomplished by one of the two methods:

- stability is maintained by submerging the stern to the sea floor, while the bow or forecastle remains above the waterline. The water depth range during the operation should be limited to that which can be tolerated by the constraints of the operation. There should be a sufficient depth of water at the forward end of the cargo to clear the main deck and cribbing, and the angle of trim should not be excessive;
- the vessel is fitted with caissons at both ends or with forecastle forward and caissons aft, such that it can submerge its main deck sufficiently deep for the cargo to float over it, normally at a small or zero trim. No contact with the sea floor should occur, unless there is a contingency plan to contact the sea floor in the event of stability problems.

With either method, once the cargo has been floated over the vessel, the vessel is de-ballasted to induce sufficient reaction to ensure no further movement of the cargo and then further de-ballasted to the voyage waterline.

In either method, minimal stability phases can be encountered during ballasting and de-ballasting. Sometimes submergence of the unloaded vessel, when no cargo water plane area is present, causes a phase of minimal stability. During de-ballasting, a phase often occurs when the buoyancy and the water plane area of the cargo are lost, while the hull still does not provide a sufficient water plane area. Frequently this phase is achieved with a pre-determined trim or heel, calculated to maximize the contribution of the cargo to the overall stability.

Such float-ons are weather-restricted operations and should be planned either in sheltered water or in weather conditions such that relative motions, particularly vertical motions, of the vessel and cargo are

minimal, and such that wind and current action on the cargo during positioning are within the capacity of the handling and guidance systems.

The stability caution in [13.10](#) should be observed. A sufficient number of ballast stages should be calculated in advance, along with the corresponding stability condition. For the reasons outlined in [13.10](#), during critical stages the righting arm should be calculated in both directions to demonstrate that no instability can occur. Suitable tolerances on varying parameters should be considered.

Where sea floor contact is planned, or available as a contingency, or where under-keel clearance is small at any stage by a specified criterion (e.g. 10% of maximum draught), adequate sea floor surveys should be carried out and requirements for sea floor preparation should be considered.

Where restraint of the cargo during float-on is temporarily reliant on friction, predictions for the maximum inclinations should be calculated, taking into account [13.10](#), to demonstrate that any sliding of the cargo cannot occur. It is recommended that 50 % of the minimum values shown in [Table 7](#) be used for this value, based on observed operations; see also both [15.15](#) and [16.17](#) on seafastening.

The cribbing or dunnage should be accurately positioned and surveyed prior to submergence of the vessel, and adequately secured against float-off.

Guideposts or another adequate positioning system should be provided to align the cargo. Allowance should be made for differential trim or heel between cargo and vessel at first contact with the guideposts. The contact points between guideposts and cargo should be clearly marked. Additional optical or other means of checking the cargo position should be available, and the position should be verified before starting and during the de-ballasting operation, until the cargo is firmly seated on the cribbing.

Adequate positioning lines and winches should be provided to manoeuvre the cargo over the cribbing and against the guideposts, and to maintain position until the cargo is firmly seated on the cribbing. Generally, the breaking strength of positioning lines and attachments should not be less than three times the maximum anticipated load. The position of the attachment points should be such that the lines are working at suitable angles at all stages of the positioning process.

Where there is a differential trim or heel between cargo and vessel at first contact, it should be demonstrated that the contact loads and pressures are within acceptable limits.

Positioning the cargo over the cribbing should be done with minimal tidal flow. However, this can be the time at which the current reverses, and it is necessary, then, to reconcile these conflicting recommendations. It should be noted that at some locations, slack water does not necessarily coincide with high or low tide. Adequate tidal height and flow surveys should be carried out to establish the behaviour at the location at the same stage of the tidal cycle.

If any sea fastening elements are pre-installed or pre-positioned, it should be confirmed that they cannot damage either the cargo or the vessel during float-over, even in the event that the initial position is incorrect. In cases where this is impractical, due to for example the number of anodes, appropriate clearances shall be selected.

Draught marks should be painted on the cargo at a point where they can easily be seen.

15.13 Lifted loadouts

If lifting is chosen as the most suitable loadout method, the following aspects shall be checked before the lift:

- loads imposed by shore-based mobile cranes on the quay shall be shown to be within allowable values derived by calculation;
- when floating cranes are moored, thruster assistance may be used if available to augment the mooring arrangement. The use of thruster systems in combination with fixed mooring shall be carefully considered and DP system setup shall incorporate relevant features in order to enable this functionality;

- guideposts or another adequate positioning system should be provided to align the cargo. Allowance should be made for differential trim or heel between cargo and vessel at first contact with the guideposts. The contact points between guideposts and cargo should be clearly marked. Additional optical or other means of checking the cargo position should be available, and the position should be verified before starting and during the de-ballasting operation, until the cargo is firmly seated on the cribbing;
- where the offshore lifting padeyes are used for loadout, and when issues are noted during load out (such as DAF not respected, or angles which are not in line with the calculations), a programme for inspection of the lift points after loadout shall be presented. As a minimum, inspection of the padeyes and their connection into the structure shall be carried out by a qualified NDT inspector in accordance with the original fabrication drawings. Access for this (including the possible de-rigging of the lift point) shall be provided as required. At the discretion of the attending surveyor, additional NDT inspections can be required.

15.14 Horizontal loadouts

Horizontal loadout other than using trailers, SPMTs or skidshoes (see chapter [15.10](#)) could be encountered as a method mainly for heavy items as topsides for transformer platforms, heavy nacelles or other foundations.

Loadouts where the structure is moved horizontally onto the barge require special consideration and care, not limited to the following reasons:

- in nearly all cases, the ballast plan shall take account of additional parameters. Structure weight transfer, transverse heel, longitudinal trim and tidal level shall all be considered;
- friction between the side of the barge and the quay can be more critical than for an end-on loadout, as there can be a smaller righting moment available in heel than in trim to overcome this force. Snagging or hang-up can lead to the ballast operator getting out of synchronisation with the structure travel. Release of the snagging load has led to instability and failures;
- stability can be more critical than for an end-on loadout and changes of heel can be significant. The moment to change the barge heel one degree should be computed and understood for all stages of loadout.

15.15 Barge reinstatement and sea fastenings

Seafastening work shall be started as soon as possible after positioning the structure onto the barge. Seafastening shall be designed to minimize offshore cutting, to provide restraint after cutting and to allow lift-off without fouling. Relevant cargo positioning tolerances should be included in the structural design and capacity calculations.

No movement of the barge shall take place until sufficient sea fastening is completed to withstand the greater of the following:

- an inclination of 5°;
- an inclination caused by damage to any one compartment of the barge.

The seafastening should also be able to resist direct wind loading and any horizontal load on the barge from inclination of the barge due to the wind.

In circumstances where very limited barge movements are required, e.g. turning from end-on to alongside the quay, before it is practical to install seafastenings fully in accordance with the provisions of this subclause, then friction should be taken into account to contribute to the seafastenings. It is recommended that the coefficient of friction be 50 % of the minimum listed in [Table 7](#), if friction is considered as a restraint to movement. Design and condition of the actual supporting structure and potential sliding surfaces at the time of movement should be taken into account. This subclause can also

apply to loadout (float-on) onto submersible barges or vessels where loadout occurs away from the dock in deep water.

Final seafastening connections shall be made in the barge ballasted condition, as close as practical to the transport condition.

Manhole covers shall be reinstalled as soon as practical after loadout.

Holes cut for ballasting purposes should be closed as soon as practical and the barge certification reinstated before sail-away.

15.16 Tugs

Suitable and class-approved tug(s) shall be available or in attendance, as necessary, for:

- barge movements;
- removal of the barge from the loadout berth in the event of deteriorating weather;
- as back-up to the moorings.

15.17 Management and organization

Sufficient management and resources should be provided to carry out the operation efficiently and safely; see [Clauses 5](#) and [6](#).

The management structure, including reporting and communication systems and links to safety and emergency services, shall be demonstrated.

Shift changes at critical stages of loadout shall be avoided. If shift changes cannot be avoided or postponed, the loadout procedure shall address this constraint and explain the hand-over process. There shall be means in place to allow the operation to be pursued safely, e.g. the key supervisory and operational personnel shall have sufficient overlap in shifts to ensure a smooth handover.

A readiness meeting, attended by all parties involved, should be held shortly before the start of the loadout.

A weather forecast predicting conditions that are within the prescribed limits, should be received prior to the start of the operation, and at intervals of not more than 12 h thereafter until the barge is moored and the seafastening is completed.

Fit-for-purpose safety procedures shall be in effect.

15.18 Loadout manual

A loadout manual and supporting document should be prepared for the operation and issued for information and approval, as appropriate. The items, in addition to those found in [6.5.2](#), that it is recommended to include in the loadout manual and supporting documents are listed in [A.3](#).

15.19 Operating manual

Operating manual and documentation for loadout should contain the following statements and assessments:

- structure to be loaded shall be assessed from structural point of view using load cases including derivation of weights and contingencies. Results to be presented with justification for high stressed members and suggestions for structural modification in case of overstressed members;
- weighing report for structure, including results of weighing operation, load cell calibration certificates and tolerance;

- site plan, showing loadout quay, position of structure, route to quay edge if applicable, position of all mooring bollards and winches and any reinforced areas with allowable bearing capacities;
- drawing showing heights above datum of quay approaches, structure support points, barge, link beams, pad (if applicable) and water levels. The differential between civil and bathymetric datums shall be clearly shown;
- statement of maximum allowable loadings on quay, quay approaches, wall, grounding pads and foundations;
- method of fendering between barge and quay, showing any sliding or rolling surfaces and their lubrication;
- barge or vessel general arrangement and compartmentation drawings, hydrostatic tables, ballast system description, tank tables, class, deck bearing capacity and bollards SWL;
- stability and strength of barge/vessel for all stages of loadout including all temporary weights on board (pumps, jacking system, winches, skids, link beams, etc.);
- in case of loadout with SPMTs, trailer specification and configuration (mechanical and hydraulic connection), allowable load on axel, allowable spine bending moments and share force, stability of SPMT system;
- if ballasting is required with portable pumps, details regarding specification and layout of pumps, pipes and hoses scheme, performance curves and maximum head should be available in manual.

Lifted loadouts have specific items that shall be present:

- crane specification, including load-radius curve;
- copy of crane certification;
- slinging arrangement;
- copy of certificates of slings, shackles and other equipment;
- for mobile cranes, position of crane at pick-up and set-down, travel route if applicable, actual and allowable ground bearing pressures at all locations;
- non-destructive testing report of lifting attachments and connection into structure;
- mooring arrangements and thruster specification for floating cranes;
- if the lift points and offshore lift rigging are re-used offshore, proposals for inspection after loadout;
- rigging calculations;
- mooring design calculations showing environmental loads, line tensions and attachment point loads for limiting weather condition for loadout, and for post-loadout moorings if applicable. Calculation should contain limiting design and operational weather conditions for loadout.

Management of the operation shall be detailed into the procedure/manual at least with the following information:

- organigram showing management structure and responsibilities;
- location of key personnel;
- details of manning levels, showing adequate coverage for all operations and emergency procedures;
- times of shift changes, if applicable;
- weather forecast arrangements;

- communications;
- adequate lighting for all critical areas;
- operation bar-chart showing time and duration of all critical activities;
- methods of monitoring barge level and trim, and ballast quantities, including consideration of hang-up between barge and quay;
- safety procedures, HAZOPs, HAZIDs and risk assessments;
- systems and equipment operating instructions;
- recording and reporting routines;
- checklists for the preparation and performance of the operations;
- readings from suitably calibrated measuring devices before and during the operations of e.g. environmental parameters (wind, wave, others).

Contingency plans shall be presented for all eventualities, including, as appropriate:

- pump failure;
- mains power supply failure;
- jack-winch failure;
- trailer/skidshoe power pack failure;
- trailer/skidshoe hydraulics failure;
- trailer tyre failure;
- tractor failure;
- failure of any computerised control or monitoring system;
- mooring system failure;
- structural failure;
- deteriorating weather.

16 Transportation

16.1 Introduction

This clause applies to offshore transportation, inshore transportation and transportation in sheltered areas, using either wet tow or dry tow including also towage of floating monopiles with adequate plugs and cable hole covers applied as well as buoyancy where required. Additional information can be found in ISO 19902:2007^[12], [Clauses 8](#) and [21](#), and in ISO 19903:2006^[13], [Clause 11](#).

16.2 General considerations

16.2.1 Manned tows

For information on manned tows, see Reference [\[48\]](#).

16.2.2 Unmanned tows

For unmanned tows, access to the towed object should be considered as a contingency, including for routine inspection and access or escape in case of emergency. Life-saving equipment, communication equipment, plans and instructions shall be provided for persons who can be temporarily on board the towed object. Consideration should be given to the nature and duration of their work on board of the towed object and to the ease of access between the towed object and supporting vessels.

16.2.3 Navigation lights, signals and day shapes

For information on navigation lights and day shapes, reference should be made to COLREGS regulations^[25]. Navigation lights shall have their own power supply and an emergency power supply. In order to prevent accidents in areas specifically prone to fog, equipment such as foghorn or sirens should be used to allow for adequate warning signals being sent.

16.2.4 Contingency

Contingency plans shall conform to 6.5. In case of any assets being close to transit routes of vessels conducting marine operations in the offshore wind farms, charts and safety zones around these assets shall be considered, which can also be covered by local rules.

16.2.5 Motion responses

The evaluation of the motion of the structure during transportation shall be based on environmental criteria in accordance with [Clause 7](#), and determined through analysis using well validated industrial software and/or model testing, assuming representative combinations of metocean parameters.

The evaluation shall be carried out for a range of headings and speeds. The maximum responses shall be based on a 3 h exposure period; where avoidance of extreme actions depends on maintaining a certain heading, consideration shall be given to maximum responses based on longer exposure period.

If linear motion response analysis predicts extreme roll or pitch amplitudes that can exceed the heeling angle at which the maximum value of the righting moment occurs, the dynamic behaviour should be verified by model testing or nonlinear analysis.

If neither a motion study nor a model test programme is performed for standard configurations and subject to satisfactory marine procedures, the default motion criteria given in Reference [\[56\]](#) may be used as guidance. Alternative default motion criteria, as set out, for example, in References [\[53\]](#) may also be used as guidance.

16.2.6 Verification of the transported object

Actions and action effects that result from wind, wind heel, wave action, accelerations and towline pull shall be considered in the design. The applicable environmental conditions should be based on the planned duration of the tow, as defined in [Clause 7](#).

Equipment, modules, etc. including temporary equipment, should be adequately sea fastened as described in [15.15](#).

Any allowable list angle or motion criteria of transported components, e.g. particularly in the nacelle, shall be specified during the design. This can e.g. include limitations due to structural integrity or due to oil tank inclination angle or tolerances for switchgear transport induced accelerations whether the switchgear is placed in a sub-structure, e.g. transition piece, in the nacelle, in the tower or in a topside of the offshore substation.

16.2.7 Structural analysis during all transport phases

The loads acting on grillages, cribbing, dunnage, seafastening and components of the cargo shall be derived from the loads acting on the cargo, according to previous sections, as applicable.

The loads shall include components due to the distribution of mass and rotational inertia of the cargo. This is of particular importance in the calculation of shear forces and bending moments in the legs of jack-up units and similar tall structures.

If the computed loads are less than the “minimum allowable seafastening force” (friction in sea fastening design) shown in [Table 10](#), then the values in the table shall apply.

Care should be taken in cases where the cargo is designed for service loads in the floating condition, but is being dry-transported. Its CoG can be higher above the roll centre in the dry-transportation condition than in any of its floating service conditions. Even though the transportation motions can appear to be less than the service motions, the loads on cargo components and ship-loose items can be greater.

16.2.8 Transport planning

SOLAS provides requirements for the planning of the voyage or towage. Sheltered towage circumstances shall be taken into account

Routeing procedures shall be agreed with the master prior to commencement of the voyage, taking into account the transport vessel or tug's capacity and fuel consumption, the weather and current conditions and normal good navigation and seamanship.

The distance between bunker ports shall be considered when deciding on the composition of the tow fleet. If tugs are released to go into port to refuel, the remaining tow vessels shall be capable of holding tow.

In case of transport in areas of potential piracy attacks, suitable risk assessment and mitigation measures shall be part of the voyage planning.

16.3 Weather routeing and forecasting

The transportation shall not start unless the forecast is for stable weather, predicting favourable environmental conditions for a period equal with the period of the tow as recommended in [Clause 7](#). The forecast should show the operational weather conditions, taking into account the contingency defined in [7.5](#).

If the transportation is a weather-unrestricted operation, departure should still take place on a favourable forecast in order to allow time to obtain adequate sea room.

Weather forecasts for the departure area should be commenced at least 48 h before the anticipated departure date.

For any towage, the weather conditions for departure from the departure port or any intermediate port or shelter area shall take into account the capabilities of the towing vessel, the marine characteristics of the tow, the forecast wind direction, any hazards close to the departure port or shelter area and the distance to the next port or shelter area. A suitable weather forecast can be one that predicts the weather window required for the operation with operational limits appropriate to the transit distance including a favourable outlook for a further 24 h for a tow.

A weather routeing service, provided by a reputable company could, when considered beneficial, be arranged prior to the start of the towage or voyage. The utilization of a weather routeing service can be a requirement of the approval. In any event, every effort shall be made by the master to obtain regular and suitable weather forecasts from a reputable source during the towage. Whenever possible, a second weather forecast should be obtained from a different independent source prior to departure.

Weather routing procedure showing criteria of assessment for alternative routes and method of route change shall be in place whenever a weather routed transport is performed.

16.4 Ports of shelter, shelter areas, holding areas

Ports of shelter, or shelter areas on or adjacent to the route, with available safe berths, mooring or holding areas, shall be agreed before departure and all necessary permissions obtained.

Where such shelter points are required as part of a weather-restricted operation, as described in 7.2, they shall be capable of entry in worsening weather.

Where holding areas are impractical, e.g. cross-ocean transits, weather forecasting capabilities to identify storms that exceed operational limits and contingency plans for routing around such storms shall be in place.

An offshore holding area near the installation site should also be identified, with all necessary permits and agreements arranged in advance.

Assisting tugs shall be engaged at commencement of the towage, at any intermediate bunkering port and at the arrival destination, as appropriate.

The master shall engage local pilotage assistance during the towage or voyage, as appropriate.

A detailed log of events shall be maintained during the towage or voyage.

16.5 Inspections during the towage or voyage

Unless the tow is manned, it should be boarded on a regular basis by the crew of the tug, particularly after a period of bad weather, in order to verify that all the towing arrangements, condition of the cargo, sea fastenings and watertight integrity of the tow are satisfactory. Suitable access shall be provided (see 13.11).

For manned tows and self-propelled vessels, the above inspections should be carried out on a daily basis as relevant.

Any adjustable sea fastenings or lashings should be re-tensioned as necessary.

16.6 Responsibility

The towmaster is responsible for the overall conduct of a tow, and towing arrangements during the towage.

If any special situations arise during the towage or voyage and it is not possible to comply with any specific recommendations, agreed procedures or international regulations, then such measures as appropriate for the safety of life and property shall be taken. The master remains solely responsible for the vessel during the voyage in accordance with maritime laws.

16.7 Hazardous materials

Hazardous substances can be considered as materials which, when released in sufficient quantities or improperly handled, have the potential to cause damage to the asset, personnel or the environment through chemical means or combustion. Unless it is necessary, the carriage of such materials should be avoided. When transported, these substances must be effectively labelled and controlled. Stowage of such materials should take into account that the transportation can be unmanned and therefore remedial action in the case of inadvertent release is limited.

The properties of hazardous material are contained in the MSDS (material safety data sheet), together with the hazards the material presents, and with information on handling, storage and emergency measures in case of accident. Considering the MSDS, a COSHH (control of substances hazardous to health) assessment shall be carried out to identify the hazards and to assess and mitigate the risks on the particular environment of the work.

The IMDG (international maritime dangerous goods) Code provides guidelines to the safe transportation or shipment of dangerous goods or hazardous materials by water on vessel.

Where identifiable hazardous material is found onboard prior to a tow/transportation taking place, it should be controlled either through isolation or removal ashore. This material should then be labelled and stored in a designated place or removed.

16.8 Ballast water

In addition to the International Convention for the control and management of ships' ballast water and sediments^[34], a number of coastal states have applied domestic regulations controlling the discharge of ballast water and sediments in their waters.

Vessels may need to change ballast water before or at their arrival port for operational reasons (loading/discharging). The voyage planning process can be covered by local laws. The ballast water management plan and records should be available for any attending surveyor or inspector.

Reference [49] requires the monitoring and recording of ballasting and de-ballasting operations. Vessels flagged in signatory states are required to have onboard and to implement a ballast water management plan. This plan is specific to each vessel and the record of ballast operations may be examined by the port state authorities.

16.9 Restricted depths, heights and manoeuvrability

The clearances recommended in the next sections are general, and each transport should be assessed on its own, taking into account the following:

- environmental conditions (including tide, currents, and forecast or expected weather conditions);
- length of areas of restricted manoeuvrability;
- any course changes within the areas of restricted manoeuvrability;
- cross section of areas of restricted manoeuvrability in relation to underwater area/shape of the base structure;
- capability of the tugs/transport vessel.

The recommended values give guidance. If it can be proved that smaller values give the same or even better level of confidence, these values should be taken.

16.10 Under-keel clearances

The under-keel clearance allowing for protrusions below the hull shall be based on an engineering analysis accounting for the effects of:

- roll, pitch and initial heel and trim;
- heave;
- tow-line pull;
- inclination due to wind;
- surveyed/expected minimum water depths and tolerance on bathymetry and on vessel positioning;
- changes in draught of the transport or towed object;
- differences in water density;
- tidal levels and currents;
- squat effects;
- expected weather conditions;
- deflections of the structure;
- errors in measurement;

- negative surge.

Furthermore, under-keel clearance shall include a margin of not less than the greater of 1 m or 10 % of the maximum draught. The 10 % may be reduced in very benign conditions.

Under-keel clearances for departure from dry-docks or building basins are covered in [16.15.2](#).

Special considerations should be given to transports in limited areas with small under-keel clearances subject to weather-restricted conditions, tidal windows and accuracy of the survey data.

If sections of the passage are tidally dependent, safe holding areas should be identified in the vicinity with adequate sea room and water depth to keep the structure afloat at low tide, while maintaining the minimum under-keel clearance. Any delay time waiting for the tide shall be included in the overall planning.

Immediately before critical sections of the passage the tidal level shall be confirmed by measurement. The use of real-time telemetry could be considered.

Use of an air cushion to reduce draft to assist in crossing localized areas of restricted water depth should be considered subject to:

- any conceivable loss of air not increasing the draft by more than the reserve on under-keel clearance;
- the recommendations contained in Reference [\[56\]](#) on air cushions.

16.11 Air draught

When passing under bridges and power cables, the overhead clearance shall be calculated allowing a margin of not less than 1 m plus dimensional tolerances excluding squat. Where clearance is limited, then a dimensional survey of the barge/vessel and structure shall take place just prior to sailaway in order to ensure that the required clearance exists.

Power cables need a “spark gap”, as well as a physical clearance. The minimum allowable clearance stated by the transmission company shall be considered. It should be noted that the catenary of the power cable changes depending in particular on wind, ice, temperature, age, and power transmitted.

The actual clearance shall be confirmed with all appropriate authorities including those responsible for the obstruction.

Immediately before the passage, the tidal level shall be confirmed by measurement.

16.12 Channel width

The minimum channel width along any legs of the tow route with the under-keel clearance and air draught required in [16.10](#) and [16.11](#) should be three times the maximum width of the towed object, allowing for yaw, local currents, wind and tidal effects, and including contingencies. The minimum channel width should also take into account the tugs configuration (if applicable).

16.13 Survey requirements

For areas where the under-keel or side clearance can be critical, a survey report that is not older than three months shall be available (or even less if the seabed is mobile). If not, the tow route should be surveyed with a minimum width of five times the beam of the object with a minimum of 500 m. Sidescan sonar and MBES bathymetric data should be provided. The spacing between depth contour lines should be appropriate for the purpose. Current surveys should be made in restricted parts of the tow route. The survey should be considered to be made again for tow route in areas where the seabed is mobile.

The survey requirements may be relaxed if it can be shown that the onboard bathymetry measurement systems and position management systems have sufficiently high precision with regard to Reference [\[63\]](#) or with project requirements.

16.14 Towline pull required, fleet composition and towing arrangement

16.14.1 Towline pull required

The tow shall be provided with tugs of sufficient power and arranged in such a manner as to give adequate speed, control and holding power. The towing resistance of the towed object should be determined by means of calculation or model tests (or by reference to previous model tests) or full-scale measurements.

Except as allowed or otherwise recommended below, the minimum towline pull required, F_{PR} , shall be calculated for zero forward speed against a 20,0 m/s wind, 5,0 m significant wave height sea state and 0,5 m/s current, acting simultaneously and collinearly. Allowance should be made for yaw of the towed objects.

For benign weather areas, lesser criteria for calculation of F_{PR} may be considered. Generally, these should not be reduced below 15,0 m/s wind, 2,0 m significant wave height sea state and 0,5 m/s current, acting simultaneously and collinearly.

For towages partly sheltered from wave action, but exposed to strong winds, alternative criteria may be considered.

If the tow route passes through an area of restricted navigation, of continuous adverse current or weather, or if a particular towing speed is required in moderate weather, a greater F_{PR} can be required. For weather-unrestricted operations in areas with limited sea room, the F_{PR} should be computed based on the design criteria defined by [Clause 7](#).

For the tow of a large structure out of dock, the F_{PR} should be based on the operational metocean criteria given in [Clause 8](#) and should utilize a minimum of 0,25 m/s forward speed.

The relationship between F_{PR} , the minimum towline pull required, expressed in kilonewtons, and the continuous static bollard pull, F_{BP} , of the tug(s) is given by [Formula \(8\)](#):

$$F_{PR} = \sum \left[F_{BP} \times \frac{T_{eff}}{100} \right] \quad (8)$$

where

T_{eff} is the tug efficiency in the sea conditions, expressed in percent;

F_{BP} is the continuous static bollard pull of each tug, expressed in kilonewtons;

$F_{BP} \times \frac{T_{eff}}{100}$ is the contribution to the F_{PR} of each tug, expressed in kilonewtons.

The tug efficiency, T_{eff} , depends on the size and configuration of the tug, the sea state considered and the towing speed achieved. In the absence of alternative information, T_{eff} may be estimated according to [Table 8](#).

**Table 8 — Estimation of the tug efficiency
(based on experience from the North Sea environment)^[56]**

Continuous static bollard pull F_{BP} kN	Tug efficiency for various sea conditions T_{eff} %		
	Calm	$H_s = 2,0 \text{ m}^a$	$H_s = 3,0 \text{ m}^a$
$F_{BP} \leq 300$	80	$50 + F_{BP}/10$	≤ 55
$300 < F_{BP} < 900$	80	80	55 – 75

^a H_s indicates the significant wave height.

Table 8 (continued)

Continuous static bollard pull F_{BP} kN	Tug efficiency for various sea conditions T_{eff} %		
	Calm	$H_s = 2,0 \text{ m}^a$	$H_s = 3,0 \text{ m}^a$
$F_{BP} \geq 900$	80	80	75

^a H_s indicates the significant wave height.

16.14.2 Towing fleet

The effectiveness of the towing fleet in achieving speed and control of orientation depends on the configuration in which the tugs are arranged, as well as the number of tugs and the power of each tug. In particular, the effective bollard pull is substantially less than the sum of the bollard pulls of the tugs, particularly when working on short towlines or with tugs in close proximity to one another.

Any tug considered for the towing operation should be fully certified for the area of operation and should have certificates for towlines, pennants, stretchers, shackles and marine fittings. The bollard pull certificate should not be older than five years or, in the case of critical tows, not older than three months. Critical tows shall be identified on a project-by-project basis through utilization of a formal risk assessment.

For certain towing operations, for example for tows involving several tugs or for single tug towages where the towed object is sensitive to wind actions or is difficult to manoeuvre, an escort tug should be provided for critical phases of the operation. The escort tug should be of sufficient bollard pull and should be available for immediate use in case any of the towing tugs require assistance.

Stern tugs should not be considered when calculating the total effective bollard pull.

16.14.3 Towing arrangement

The MBS of the towline shall be related to the continuous static bollard pull of the tug (F_{BP}), as given in [Table 9](#).

Table 9 — MBS of the towline^[56]

Bollard pull F_{BP} kN	Benign areas MBS kN	Other areas MBS kN
$F_{BP} \leq 400$	$2,0 F_{BP}$	$3,0 F_{BP}$
$400 < F_{BP} \leq 900$	$2,0 F_{BP}$	$(3,8 - F_{BP}/500) F_{BP}$
$F_{BP} > 900$	$2,0 F_{BP}$	$2,0 F_{BP}$

The design strength of the towline connections to the tow, including bridle legs, shackles, chain pennants and fairleads, where fitted (including any shackle between the towline and the bridle apex), shall not be less than 1,3 times the MBS of the towline. The design strengths of shackles or other mooring components can be applied for towing.

A retrieval system should be available to retrieve the part of the towing arrangement directly connected to the towed structure, in case any other part of the tow arrangement fails.

Transport vessels or cargo barges shall be equipped with a suitable emergency towline in good condition with an MBS of not less than the values given in [Table 9](#). The emergency towline shall be fitted with a pick-up line.

16.14.4 Towline length

The towline shall, at all times, be sufficient to keep the peak loads within the SWL of the towline. For critical tows, an analysis of the towline dynamics is recommended.

A table that shows the catenary depth for various combinations of towline tension and length shall be displayed on the bridge to facilitate a good balance between sufficient towline length and required clearance from the sea floor.

16.15 Tow out from dry dock

16.15.1 Introduction

Guidelines are given in [16.15.2](#) to [16.15.7](#) for the marine operations concerning the float-out of a structure from the dry dock, the tow out until clear of the dock sill and the preparation for onward towage. Examples for such structures are some topsides for offshore substations or offshore accommodation platforms.

16.15.2 Under-keel clearance

The under-keel clearance in the dry dock shall at no time be less than 0,5 m after corrections for the effect of possible deflections of base structure, towline pull, wind heeling, squat effects and variations in sea water density. It is recommended that during the initial design phase, an under-keel clearance of 1 m is used.

In areas outside the dock, the under-keel clearance shall, at no time, be less than 1 m, or 10 % of the maximum draught, whichever is the greater. Minimum water levels and the effect of possible deflections of the base structure, towline pull, wind heeling, squat effects and variations in sea water density should be taken into account.

The minimum under-keel clearance for float-out should be maintained for the duration of an adequate period for float-out, including contingencies.

16.15.3 Side clearances

Side clearances for exit from a dry dock are dependent on the design of the structure, the shape of the dock walls and gates, the method used to control the position during float-out and the environment.

If the structure is winched out along fenders on one side of the dock, there should be adequate clearance on the opposite side in order to allow the operation to proceed safely, accounting for possible corrective action in case of emergency.

When tugs are used to control the position during float-out, additional clearance can be required to give the tugs enough sea room to operate.

Additional fendering should be considered if there is no means to adjust the transversal movement in the dry dock.

16.15.4 Air cushion/air pressure

The following apply when an air skirt compartment is used to temporarily reduce the draught of the structure:

- a water seal with a minimum height of 0,25 m should be maintained inside the skirt compartment during the float-out operation until the structure has arrived at the holding area outside the dock;
- the air skirt compartments should be sized to withstand safely an internal air pressure equivalent to 130 % of the water head between the bottom tip of the skirt and the still water level;

- the skirt compartments should be tested for airtightness prior to float-out. The compressor capacity installed on board should be adequate to cope with any foreseeable leakage after breakdown of any one compressor or system;
- piping should be secure, protected and of adequate capacity and strength. Supply lines should have non-return valves. A venting system should be provided to guarantee that air is removed after use to ensure that no residual free surface remains;
- a reliable method of measuring the water seal should be provided;
- the air cushion should be isolated in separate compartments, so that failure of any part of the system does not cause a loss of buoyancy that is outside acceptable criteria for stability, draught or freeboard;
- the stability calculations should take into account the compressibility of the air as well as the free surface effects.

16.15.5 Capacity of winching and towing arrangements

Winches, winch wire ropes and control lines should have sufficient capacity to hold or manoeuvre the structure in the design environmental conditions.

The breaking strength of any wire rope used to hold or manoeuvre the structure should comply with [19.11](#).

16.15.6 Positioning systems

Two calibrated independent positioning systems should be provided. The position of the structure relative to the dry dock should be continuously updated with an interval of not more than 5 s. The required accuracy of the system should be determined through risk assessment, taking into account the minimum clearance between the structure and the dock. The recommended accuracy should be the smaller of half the minimum clearance or 2 m. Visibility situation shall be taken into account during tow out.

16.15.7 Survey requirements

For the tow out operation from the dock sill to the holding area for hand-over for inland tow, an adequate area should be surveyed, taking into account the size and yaw of the structure and the required area of manoeuvrability of the tugs.

16.16 Inshore tow

16.16.1 Tow route and towing clearances

If passages through narrows are tide-dependent, the tow route selection should allow for holding areas in the vicinity with adequate sea room and water depth to keep the structure afloat at low tide on standby, while maintaining the minimum under-keel clearance.

Where clearance is limited, a dimensional survey of the barge/vessel and structure including changes in draught of the towed object shall take place just prior to sail-away in order to ensure that the required clearance exists.

Passages through narrows and passing under bridges and power cables should not take place in darkness.

The recommended clearances are given as guidance, and each tow should be assessed on a case-by-case basis, taking into account environmental conditions, length of narrows, any course changes within the narrows, cross-section of narrows relative to underwater area and underwater shape of the base structure and capability of the tugs. If it can be proven that smaller values of clearances give the same level of confidence, these values may be used.

16.16.2 Positioning systems

Guidance for positioning systems are given in [16.15.6](#) adapted to structure and towing set-up instead of structure and dry dock.

16.17 Transport onboard a vessel/Offshore tow

16.17.1 Vessel selection

The transport vessel should be selected based on its capacity to suit operations of the transport, including loadout and offload, and to demonstrate that the vessel meets deadweight, deck space, strength and stability requirements for the marine operation. Vessels conducting transport can be e.g. heavy lift vessels, barges or self-propelled jack-up vessels.

16.17.2 Stability

For stability requirements, see [Clause 13](#).

16.17.3 Sea fastening

For sea fastening of objects for dry tow on a barge or aboard a heavy transport vessel, the following considerations apply.

- The provisions of [15.15](#), [16.2.5](#) and [16.2.6](#) apply to the design of the sea fastening.
- Sea fastening should be designed with details that are robust with regard to fatigue; for critical transports (typically when total exposure exceeds 10 days and for seafastening of insured components), a fatigue assessment should be made and the calculated fatigue lives of the sea fastening and their connections shall be at least five times the anticipated transit time.
- For possible slam loads and their effects on overhanging parts of the cargo, such as capped pile sleeves, appropriate slam calculations should be prepared and documented.
- If the cargo becomes submerged when the vessel heels or rolls, the weight of the cargo is reduced by an amount equal to the buoyancy of the submerged cargo. This reduces the friction forces between the object and the vessel and the sea fastenings should be designed to account for this loss of resistance.
- A detailed analysis of heavy transport vessel or barge and its cargo, taking into account the cargo overhang, arrangement of cribbing and sea fastening, should be performed to enable appropriate local and global strength checking.
- For cargos supported on the deck by cribbing or dunnage, and in the absence of more detailed analysis, the coefficients of friction in [Table 10](#) may be used for the combination of cargo weights, cargo overhangs and arrangements of cribbing and sea fastenings listed therein. The computed frictional force on the cribbing can be deducted from the computed loading when determining the forces to be carried by the cribbing and sea fastenings. The sea fastening design strength shall be greater than the minimum force derived from the data in [Table 10](#), which presents the maximum coefficients of friction and the minimum force, expressed as a percentage of cargo weight.
- It is advisable to design seafastening as to allow for multiple use for various projects and dimensions of components.

When using the information in [Table 10](#) (which implies that seafastening philosophy accounts for friction), the following apply.

- Friction forces shall be computed using the reaction normal to the deck between the vessel and the cargo.

- The cargo should be supported by wood dunnage or cribbing; friction is not allowed for steel-to-steel interfaces.
- The overhang is the distance from the side of the vessel to the extreme outer edge of the cargo.
- For wood cribbing less than 600 mm high and with a width no less than 300 mm, the full friction force may be assumed to act in any direction relative to the cribbing.
- For cribbing heights between 600 mm and 900 mm high and with a width no less than 300 mm, the calculated percentage friction force assumed to act in a direction at right angles to the line of the cribbing should not exceed the calculated factor, f_{fr} , expressed as a percentage, as given by [Formula \(9\)](#):

$$f_{fr} = \frac{900 - H_c}{3} \quad (9)$$

where H_c is the height of the cribbing above deck, expressed in millimetres.

- For wood cribbing over 900 mm high, or with a width less than 300 mm, no friction force shall be assumed to act in a direction at right angles to the line of the cribbing.
- For cribbing with a height greater than its width, movement in the direction orthogonal to the length of the cribbing shall be prevented by steelwork designed to carry the full friction force in that direction.
- When the cribbing arrangement is predominantly in a single direction, the calculated friction force orthogonal to the predominant cribbing direction should be reduced accordingly unless the sea fastenings acting in the orthogonal direction are fitted with an interface that is compliant with the cargo and allows the development of the cribbing friction as the actions on the sea fastenings develop. Such interfaces can be comprised of an elastomeric bearing pad.
- The value of the minimum sea fastening force listed in [Table 10](#) is the minimum value, expressed as a percentage of cargo weight, for which the sea fastening should be designed in the event that the computed sea fastening force is less than this value.
- For very short duration moves in sheltered water, such as turning a barge back alongside the quay after a loadout, friction forces should be considered. It should be demonstrated that all parts of the load path, including the potential sliding surfaces, are capable of withstanding these forces.

Table 10 — Allowance of friction in sea fastening design^[56]

Overhang m	Maximum coefficient of friction						
	Cargo weight						
	W_c kN						
	<1 000	1 000 to <10 000	10 000 to <50 000	50 000 to <100 000	100 000 to <200 000	200 000 to <400 000	≥400 000
None	0	0,10	0,20	0,20	0,20	0,20	0,20
<15	0	0	0,10	0,20	0,20	0,20	0,20
15 to <25	0	0	0	0,10	0,20	0,20	0,20
25 to <35	0	0	0	0	0,10	0,20	0,20
These friction coefficients shall be accounted for when seafastening philosophy is made using friction only. Otherwise, the beneficial effect of friction is normally neglected, resulting in conservative results.							
a	≥15 – $W_c/40\ 000$.						
b	≥7,5 – $W_c/40\ 000$.						
c	≥3,5 – $W_c/200\ 000$.						

Table 10 (continued)

Overhang m	Maximum coefficient of friction						
	Cargo weight W_c kN						
	<1 000	1 000 to <10 000	10 000 to <50 000	50 000 to <100 000	100 000 to <200 000	200 000 to <400 000	≥400 000
35 to <45	0	0	0	0	0	0,10	0,10
≥45	0	0	0	0	0	0	0
Direction	Minimum sea fastening force % W_c						
Transverse	—	10	10	10	10	^a	5
Longitudinal	—	5	5	5	^b	^c	1,5
These friction coefficients shall be accounted for when seafastening philosophy is made using friction only. Otherwise, the beneficial effect of friction is normally neglected, resulting in conservative results. ^a ≥15 – $W_c/40\ 000$. ^b ≥7,5 – $W_c/40\ 000$. ^c ≥3,5 – $W_c/200\ 000$.							

16.17.4 Vortex shedding

For requirements, see [9.6.2](#).

16.17.5 Navigation systems

Navigation data shall be provided by two independent on-board systems and suit the navigational constraints of the transportation route.

16.18 Transport manual

A transport manual and supporting document shall be prepared for the operation. The items, in addition to those found in [6.5.2](#), that it is recommended to include in the transport manual and supporting documents are given in [A.3](#).

A transportation or towing manual is required for all transportations or towages for the following reasons:

- it shall provide the master with the key information that he needs, including the cargo and route;
- it shall describe the structural and any other limitations of the cargo;
- it shall summarize contingency plans in the event of an emergency including contact details;
- it shall give approving bodies the key information that they require for approval;
- it shall define the responsibilities of different parties if parts of the transport/tow and installation are performed by different contractors. The scope split between the contractors shall be clearly defined, to ensure that all parties are aware of their responsibilities, handover points and reporting lines.

It shall contain information about:

- the cargo;
- routeing, including possible deviations to shelter points if required;
- what to do in an emergency;

- contact details (owner, local authorities, MWS, etc.);
- organigram showing the scope split between different contractors (if applicable). These shall be clearly defined, to ensure that all parties are aware of their responsibilities, handover points and reporting lines.

Manuals shall satisfy the requirements of this subclause, noting that local authority requirements can also be applicable.

Detailed calculations and other relevant documents should be in separate manuals referenced in the transportation or towage manual.

17 Temporary mooring and stationkeeping for marine operations

17.1 Introduction

The design of temporary moorings and stationkeeping systems (including DP) for marine operations shall be in accordance with ISO 19901-7, as applicable, and with the provisions presented in [7.4.2](#) (return periods), [15.7](#) (loadout) and [Clause 18](#) (installation).

The temporary mooring systems include components, from the anchor points at the sea floor or the quayside to the mooring brackets or winches on the unit, that are required to hold the structure in a safe and stable position inshore and offshore, during construction and assembly afloat of offshore structures.

Temporary mooring systems are generally required during the construction phases of offshore structures for inshore or offshore applications and for various durations. The most frequently used types of moorings are listed as follows.

- Standby moorings: These moorings are used to hold the main structure or one of its components (e.g. topsides on a barge) in a safe position during standby before or after the performance of given operations. These standby moorings are of the catenary type or consist of a berthing alongside a quay or another floating unit.
- Positioning moorings: These moorings are used for positioning non-propelled jack-up installation barges in circumstances where the moorings are not used for stationkeeping.
- Position keeping moorings: These moorings are used as a positioning aid during precise operations, such as inshore loadout, inshore deck mating or offshore installation.
- Jack-up legs/spudpoles: These systems are used to provide temporary stationkeeping or holding forces to perform offshore operations such as cable laying, beach pull or diving support.
- Offshore moorings used for propulsion: These moorings are used for exact positioning within a certain limited range or e.g. for moving along a cable route.

17.2 Environmental criteria

The environmental conditions for consideration for the design of temporary mooring systems depend on the intended length of deployment during the construction phase afloat (see [Clause 7](#), where the design criteria versus duration of operation are defined).

Extreme environmental conditions that can exist locally, such as hurricanes or tropical cyclones, shall be accounted for when designing stationkeeping systems for inshore construction or offshore installation.

The environmental conditions shall be applied with due regard to local circumstances specific to the mooring location and its surroundings, in order to account for any directional effect or instability that can be generated by the landscape contour and/or the sea floor bathymetry.

In particular, when the temporary construction mooring is set up close to the shore, special consideration shall be paid to:

- change of wave direction when rounding the shore contour;
- instability of the tidal current in speed and direction due to the bathymetry close to headlands;
- increase in wind speed and change of direction when close to landscape highs.

Offshore installation mooring systems, deployed to provide a precise positioning aid during a temporary stage of offshore installation, should be designed based upon specific metocean criteria and shall meet stringent operability criteria in terms of mooring response and manoeuvrability.

Alternatively, specific operational limits shall be defined to be able to evade the extreme conditions and move the vessel or structure to a sheltered area through the duration of the extreme condition.

17.3 Determination of mooring response

17.3.1 Analysis methods

For a determination of the mooring response and the design of the temporary mooring systems, analyses are normally carried out. The three methods generally used to compute the floating structure response and the associated forces in the mooring lines are:

- the frequency domain approach;
- the time domain approach;
- the combined time and frequency domain approach.

These methods involve different degrees of approximation and different limitations and, therefore, do not necessarily yield consistent results. If verification of the approach selected for the mooring design is required, model test data or an alternative approach should be used.

For detailed information on the analysis methods, see ISO 19901-7.

The analysis shall take into account environmental actions, including shallow water wave effects, if applicable. Guidance on calculations of actions induced by the environment can be found in ISO 19901-7.

17.3.2 General considerations on the mooring design

The calculation of the wind, wave and current actions shall be based upon recognized methods and account for any directional effect. The design of the temporary mooring system shall be checked for the various possible draughts and outfitting configurations of the structure, in order to document which construction phases can govern the sizing of the mooring components. Transient conditions shall be considered, however limited reduction of stability can be accepted, if an action plan for the execution of return to define safe position exists.

Wind actions should account for the variation of wind speed against height. Shielding effects and solidification effects should be included where appropriate. For large deck structures attracting high wind actions, the wind coefficients should preferably be validated by wind tunnel tests.

Wave drift actions should be investigated for the range of sea states that are likely to occur at the mooring site. In the absence of more precise site data, the wave data for sheltered locations can be established by accounting for the fetch from various sectors. Finite water depth should be accounted for, if applicable.

The calculation of current actions should preferably be based on detailed site data. In the absence of such data, a conservative value for the current speed should be established, based on the combination of tidal current, wind-generated current and currents generated by other causes, such as storm surges.

Where current actions are significant compared to the overall environmental actions, current actions should be calculated based on recognized methods or model tests.

Calculated wind, wave and current actions should include the contributions of barges and construction equipment likely to be moored temporarily alongside the structure that rely on the holding capacity of the temporary mooring system.

For inshore or offshore temporary moorings used as stationkeeping aids without stringent positioning requirements, a quasi-static mooring analysis can be adequate, provided that the influence of low frequency motions on the mooring response is included.

For temporary offshore moorings with strict positioning requirements, or if critical clearances between structures and vessels exist, model tests should be carried out if motion analyses are not expected to be sufficiently accurate.

For tall structures anchored to mooring systems in areas that are subjected to large current variations, whether or not of tidal nature, a check should be made that the mooring response is safe with respect to potential in-line and transverse vortex shedding that can generate vortex induced motions.

17.4 Sizing of mooring lines

17.4.1 General considerations

The design forces of individual lines should be based on the maximum actions and motions obtained from the analyses performed.

The calculations should account for the change of geometry of the mooring pattern after excursions due to relevant excitations.

The mooring system should be checked for suitability in intact conditions, for redundancy and for transient conditions, if relevant.

The intact condition is the condition in which all mooring lines are intact and all thrusters, if any, are working.

The redundancy check is the condition in which the structure has a new mean position after a single line breakage or a failure of one or more thrusters, as appropriately assessed by the FMEA and for DP vessels in accordance with the DP capability analysis.

The transient condition is the condition in which the structure undergoes transient motions between the intact and redundancy check conditions, including the possibility of overshoot, as a result of a single mooring line breakage or a failure of one or more thrusters, as appropriately assessed by the FMEA.

17.4.2 Line tension limits and design safety factors

The line tension limits applied in the quasi-static or dynamic mooring analyses shall comply with the requirements set forth in [Table 11](#). The corresponding design safety factors are also listed.

Table 11 — ULS line tension limits and design safety factors

Analysis condition	Analysis method	Line tension limit % of MBS	Design safety factor
Intact	Quasi-static	50	2,00
	Dynamic	60	1,67

^a From ISO 19901-7, Table 5, and Reference [56], Table 17.3.

^b Applies also for operational or temporary mooring (one line broken).

Table 11 (continued)

Analysis condition	Analysis method	Line tension limit % of MBS	Design safety factor
Redundancy check	Quasi-static	70	1,43
	Dynamic	80	1,25
Transient ^b	Quasi-static or dynamic	95	1,05
^a From ISO 19901-7, Table 5, and Reference [56], Table 17.3.			
^b Applies also for operational or temporary mooring (one line broken).			

17.4.3 Particular mooring conditions

In the case where mooring pontoons are used along with one or several mooring lines, it should be demonstrated that they have sufficient strength, stability and reserve buoyancy when subjected to the maximum horizontal and vertical actions generated by the mooring in the intact and redundancy check conditions, for construction stages and draughts of the structure.

In the case where local current conditions and moored structure geometry can cause vortex shedding excitation of the moored structure, calculations of the mooring line strength should also account for the effect of the in-line and transverse vortex induced motions. These effects should be evaluated based on recognized methods.

For temporary moorings intended for long duration or where a chain is being re-used, consideration should be made for fatigue, taking into account the chain history.

For moorings alongside quays, consideration should be given to ensuring a correct balance of the line tensions.

17.5 Sizing of anchors

Temporary mooring systems normally include drag anchors, the holding capacity of which depends upon their correct embedment into the soil.

Sizing according to equipment number shall be considered for vessels or structures to which the specific rules apply.

When drag anchors are used, they should be sized to have a UHC greater than:

- 1,5 times the maximum force calculated in the line at the anchor point, in the intact condition;
- 1,0 times the maximum force calculated in the line at the anchor point, in the redundancy check condition.

In case alternative anchoring systems are used, applicability of ISO 19901-7 and Reference [56] should be checked.

Calculations of anchor UHC shall take account of any uncertainties in the soil characteristics.

Other design safety factors on the anchor UHC can apply in particular cases, based on specific anchor types and soil conditions, and if approved by a recognized organization.

Where drag anchors are used, the mooring lines should generally be designed to avoid uplift at the anchor for extreme forces calculated in the redundancy check. If extreme forces induce uplift at the anchoring point, reduction of the holding capacity should be considered for conventional drag anchors. However, special types of drag anchors that can accept a limited uplift under extreme conditions can be used, provided that they have been tested and proven under similar conditions.

17.6 Sizing of attachments

Connections, such as mooring brackets on the structure or fixed points on the shore, should be sized for a design strength not less than 1,3 times the required breaking strength of the weakest component of the mooring line.

The design strength of such connections should reflect:

- variations of the angle of the line in the horizontal plane, accounting for possible deformations of the mooring pattern under extreme excursions and yaw motions of the structure or platform, in the intact and/or redundancy check conditions;
- variations of the angle of the line in the vertical plane, accounting for possible draught configurations of the structure or platform when connected to the temporary mooring system.

17.7 Sizing of mooring line components

Mooring line components should be sized following the principles listed in [17.4](#), [17.5](#) and [17.6](#).

Shackles and any component located along the mooring line should have a design strength equal to or larger than the design breaking strength (WLL) of the mooring line itself; see also [17.6](#).

Other components used to connect or lead the mooring line, e.g. fairleaders, winches, stoppers, etc., should have a design strength in accordance with [17.6](#).

Due consideration for wear, shock loads and chafing should be made in the design and specification of the mooring line components. It also should be checked that the mooring components are well matched to each other, so as to maintain the expected level of safety of the mooring system.

17.8 Clearances under extreme conditions

Adequate under-keel and side clearances with the seabed and with any other obstructions shall be maintained when the structure reaches the maximum excursions and rotations on its mooring, under extreme environmental conditions coming from any direction, in both the intact and redundancy check conditions.

The evaluation of minimum under-keel and side clearances should be made at the lowest and outermost part of the structure, after allowance for possible reduction effects, such as structure heel and pitch and low water density.

A detailed bathymetry of the site resulting from a recent underwater survey should be available when assessing minimum clearances with the seabed contour, and survey inaccuracies should be accounted for.

When a large object is moored at its deepest construction draught on a catenary inshore construction mooring, the clearances with the seabed at the maximum excursion should be in excess of 5 m vertically and 25 m horizontally in the intact and redundancy check conditions, including transient stages. Compatibility with respective tidal regimes shall be considered.

In the case of an inshore construction barge moored independently in the vicinity of the structure, smaller values of clearance between each unit or its appurtenances should be acceptable based on mooring analyses that account for dynamic motions in the design of the two mooring systems.

Clearance between any mooring line and any structure including other mooring lines, but other than assets of the offshore wind farm, e.g. cables, foundations, jack-up zones, should not be less than 10 m, unless appropriate risk assessments are performed to demonstrate that a smaller value can be used.

In the case of objects moored alongside a quay or alongside other objects, smaller side clearances may be considered as long as the motion responses of the object under the design environmental conditions have been taken into account, and the object has been equipped with appropriate fenders.

Likewise, the under-keel clearance for objects that are moored alongside a quay or alongside other objects, in completely sheltered areas only, may be reduced to a minimum of 0,5 m, once possible clearance reduction effects, such as tide, environmental actions acting on the object, trim and heel, and wind heeling effects, have been taken into account and provided a recent underwater survey has been performed.

Regarding horizontal clearance from cables and cable route corridors, see [Clause 20](#).

For clearances for crane vessels, their associated mooring system and lifted objects, see [19.9](#).

17.9 Clearances during positioning

Appropriate clearances should be maintained during the positioning of floating structure. Where there is a risk of heavy contact between structures, a suitable tug support and fendering system between vessels should be installed.

The minimum clearances indicated in [Table 12](#) should be maintained during positioning considering maximum environmental conditions that can be tolerated during temporary mooring.

Table 12 — Guidance on clearances during positioning

Units/structures and mooring elements involved	Minimum clearance during positioning	
	Vertical	Horizontal
Line and unit	5 m	5 m
Line and subsea structure	15 m	150 m
Line and unprotected cables	30 m	150 m
Line and protected cables	15 m	50 m
Line of several units	20 m	—
Anchor and sub-sea structure	—	100 m
Anchor and cables	—	100 m
Anchor and cables (line crossing cables)	—	300 m

17.10 Tensioning of moorings

After laying, drag anchors shall be tested at least 80 % of calculated maximum force generated in the line under the design environmental conditions, in the intact mooring system as predicted by the chosen design methodology. The test load should be applied gradually in the line and then maintained for a duration of at least 15 min; see also ISO 19901-7. During the test, uplift of the drag anchors shall be avoided.

17.11 Other stationkeeping means

17.11.1 Introduction

Vessels involved in specific installation operations (e.g. transport vessels, installation vessels and the structure being installed) sometimes need to be controlled by a stationkeeping system other than a mooring.

The stationkeeping system can consist of:

- a DP system;
- purpose-built mooring arrangements;
- tugs, moored and used as winch stations.

17.11.2 DP systems

DP systems should be designed, equipped and operated in accordance with References [54] and [36].

17.11.3 Purpose-built mooring arrangements

17.11.4 Use of tugs

In certain circumstances, a tug can be used to assist in a temporary mooring system. It is, then, normally connected at its bow to a pre-laid mooring, its towing winch being used to tension up the towline connected to the structure. With this arrangement, the tug effectively becomes a winch barge.

In such a case, some special considerations apply to the pre-laid mooring and the design of the tug. In particular, it should be demonstrated that the moored tug is able to function in sea conditions coming from any direction.

The connection to the pre-laid line at the bow of the tug should be checked to be suitable for the design conditions of the mooring system.

17.12 System for common reference stations

Due to multiple installation locations at an offshore installation site, it is crucial that all vessels conducting installation works use a common reference station for component and vessel positioning as well as as-built-data. A system shall be used that allows for this requirement to send out correction data over e.g. radio modem. The principle of such a system is based on the comparison of a known position of a GNSS (global navigation satellite system) reference station with the computed positions from the actual measurements.

During the construction phase, a fully workable GNSS-RTK reference station should be positioned at the offshore installation site including but not limited to:

- GNSS receiver;
- radio with omnidirectional antenna;
- power backup;
- interface capability with standard vessel GNSS system;
- verification that the broadcasted correction signals from the system can be received across the entire offshore installation site.

The owner's construction management should provide all sufficient information and procedures on how to use the reference station as such including but not limited to all specification for technical equipment needed on vessel side.

An appropriate location at the offshore installation site shall be determined where the system including potential back-up units can be installed.

Companies conducting the installation should use the RTK reference station for positioning of components and vessels during installation and when determining the site-specific coordinates of the installed components or ensure common reference station by other means.

18 Offshore installation operations

18.1 Introduction

The requirements, guidance and recommendations for marine operations involved in the offshore installation of structures, both below and above the surface, are provided in this [Clause 18](#). Installation of cables is covered in [Clause 20](#).

18.1.1 Foundation

Foundation(s) is(are) the base on which the WTG is positioned, required to ensure that forces applied by the operation of the WTG can be absorbed and that the WTG is kept in position. Usual types of foundation consist of, but are not limited to:

- monopiles;
- steel jackets (normally 3- or 4-“legged”);
- gravity bases;
- suction bases;
- moored floating foundations.

The type of foundation chosen is normally consistent through the whole offshore wind farm.

18.1.2 Transition piece

The transition pieces can be an integrated part of the foundation structure, or can be placed after the installation of the foundation either in one piece or separate units.

18.1.3 Wind turbine generator

Wind turbine generators are normally composed of the following components:

- tower;
- nacelle;
- blades.

Different installation setups for each of the above components are not detailed in this document.

18.1.4 Offshore substation/Offshore accommodation platforms

In case direct grid connection to shore is not possible or not economic, offshore wind farms include offshore substations usually consisting of a topside on a jacket foundation. In order to optimize accessibility of the assets during operations, some offshore wind farms may additionally have offshore accommodation platforms, usually consisting of a topside on a jacket foundation.

18.1.5 Installation plan

The installation plan is part of the project execution plan and consists of a conceptual and a detailed part. It shall be prepared before the start of the installation. Items included in the installation plan documentation are listed in [A.4](#) and here below.

18.1.5.1 Conceptual installation plan

The conceptual part shall provide basic information about the following subjects:

- vessel description, including:
 - class and flag;
 - dimensions;
 - air draught;
 - maximum draught/light ship draught;
 - GA-drawings;
 - cargo capacity;
 - accommodation;
 - autonomy;
 - deck strength;
- operability values (transport, operation, survival limits for jack-ups);
- transit speed;
- jacking system description and capability, if applicable;
- seakeeping capability (DP, anchoring);
- outfitting particulars, including :
 - main and auxiliary cranes;
 - access systems;
 - winch system;
 - helideck;
 - ballasting system;
 - cooling system;
 - power supply;
 - illumination arrangement;
 - monitoring and information system (LAN, TV);
 - preinstalled seafastening system;
 - ROV systems;
- sensor systems (positioning reference systems, DGPS, radar, satellite, laser surveying, taut wire, hydro-acoustic);
- offshore location description, including:
 - water depth;
 - soil condition;

- restrictions;
- risks;
- harbours;
- location;
- tide size;
- sheltered areas/not sheltered (swell, waves, current);
- docking capacity (bollards, quay length and height);
- quay capacity (dimensions, bearing capacity);
- quay restrictions (e.g. minimum distance of jacking legs);
- heavy load logistic infrastructure (crane capacity, RoRo, skids, preassembly of components);
- sea bottom profile (jacking location, on bottom obstruction, bearing capacity);
- inshore and sea access (inland waterways, roads, air draft);
- resources (fuelling, water and power supply, repair facilities, man power);
- see also [18.6.3](#) for further details on risk assessment for punch-through risk and risk of uncontrolled movement of jacket legs;
- basic RAMS, including:
 - basic sequence and schedule of operations;
 - installation tolerances;
 - operation restrictions;
 - interface descriptions;
 - components and modularity (CoG, weight, attachment points, tugline connection points);
 - basic GA-drawings of components, lifting gear and lifting operations;
 - resources (equipment, tools, lifting devices, qualified man power);
- basic risk assessment;
- statistical and historical data about environmental conditions;
- average weather and seastate prognosis, including :
 - wind (main direction, mean wind, gusts);
 - waves (main direction, significant wave height, swell, wave scatter diagram);
- current;
- tidal excursion.

18.1.5.2 Detailed installation plan

The detailed installation plan starts after the following boundary conditions have been defined:

- baseport;

- installation units (jack-up vessel or barge, cable layer);
- transportation units (feeder vessels, work boats);
- installation method;
- installation milestones (start, operational period);
- basic impact of environmental conditions.

The detailed installation plan includes the following elements:

- RAMSs for operations with the installation unit:
 - deck layout of installation unit;
 - lifting plan for offshore installation;
 - lifting plan for loadout at baseport.
- risk assessments, HAZOP/HAZID studies to be completed at an early stage so that the findings can be incorporated into the operational procedures.
- the arrangements for control, manoeuvring and mooring of barges and/or other craft alongside the installation vessel
- a weather forecast from an approved source, predicting that conditions are within the prescribed limits, shall be received prior to the start of the operation, and at 12 hourly intervals thereafter, until the operation is deemed complete.

18.1.6 Cargo weight details and CoG information

Weight and CoG position assessment shall be planned in accordance with [Clause 12](#).

Dynamical effect shall be correlated with the type of installation vessel (jack-up, semi-jack-up, floating) and duration to complete the installation (including contingency).

18.2 Installation site

18.2.1 Sea floor survey

A set of surveys of the site sea floor area shall be carried out to determine bottom topography, identify obstructions and possible hazards such as UXOs, boulders, etc.

The major results of these surveys shall be detailed in the site chart which shall be made available to all parties and updated on a regular basis and distributed.

Measurements locating pre-existing structures shall be performed.

Surveys are normally performed by vessels and require a marine operation.

The normal set of surveys providing sufficient information is detailed in ISO 19905-1^[14] and References [\[56\]](#) and [\[57\]](#).

Sea floor survey shall be carried out sufficiently early to allow processing of the gathered data and to take the results into account in the project's preparation.

Sea floor survey data should feed a GDB (geo data base) of a GIS (geographical information system) in order to facilitate the exchange of data and other information including analysis report between the relevant parties.

18.2.2 Soil survey

Site-specific geophysical and geotechnical data shall be made available to design and plan the installation operations providing e.g. results of bore holes and cone penetration test. See ISO 19901-8^[9] and Reference ^[57].

Soil surveys require a clear definition before being initiated including, but not limited to:

- campaign planning;
- survey set-up (number of vessels, equipment required, etc);
- raw data collection and interpretation;
- the full scope of the survey shall result in a site-specific chart as described in [18.2.4](#).

Soil survey shall be carried out sufficiently early to allow processing of the gathered data and to take the results into account in the project's preparation.

Soil survey data should feed a GDB (geo data base) of a GIS (geographical information system) in order to facilitate the exchange of data and other information including analysis report between the relevant parties.

18.2.3 Soil preparation

Based on the results of the site-specific sea floor survey and the requirements specific for the installation of the foundation structure, soil preparations could be recommended. This could comprise levelling measures of the seabed or placing any scour protection layers where advisable.

Where suitable, instead of levelling the seabed, the foundation, particularly jacket structures, could be directly equipped with temporary support material e.g. underneath mud mats which would compensate for slight deviations in sea floor level during installation. After final fixation of the jacket, this material would remain at its place but would not be structurally relevant^[57].

18.2.4 Site charts

Site-specific charts shall be made available to all parties working in the offshore wind farm during installation operations. The site charts shall provide detailed coordination information on e.g.:

- all existing structures;
- locations of components which were already installed during the campaign;
- planned locations of components;
- exclusion zones for e.g. jacking and anchoring;
- cable corridors;
- locations of any buoys, e.g. cardinal buoys or wave measurement devices;
- locations of wrecks or other suspected objects including UXO.

The site chart shall be updated on a regular basis and provided to all parties working during the installation operations.

Charts displaying the results of survey processing and analysis could be generated by GIS tools.

18.2.5 Unexploded ordnance (UXO)

18.2.5.1 General

UXO may pose a risk to offshore wind farms. Proper investigation shall be undertaken to assess and mitigate this risk as described in the following subclauses. Further information can be found in Reference [1].

18.2.5.2 UXO survey

A specific UXO survey shall be carried out if desktop study or other sources indicate that there is a possibility of UXO presence.

The performance of a UXO survey should be based upon the findings of the desk study which should:

- review the risk of encountering munitions, UXO, dumped chemicals and other dangerous objects and substances at or near the proposed site;
- assess which methods are most suitable for locating the hazardous items;
- recommend a risk mitigations strategy.

Further evidence for the requirement of a UXO survey shall be provided by the results of the geophysical and geotechnical surveys.

UXO survey shall classify contacts laying on the seabed or buried, and suspicious obstructions shall be classed as possible UXO (pUXO or "UXO-like"). Proper planning of the campaign including area to be surveyed, sensors to be used, accuracies required, detection thresholds, definition of swath for all equipment as well as coverage, line separation, tow height and accuracy of measurements shall be required.

All identified and unidentified items shall be indicated on the site chart and included in the list of objects. The list of objects shall be made available to all relevant parties and updated when necessary.

18.2.5.3 pUXO definition and detail

Possible UXOs (pUXOs or "UXO-like") are items on the sea floor or the seabed which present physical characteristics of UXO (shape, dimensions). These items shall be considered as dangerous as an identified UXO until their true nature has been verified (by ROV or diver for instance).

Deliverables of the desktop study are:

- comprehensive and qualitative historical study of events which generate a pyrotechnic risk zone;
- threat assessment including all ordnances susceptible to be encountered;
- risk assessment related to marine operations.

The type of the most likely UXO shall be defined resulting in a minimum threat item value. This value defines the smallest hazard item that needs to be mitigated for an ALARP certification.

In addition, the UXO clearance areas around the structures in the offshore wind farms shall be defined. Clearance areas depend on the UXO risk assessment and site-specific planning. Planning shall take into consideration the largest vessel which intervenes with the seabed (using jacking legs or anchors), the intervention from pilling, ploughing and any form of seabed intervention. Until the pUXO is identified either as a UXO or as an object not comparable with an UXO the item shall be placed on the site map and an exclusion zone provided in a radius around it.

18.2.5.4 ALARP principle

The ALARP certification does not eliminate all UXO risk on the site to “zero”, as to do so would be impracticable and prohibitively expensive. Whilst a minor residual risk may remain, it is considered to be at a “*de minimus*” level and thus reasonable to be carried by those parties involved and therefore all parties should be involved in setting the “*de minimus*” level.

The following UXO risk mitigation actions are recommended (where applicable):

- investigation of previous UXO clearance activities on site;
- investigate seabed changes;
- UXO survey and target discrimination;
- micro-siting and re-routing;
- detailed ROV inspection;
- UXO clearance operation;
- removal of magnetic debris from the detonation;
- UXO clearance certificates.

UXO sign-off certificates are valid for a certain time, e.g. five years, depending on the seabed mobility observed at the site.

18.2.5.5 Exclusion zone

An exclusion zone shall be indicated around each object identified as pUXO.

The exclusion zone is determined by the planned intrusive activity such as:

- foundation installation including scour protection;
- jack-up leg;
- cable installation;
- cable or foundation protection material/mattressing;
- anchors.

Normally, this exclusion zone ranges from 10 m to 50 m and shall clearly indicate that the seafloor and seabed is not to be disturbed in any way within the zone.

Exclusion zones shall be agreed between all relevant parties at an early stage of the project.

18.2.5.6 Vessel safety zone

The vessel operator shall identify the requirement for a vessel safety zone enabling the vessel to stay clear of the exclusion zone.

The safety zone shall be established by the operator using all variables which could impact position and movement of the vessel such as:

- environmental factors;
- position system uncertainty;
- leg sway;
- sediment transportation due to penetrating legs (spudcan).

The safety zone shall be established around the outside perimeter of the vessel to avoid a safety distance being less than the width of the vessel, allowing the vessel to position above an exclusion zone with the actual hazard then being positioned directly under the vessel.

18.3 Systems and equipment

18.3.1 Introduction

Guidelines for the selection of operational systems and equipment in general are given in [Clauses 5](#) and [6](#). Considerations regarding specific items of systems and equipment are given in [18.3.2](#) to [18.3.6](#).

18.3.2 Vessels

The installation operation can be a direct continuation of the offshore transportation, using the transportation fleet as the core of the installation fleet.

18.3.2.1 Self-elevating vessels

Each stage of the proposed operations shall be considered separately because different limiting environmental criteria apply to each sequential jack-up operating mode.

Jack-up operations can typically be divided into the following stages:

- transport;
- positioning (including preloading and jacking up);
- elevated operations (including lifting and load transfer operations);
- survival mode;
- move out including jacking down and re-floating.

Generic procedures for re-floating, towing or self-propulsion, dynamic positioning, jacking, preloading, and elevated operations as applicable to the routine operation of the jack-up are usually included in the vessel's operating manual.

18.3.2.2 Dynamic positioned vessels

A vessel with a minimum DP Class 2 should generally be preferable. For application of vessels with DP Class 1 or lower a detailed safety analysis (FMEA) for the planned operation is recommended.

DP operating and positioning procedures (as applicable) should be documented and include station keeping analyses/capability plots, vessel DP system FMEA and annual trials reports.

Any seagoing vessel must be able to survive in weathers which are at least equal to the operational limits determined for the voyage.

Any lifting operation shall be conducted within the weather limitations documented for the vessel and the equipment used to ensure safe operations. The design and operating criteria shall take into account metocean reduction factors as mentioned in [Clause 7](#). Refer to [Clause 19](#) for the design of lifting equipment.

For further information, see Reference [\[54\]](#).

18.3.3 Equipment

All handling equipment used for installation, such as upending systems, grippers, lift tools, shall have a valid certificate from a recognized certification body.

Spare parts shall be provided to minimize equipment breakdown.

Only trained and competent personnel can manipulate, maintain or repair the tools.

18.3.4 Position reference system

Normally, two independent on-board positioning reference systems (PRSS) shall be utilized for operational monitoring and control purposes for the positioning of components (one being used as principal system and the other as secondary system). Both systems shall be in operation at any time, each serving as the back-up for the other. Each should be fed by an independent power source.

18.3.5 Ballast systems

Ballast system on the installation vessel should be sufficient and designed for the purpose, whether this is assisting in obtaining the required pre-load or ensuring that the loading remains within the longitudinal strength capacity.

On floating units, ballast systems shall be considered as the prime operational systems for installation purposes, where draught, trim, heel and stability are vital for a successful operation; see [Clause 14](#) for further guidelines.

18.3.6 Transport vessel interface with marine equipment

If the transport vessel is a launch barge, cargo barge or vessel, consideration shall be given to handling and positioning during the installation activity.

18.4 Positioning of vessels

Vessels used in offshore construction of windfarms can be positioned fundamentally by three methods:

- dynamically positioned (DP) vessels;
- moored by use of an anchor spread;
- vessels positioned by the use of assisting vessels.

The notations assigned to units with dynamic positioning systems should be provided by classification societies.

The dynamic positioning system includes requirements for the following subsystems, control panels and back-up systems which are necessary to dynamically position the unit:

- power system;
- thruster system;
- DP control system;
- computer system/joystick system:
 - sensor system(s);
 - control stations and display system (operator panels);
 - position reference system(s);
 - associated cabling and cable routeing;
 - networks;
 - for DP2 vessels, redundancy of all active components;

- for DP3 vessels, redundancy of all components and A-60 physical fire separation of the components.

Those systems are periodically checked and tuned during DP-trials. Before any position keeping operation using DP, the system shall be checked in open waters and the calibration of all systems confirmed.

See also References [36] and [54].

18.5 Site reference system

Refer to 6.5.8.

18.6 Geotechnical site-specific assessment for jack-up operations

18.6.1 Introduction

Geotechnical site-specific assessment should be performed in accordance with ISO 19905-1^[14] and Reference [57].

The following section should not be used isolated, but only with reference to the referenced documents in their newest version.

18.6.2 Required soil investigations

Site-specific geotechnical information is required. The type and amount of data required depend upon the particular circumstances, such as the type of jack-up, soil conditions and previous experience of the site, or nearby sites, for which the assessment is being performed.

For sites where previous preloading and elevated operations have been performed by jack-ups, it can be sufficient to identify the location of existing jack-up footprints. In this case the details of the previous jack-up footing design and the preload applied should be available and it should be verified that the foundation bearing pressure applied previously was in excess of the pressure to be applied by the jack-up under consideration. In the absence of such verification, soil investigation involving boreholes or CPT is required.

The location and number of boreholes or CPTs required should account for lateral variability of the soil conditions, regional experience and the geophysical investigation. A borehole may not be required if there is sufficient relevant historical data and/or geophysical tie lines to boreholes in close proximity to the proposed jack-up location.

The geotechnical investigation should comprise a minimum of one borehole to a depth equal to 30 m or the anticipated penetration plus 1,5 to 2,0 times the footing diameter, whichever is greater. Investigation to lesser depths may be accepted in cases where only small penetrations are anticipated in hard soils; however, in such cases, the advance approval of a geotechnical engineer with appropriate experience with jack-up foundation assessments is recommended, and the reduced depth of investigation shall be justified in the foundation assessment. Estimations due to boreholes at positions in the vicinity of the jack-up zone in combination with CPTs and geophysical data are also possible if the soil properties allow for such estimates.

All layers shall be adequately investigated, including any transition zones between strata, such that the geotechnical properties of all layers are known with confidence and that there are no significant gaps in the site investigation record. Laboratory testing of soil samples can be required.

The nature of the seabed surface soil, together with the water depth and the current and wave regimes shall be assessed to determine whether potential for scour exists. The assessment should consider whether scour has occurred around existing fixed or temporary structures such as foundations in the vicinity (if any) and records of previous scour that affected earlier jack-up installations. In the event

that the assessment indicates that the integrity of the jack-up foundation could be adversely affected, then seabed soil samples can be required and a scour analysis should be performed.

The soil investigation shall produce sufficient reliable data on which to base a competent analysis that provides a recommended soil strength design profile giving lower and upper bound strength estimates. This should be carried forward into the jack-up site-specific assessment as per ISO 19905-1^[14] and Reference [61].

18.6.3 Penetration analysis, punch-through and horizontal-vertical-interaction

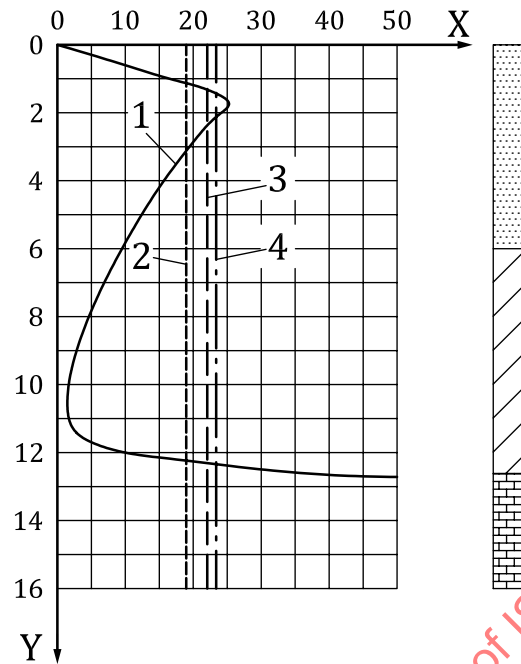
The jack-up foundation assessment is required in all cases where the jack-up is to be preloaded and elevated above the sea surface to a working air gap or to the minimum safe survival air gap on location. The scope of the assessment and the amount of data required depend upon the particular circumstances, such as the type of jack-up, the soil conditions and variations in the soil across the site, and upon previous experience of the site, or nearby sites, for which the assessment is being performed.

The combinations of vertical and horizontal load shall be checked against a foundation bearing capacity envelope. The resistance factor may be taken as 1,0 when the load-penetration curve indicates significant additional capacity for acceptable levels of additional settlement. Minor settlement not exceeding the limits contained in the operating manual may be acceptable provided that:

- the jack-up can withstand the storm loading plus the effects of the inclination;
- the lateral deflections do not result in contact with adjacent structures;
- the jacking system remains fully operational at the angle of inclination considered.

Consideration shall be given to the operating limits of the jacking system. The capacity of jacking systems to elevate or lower the hull can be significantly reduced or eliminated by leg guide friction (binding) caused by small angles of inclination. Additionally, some hydraulic recycling jacking systems cannot usually be jacked at angles of inclination greater than 1,0 degree because even this small angle can result in inability to extract or engage the fixed and working pins (or catcher beams).

Extreme caution should be exercised if the soil profile reveals a risk of punch-through when it should be demonstrated that there is an adequate safety factor to ensure against punch-through occurring in both extreme (abnormal) storm events and operating conditions. Particular attention shall be paid to the appropriate safety factor in cases where the jack-up's maximum preload capacity does not produce significantly greater foundation bearing pressure than that to be applied in the operating or survival modes (see [Figure 7](#)).



Key

- X soil resistance in Nm
- Y depth below mudline in m
- 1 predicted leg penetration curve
- 2 operating load
- 3 storm load
- 4 maximum preload load

Figure 7 — Predicted leg penetration curve^[58]

Calculation of the safety factor against punch-through should normally be in accordance with the recommended practice; however, alternative methods that can provide an equivalent or greater level of safety exist and therefore consideration should be given as to which method is appropriate in the circumstances. See also Reference [57]. Ultimately, the assessment of punch-through risk requires a high level of expertise and the exercise of sound judgment based on experience.

Consideration should be given to the limits of maximum and minimum penetration as determined by the jack-up design or operating manual. In cases where the limits stated in the manual are related simply to a sample elevated condition and the leg length installed, it can be ignored provided the leg length is sufficient to meet the survival air gap defined in References [58], [57]. An analysis should be carried out for any case where the maximum or minimum penetration limit stated in the manual is related to leg or spudcan structural strength or to the jack-up's capacity for leg extraction.

Particular consideration shall be given to the requirement for extracting the leg footings and the probable effectiveness of the leg jetting system (if fitted). Temporary inability to extract the legs from the soil can involve serious risk if the unit cannot be quickly removed to shelter and/or cannot achieve the elevated survival mode and remain on location.

For jack-ups fitted with hydraulic recycling jacking systems, there is the additional risk that the jacking systems can become temporarily immobilised through inability to extract fixed or working pins during the leg extraction operation. If this occurs during a rising tidal cycle, then damage or flooding can result.

The potential for seabed scour shall be considered and the potential impact this can have on the integrity of the jack-up foundation over time. At locations where risk of scour is deemed to exist, the foundation assessment shall include an assessment of the potential depth and rate of soil removal and that can affect foundation stability. The assessment shall include a caution to the effect that special

jacking procedures can be required to mitigate the risk of foundation instability and should also recommend scour protection measures where appropriate.

18.7 Vessel operation manual

Any operational document involving a jack-up unit should contain as minimum all information relevant to the safety of the unit, personnel and major items of equipment on board the unit, including, but not limited to:

- general specification, setting out limitations on operating water depths and corresponding environmental conditions;
- general arrangement plans and elevations;
- compartmentation and piping systems;
- weights and CoG of hull and equipment, legs and spudcans;
- loading instructions, giving limitations on weight and CoG, with worked examples of loading calculations for elevated and afloat conditions;
- details of jacking system, stating maximum elevating, lowering and holding loads and all necessary checks before jacking operations, including where applicable the required torque and brake clearance for each motor;
- variable load capacities;
- tank calibration tables;
- details of propulsion units (if any);
- details of critical downflooding openings, means of closure, and instructions for ensuring closed under tow;
- limitations for going on and off location;
- critical motion curves for towage for relevant leg lengths and positions;
- preloading instructions;
- maximum and minimum permitted penetration, and reasons for any restrictions;
- instructions for filling and emptying spudcans;
- jetting system layout and operation;
- maintenance schedules for machinery and systems. inspection schedules for structure;
- reference to more detailed manuals for machinery and systems;
- allowable loadings and positions of cantilever and substructure for operating and survival conditions;
- calculations on allowable loadings during survival condition of jack-up vessel specifying the number of components allowed to be stored on deck during these conditions also taking into account the specific season in which the installation is conducted and the probability of survival mode conditions being reached during this season;
- emergency procedures in case of punch through.

18.8 Jack-up preloading procedure

At locations where there is a risk of leg runs, rapid penetration or punch-through, a cautious approach should be taken. The initial preload should generally follow procedures given in the marine operation manual. In case of potential punch-through locations, additional safety precautions should be taken during preloading.

Once full load has been achieved, the preload should be held for a sufficient time period specified by a geotechnical engineer based on the actual site-specific soil conditions. At the end of this time period, the load decrease should be negligible. Under some circumstances, geotechnical advice can be that longer hold times are required. Such longer hold times are typically required at locations where there is a high risk of punch through and in very soft formations when leg penetrations are in slow increments.

18.9 Ballasting

Ballasting or deballasting of a barge or vessel is part of a marine operation and, as such, detailed procedures should be established and implemented.

Operation of ballast systems should be considered during HAZID or similar sessions; see [5.4.2](#).

Ballast operators, in addition to operational managers and personnel vital to the performance of the operation, should participate in such sessions.

The design issues for ballasting, deballasting and addition of heavy ballast are dealt with in [Clause 14](#).

18.10 Lifted installations

18.10.1 Introduction

This section is to be considered a generic description of installation operation when the structures are lifted by means of cranes on floating vessels (DP mode or anchored) or jacked-up vessels.

Lifting and lowering operations are generally carried out by floating cranes, vessel cranes or cranes on jack-up vessels, but can also be achieved by numerous types of equipment using specially rigged rotary, traction and linear winch systems, etc. The lifting systems should comply with one international recognized standard and be fitted for purpose to accepted classification standards.

For detailed information on required equipment for lifting operations, see [Clause 19](#).

18.10.2 Installation of liftable jackets

Main aspects involved in installation of lattice structures or jackets are the following:

- rigging;
- lifting points;
- crane operations;
- weather conditions;
- content of RAMS;
- barge/jack-up platform;
- jack-up leg positions (if the case).

18.10.3 Installation of templates for piles

In order to increase productivity, efficiency and utilize wisely operational windows, a method of pre-piling through a template followed by a jacket or tripod type foundation installation over pre-piled arrangement has become a favoured installation method used on wind farm jacket foundations.

Templates are mainly installation aids of type pin/bucket which are lowered on seabed to ensure verticality of the piles during the initial stages of hammering.

Template installation influences the position of the piles and further position of foundations for WTGs.

Survey equipment should be certified, calibrated and tested as applicable during the mobilisation for template installation.

As templates are lowered and, furthermore, lifted through splash zone an operation specific study is advisable to be performed to achieve a more realistic load case using [Clause 19](#) recommended method.

Lifting of the template should account among other for friction of template with installed piles and influence of skewed lift over the strength of template/piles.

18.10.4 Installation of piles

18.10.4.1 General

Installation of piles is mainly influenced by soil type, on-bottom stability (see also [7.3.2](#) and [18.6.2](#)), recurrent weather and type of installation vessel.

18.10.4.2 Upending of monopiles

Monopiles are normally carried horizontally on the installation vessel. Prior to installation, the monopile is upended and placed in the correct position and kept vertical and in alignment by means of a pilegripper which is attached to the vessel hull.

The upending method for the monopile relies on the position of the pile gripper and the direction in which it has been transported offshore, transversely or longitudinally.

Upending onboard can utilise more cranes or SPMT and upending bucket construction to ensure control of the load once the pile is vertical.

18.10.4.3 Piling

The monopile, once placed in the pilegripper, is then designed to self-penetrate to a level where the crane can be released to pick up the pile driving device.

The pile driving device is placed on the pile and starts to apply force to the top of the monopile forcing it into the soil.

18.10.5 Installation of transition pieces

Installation of transition pieces is mainly influenced by significant wave height and swell effects. Provision of appropriate guides/guide fingers is recommended. Where grouting is required as a sequential operation, suitable weather window selection shall reflect the operational limits of the stand-alone situation of an ungrouted transition piece. See also [18.14](#) and [18.15](#).

18.10.6 Installation of GBS

Installation of gravity-based foundations shall involve a marine spread that is capable of controlling the load until resting safely on the seabed.

18.10.7 Transfer of items from a barge to the deck of a crane vessel/jack-up vessel

Lifting items from a floating structure should account in rigging and lift points design for dynamical loads from motion response of floating vessel.

Lifting speed should be coordinated with floating vessel motion, existence of motion compensation (on vessel or crane) and crane capabilities.

Mooring arrangements shall be conducted according to [Clause 17](#).

Ballasting procedures shall be conducted according to [Clause 14](#).

Cranes used for lifts between a fixed structure and a floating object shall be suitable for dynamic offshore lifts.

18.10.8 Installation of towers

Lifting tools or aids (pad eyes, hook-up lugs, etc.) should be certified by a recognized organization. Their structure should be designed for maximum loads during transport and installation.

18.10.9 Installation of WTG including nacelle, hub and blades

All special items (nacelles, blades, hubs) should be designed and certified for transport and installation at their desired location. All lift points should include consequence factors not less than 30 % as per [Clause 19](#) resulting in a factor 1:3 when applied to the design loads.

Due to relative high sensitivity to clash loads, deck layout shall provide for sufficient clearances between the lifted objects and the structures on board the transport and installation vessels.

18.10.10 Installation of topsides of offshore substations/accommodation platforms

The installation of offshore substations or accommodation platforms includes the installation of the substructure, e.g. jacket foundation, and the installation of the topside. Depending on the weight of the topside, installation can either be carried out as a lifted operation or as a float-over installation.

In case of a lifted operation, jacket foundation and topside are usually towed offshore on a cargo barge, and the cargo barge is usually moored to the installation vessel which is anchored or operates in DP mode. Lifting procedures for piles, jacket and topside shall be designed to account of the specific mooring arrangement.

Lifting tools or aids (padeyes, hook-up lugs, etc.) at the topside and jacket should be certified by a recognized organization.

18.10.11 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

- structure weight and CoG and sensitivity to variations in these parameters;
- hook load and lowering system capacity;
- lift rigging specification, testing and design; see [Clause 19](#);
- wind, wave and current;
- provision of anti-twist systems or suitable arrangements to overcome problems due to the natural rotation induced by the lay of wire ropes, if applicable to the crane type.

Equipment shall be protected against damage from the slings when tightening the system for lifting. The slings should be protected against sharp edges and corners that can cause damage to the slings.

18.10.12 Operational control parameters

The following parameters shall be considered, monitored and controlled during lifting and lowering:

- hook load;
- hook lowering and hoisting speed;
- environmental conditions;
- position of the lifted object, crane and transportation barge or vessel, as appropriate;
- barge or vessel and structure clearances;
- access for connecting rigging to hook, and egress;
- procedure for removal of rigging from structure lift points;
- tugger wires/tag lines;
- outreach;
- hook height.

18.11 Lowering by ballasting

18.11.1 Introduction

Floating objects that are lowered in a controlled way by ballasting should project through the water plane; their stability shall be positive throughout.

For objects that are fully submerged during installation, special lowering and control procedures shall be developed.

18.11.2 Operational aspects

Aspects to be considered during planning and design shall include, as appropriate:

- provision of a gravity and/or pumped ballast system that allows the operation to be completed within the specified weather window;
- performance of failure modes and effects analysis;
- monitoring of stability throughout lowering, including an assessment of whether inclining the structure to maintain positive stability is necessary;
- provision of contingency de-ballasting methods;
- determination of heavy ballast requirements for stability of the floating structure and provision of an additional ballast system, if required;
- consideration of the change in water density with depth;
- consideration of compression of structure and resulting decrease of volume with depth.

18.11.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during the operation:

- position and orientation;
- wind and current directions;

- stability;
- ballasting rate;
- ballast weight;
- mode and status of operational valves;
- layout of tugger lines and winches where these are required to bring the object into position;
- sand excavation, if necessary;
- cleaning of steel surfaces from marine growth.

18.12 Precise positioning on the sea floor by active and passive means

18.12.1 Introduction

For precise positioning of objects on the sea floor, e.g. piling templates, jacket foundations passive positioning means, such as winches or tugs used as winch stations, can be used in combination with passive positioning means, such as docking piles and bumpers.

18.12.2 Operational design aspects

Aspects for consideration during planning and design shall include, as appropriate:

- water depth;
- means of positioning and control to maintain the object within the required vertical boundaries;
- limiting environmental conditions for lowering, positioning and setting down of the object;
- achievable lowering rate of the object;
- dynamic behaviour of the object during lowering, positioning and setting down;
- applicable procedure for touchdown, e.g. using a small inclination to aid precise positioning of the object;
- on-bottom stability of the object prior to set-down, e.g. using a large inclination at the initiation of set-down to maintain stability of the object during the final lowering period.;
- on-bottom stability of the object after set-down and prior to fixing it in place.

18.12.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during precise positioning and setting down:

- environmental conditions, during the operation and as forecast;
- position and orientation of the lowered object and the existing structure, including their relative position;
- wind and current directions;
- forces in positioning lines;
- dynamic behaviour of the lowered object.

18.13 Skirt penetration

18.13.1 Introduction

For general information and design issues of skirts, see ISO 19901-4^[7] and ISO 19903^[13].

18.13.2 Gravity penetration

Gravity penetration is achieved by adding weight to the structure by ballasting, while simultaneously allowing water from skirt compartments to discharge into the sea.

18.13.3 Suction penetration

Suction penetration is achieved by creating an underpressure in the skirt compartments to generate a downward action.

18.13.4 Operational design aspects

Aspects for consideration during planning and design shall include, as appropriate:

- limiting environmental conditions;
- soil conditions;
- skirt configuration;
- skirt water evacuation system;
- predicted skirt penetration resistance;
- water ballast system;
- grouting system;
- limitations to differential water pressure between skirt compartments and ambient sea;
- limitations to differential water pressure between ballast compartments and ambient sea;
- limitations to environmental conditions during the operation;
- tolerances on structure verticality and skirt penetration depth for the as-installed structure.

18.13.5 Operational control parameters

The following parameters shall be considered, monitored and controlled during skirt penetration:

- environmental conditions, during the operation and as forecast;
- skirt penetration depth, by paint marks or similar;
- inclination of the structure;
- sealing of the skirt compartments during initial weight penetration before creating the underpressure, if applicable;
- differential water pressure between skirt compartments and ambient sea;
- differential water pressure between ballast compartments and ambient sea;
- grout control.

18.14 Pile installation

18.14.1 Introduction

Steel structures are generally secured to the seabed by open-ended tubular steel piles that are welded, grouted or bolted to the structure. The design of piles, including their connections to the structure, the required pile penetrations and the method of installing piles to their design penetrations, are strongly affected by soil conditions, by environmental conditions and by available equipment.

Piles are normally lowered from above the water to the sea floor by guiding them through an arrangement of pile guides to control their position and orientation (either vertical or inclined). Thereafter, their design penetrations are achieved by driving, vibrating, drilling or combinations thereof.

18.14.2 Operational design aspects

Aspects for consideration during planning and design shall include, as appropriate:

- soil conditions;
- limiting environmental conditions for each pile installation stage in view of the foundation capacity of the structure;
- metocean criteria and limitations;
- configuration, dimensions and weights of piles;
- sequence of pile stabbing, sequence of pile installation to penetration and associated time scales;
- lifting and upending equipment for piles;
- free head for handling of piles and piling equipment;
- guiding system (e.g. pile gripper) for the lowering of the piles;
- pile sway due to waves and current;
- welding equipment requirements for welding pile sections together and for securing piles to the structure, if applicable;
- interactions of equipment used for piling with the pile and the soil;
- equipment specifications for driving or vibrating piles for penetration, for drilling oversize holes in the seabed in which piles are lowered, or for drilling or jetting out soil plugs from within the piles, as applicable;
- contingency measures in the event of inadequate or excessive penetration rates;
- penetrations due to self-weight of the pile without and with the pile driving hammer stabbed on top of the pile;
- stresses during driving, including *P*-delta effects, if applicable;
- design penetration, allowable excess or shortage of design penetration, and refusal criteria;
- resistance to sliding or overturning of the structure in unpiled condition;
- method of securing piles to the structure (welding, swaging or grouting);
- specification for grout material;
- equipment specification for grouting piles *in situ* and/or to the structure;

- sequence of grouting;
- equipment specification for bolting piles to the structure, if applicable;
- pile stability.

18.14.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during piling:

- environmental conditions, during the operation and as forecast;
- pile position and verticality, if required;
- pile sway, if required;
- pile penetration versus blow counts;
- performance of pile equipment;
- pile installation sequence and modifications thereof to suit actual and forecast environmental conditions;
- required time to reach a secure position versus available weather window;
- final heading, position and verticality of the structure, and pile penetrations achieved.

18.15 Grouting

18.15.1 Introduction

The voids between the:

- skirt compartments of the base of a gravity structure and the sea floor;
- transition pieces and monopile foundations;
- pre-piles or post-piled piles of jacket foundations;
- connections between topside and jacket of offshore substations

are commonly filled with grout to improve the structure's foundation capacity or to allow for a connection between topside and jacket of offshore substations. The grouted connection of e.g. a monopile and transition piece can be supported by using shear-keys structurally integrated e.g. in the overlap area between both components. In addition, the overlap area can be of a conical shape.

18.15.2 Grouting of pile/transition piece structure

Location of grouting equipment either on board the installation vessel or on a separate grout vessel as well as length of grout hoses with corresponding grout pumps should be determined during planning.

Any temperature restrictions, whether air or water, shall be included in the planning of the duration of the operations including pre-heating and insulation requirements.

The following operational aspects should be followed:

- normal grouting procedure including contingency procedure shall be determined;
- sea fastening of grout spread;
- power and water supply, sediment containers;

- monitoring plan of grout quality with defined acceptance criteria;
- monitor grout filling during operation;
- grout hose arrangement connection to grout annuli;
- stopping procedure;
- quality control, test and post grouting inspections;
- temperature log.

18.15.3 Underbase grouting of pile/jacket structure

In addition to the general information of [18.15.2](#), the following specific operational aspects should be followed:

- plan for optimal positioning of grout annuli and grout lines;
- establish primary and secondary grout line for each jacket leg;
- clean annuli of any soil;
- observe grout overflow at top of each pile sleeve; (note: national legislations can provide more stringent requirements);
- pre-define minimum overage (e.g. 10 %) of grout material excess of the theoretical annulus volume to be pumped to the annulus after good quality grout reached (note that national legislations can provide more stringent requirements);
- ROV deployment for monitoring grouting progress.

18.15.4 Operational design aspects

Aspects for consideration during planning and design shall include, as appropriate:

- limiting environmental conditions;
- grout property specifications: fluidity and flow, hardening, strength, durability, density of mix;
- skirt compartment configuration and theoretical volumes;
- operational schedule;
- compartment grouting sequence for optimal improvement of the structure's foundation capacity;
- supply logistics of grout material;
- capacity of grout mixing plant and grout distribution system;
- potential of undesired grout dilution in skirt compartments;
- acceptance criteria for grouting operations;
- structural and geotechnical grout pressure limitations.

18.15.5 Preparations

Activities carried out prior to the start of operations include:

- commissioning and calibration of the grout mixing plant;
- testing of the pumpability of the grout mix;

- checking of grout distribution lines;
- sand excavation (if necessary);
- cleaning of steel surfaces from marine growth.

18.15.6 Operational control parameters

The following parameters shall be considered, monitored and controlled during underbase grouting operations:

- environmental conditions, during the operation and as forecast;
- grouting sequence versus actual and forecast environmental conditions;
- quality of grout mix;
- grout injection rate and accumulated volume in each skirt compartment;
- blockage of grouting lines;
- grout returns at skirt compartment outlets;
- hydraulic pressures in skirt compartments;
- hydraulic piping in soil around skirts;
- acceptance criteria for grouting operations;
- final heading, position and verticality of the structure and penetration depth of skirts.

18.16 Bolted connections of foundation

As alternative to a grouted connection of a pile-shaped foundation, the foundation components (monopile and transitions piece) can be bolted during installation.

Installation procedures shall reflect the specific requirements for efficient bolting.

18.17 Welding of piles/foundation to topsides

National requirements can apply to offshore welding procedures specifications, see for example EN 1090-1^[18] and EN 1090-2^[19]. Corresponding NDT procedures shall be in place. The waiting time between end of welding operations and the NDT shall be aligned to the installation operations; national requirements can also apply.

Required welding procedure qualifications records of the contractor performing the installation shall be in place.

18.18 Noise mitigation measures

Hydrosound emissions during piling of foundation structures can negatively influence on marine mammals. Depending on the national regulations, noise mitigation measures can be required during piling to minimize hydrosound emissions. Various noise mitigation techniques can be applied. The efficiency of the chosen method shall be documented by defined measurements.

Prior to piling, deterrent measures should be undertaken to prevent injury of marine organisms. Deterrent effects shall achieve the directed relocation of animals (here marine mammals) away from the construction site. For this, acoustic devices, i.e. pinger and seal scarer, should be used to scare animals away from the construction site.

The coordination between installation/piling operations and any chosen noise mitigation measures shall be included in the engineering and planning of the marine operations.

18.19 Crew transfer to and from installation units

Guidance regarding crew transfer is stated in Reference [37].

The method for personnel transfer shall be available, appropriately risk-assessed, and required training, competences as well as required equipment specified and certified where necessary. Personnel being transferred should be briefed prior to the transfer and should be familiar with the transfer and the equipment being used. The personnel should be physically able to conduct the transfer and should understand the intended activity. Adequate personal protective equipment (PPE) should be worn. The duties of personnel supervising or otherwise involved in supporting personnel transfer should be clearly defined.

Gangways are the primary means by which personnel transfer between a vessel (installation unit) and a foundation, particularly monopiles with transition piles already installed is conducted. Gangways should be constructed of appropriate material, be of appropriate length and width, fitted with non-slip walkways and handrails with sufficient lighting and should be placed with safe angles of inclination. Appropriate maintenance is required and landing points at foundations shall be designed for the loads related to positioning the gangways.

Personnel transfer can also be conducted using crew transfer vessels (CTV) or similar allowing transfer to and from the CTV via a boatlanding at the foundation. Seaworthiness of the CTV should be considered when choosing the right CTV appropriate for the conditions in the area of operation. During stepping over between CTV and boatlanding, experienced assistance shall be available on the CTV for the personnel conducting the transfer. The likelihood of water surging up between the CTV and the boatlanding once in close proximity should be risk-assessed.

Other means of personnel transfer stated in Reference [37] should be handled with similar care and diligence.

Boat to boat transfer, without dedicated transfer equipment is forbidden.

18.20 Offshore completion

18.20.1 Introduction

After completion of the installation operations and usually before the installation vessel leaves the offshore site, the following activities shall be performed.

18.20.2 ROV inspection

A ROV survey shall be carried out according to an agreed plan to check for possible damage and debris, and to ensure that any installation and positioning aids have been removed, e.g. slings, rigging, transponders. The most adequate method and sensors shall be used to perform this completion survey or “as built survey”. To facilitate the survey, the structures are generally suitably marked for reference purposes prior to the installation.

The following items (but not limited to), wherever applicable, shall be inspected and checked for damage:

- paint coatings;
- anodes;
- scouring of the top soil layers;
- cables free spans.

18.20.3 Removal of temporary equipment

Temporary equipment shall be removed in accordance with plans agreed to as part of the operational planning and design phase.

18.20.4 Scour protection

Depending on the geometry of the base, moving sand dunes, and local current conditions, the foundations can require the application of anti-scour measures, such as graded rock, gravel and/or mattresses.

18.20.5 Final inspection

An inspection shall be performed at the end of the installation operations. It shall in particular ensure that all temporary items have been removed, and that the asset is clean, pre-commissioned, and ready for use.

A final inspection report shall be issued. This report shall include the list and description of all installation items still open (if any).

18.21 Project execution manual

The project execution manual shall include, as a minimum, details about the following. If some of this information is not directly included in the project execution manual, the project execution manual shall indicate in which document the information can be found:

- specifications of:
 - vessels;
 - lifting equipment;
 - tools;
 - machines;
 - access systems;
 - accessories;
- organization;
- communication routines and systems;
- general arrangement;
- operational procedure/(detailed) task plan(s);
- operation schedule;
- contingency planning and emergency procedures;
- permissible load conditions;
- environmental operation criteria;
- monitoring during the operation;
- tolerances;
- permissible draughts, trim, and heel and corresponding ballasting plan;
- systems and equipment including layout;

- systems and equipment operational instructions;
- vessels involved;
- tow routes and ports of refuge;
- navigation;
- weather (forecast) and current/wave reporting;
- safety equipment;
- recording and reporting routines;
- sample forms;
- check lists for preparation and performance of the operation;
- test and commissioning plans;
- contingency plans for high occurrence/high consequences risks;
- key personnel and responsibilities;
- clear step-by-step containing handover and hold points;
- management of change procedure;
- approach and positioning procedures;
- transport procedures (night/day);
- jacking procedures;
- operating limits;
- emergency procedures in case of punch through, for self-elevating units.

The project execution manual should state reporting and recording in a timely manner (daily, hourly) to the responsible parties (owner, certification, MWS, etc.)

19 Design and operation of lifting equipment

19.1 Introduction

This Clause gives requirements and guidance for the design and execution of lifting operations (onshore, inshore and offshore). It covers lifting operations by floating crane vessels, including crane barges, crane ships and semi-submersible crane vessels and jack-up vessels. Onshore lifts by land-based cranes are also included when they form part of a marine operation such as a loadout.

Additional guidance on lifting operations can be found in Reference [35].

Lift points on the object being lifted and lifting equipment (rigging) between the lift point(s) and the crane hook(s) are critically important components in all lifting operations.

Lift points can be of various types, including the following:

- padeyes, where a shackle pin passes through a hole in a padeye plate attached to or built into the structure, while the sling is connected to the shackle; the padeye plate is normally reinforced by cheek plates to increase its strength and provided with non-load bearing spacer plates to avoid undue slack between the shackle and the padeye, thereby reducing eccentricity between the padeye plate and the sling;

- trunnions, where a sling, or an eye of a sling, or a grommet passes around a short tubular, which transfers the forces into the structure and which allows rotation of the sling around the axis of the trunnion;
- padears, which are similar to trunnions, but in which rotation of the sling is not intended.

Lifting equipment (rigging) between the lift point(s) and the crane hook(s) includes slings, which can be divided into:

- steel slings, which are either:
 - steel wire rope slings (SWRS) of single wire rope construction, or
 - steel cable-laid slings (SCLS) of cable-laid construction;
- fibre rope slings (FRS) of various types of construction;
- grommets, which can be divided into:
 - steel wire rope grommets (SWRG), which are always of cable-laid construction, and
 - fibre rope grommets (FRG), the construction of which can vary;
- shackles;
- spreader bars and spreader frames;
- lifting tools.

Where appropriate, the particular type of sling or grommet is indicated by the abbreviated designation shown above.

Where lifting tools are used as part of a lifting arrangement, the maximum loads imposed on such tools shall not exceed the stated certified WLL for the tool. The lifting tool shall be used and operated following its design intent. Mitigating measures for cases where a special lifting tool or guide system fails to operate properly shall be in place to avoid being stuck in any situation without a means to achieve a safe condition. Test certificates shall be issued or endorsed by a body approved for the certification of this type of equipment^[56]. A yearly functional test and pressure test with a sample load should be performed and witnessed by a third party. A proof load test should be performed every 5 years.

External and internal hydraulic lifting tools shall always have^[56]:

- remote monitoring system close to the crane driver's cabin or to the lifting supervisor in case no "fail-safe" system is implemented;
- a pressure gauge (or indicator) in the system showing when the tool is closed or open;
- a duplicate pressure gauge (or indicator), as close as safely possible to the tool to avoid influences in pressure reading;
- a method to release the tool in the event of hydraulic system failure.

Automatic lifting tools shall be appropriately designed to control the stress in the lifted item in order to prevent excessive local stress for sensitive items. Redundant mechanical systems shall be in place in case of power loss^[35].

Consideration should be given to code the rigging, i.e. one code per rigging set to each lift/upend point. This is good practice to avoid mixing up slings and connectors, especially when they are pre-checked "loosely" on the ground or deck before attaching to the lift points^[35].

To ensure the safety of lifting operations, it is necessary that the actions and resistances be determined and compared by a structured and coherent procedure. Two methods can be used for design verification:

- a partial factor design (PFD) method;
- a working stress design (WSD) method.

The basic principle in both methods is the same and simple: the action effects resulting from the applied actions shall be smaller, by an adequate margin, than the resistances (strengths) of lift points and lifting equipment. However, the two methods differ in detail and in terminology used.

Both methods are allowed. The PFD method is the method underlying this document and is also the preferred method for lifting operations. However, for lifting operations, the WSD method is the one most commonly applied in practice.

Actions and action effects are discussed in [19.3](#); resistances (strengths) are discussed in [19.11](#). Design checks (verification) according to the PFD and WSD methods are specified in [19.12](#).

In addition to the design checks for strength, recommendations and guidance on certain design aspects and operational considerations for lifting operations are given in [19.13](#) to [19.19](#).

In a PFD method, the PFD design actions and action effects shall not exceed the corresponding PFD design strengths. In a WSD method, the WSD design actions and action effects shall not exceed the WSD design strengths (in WSD methods, also referred to as allowable values or as working load limits (WLLs) divided by specific safety factors).

19.2 Rigging geometry

In general, the rigging geometry shall be configured such that the maximum tilt of the lifted structure does not exceed 2°.

In special circumstances, the angle of tilt may exceed 2° to permit the effective use of installation aids. Such lifted structures shall be reviewed as special cases.

Unbalanced loading of the prongs on the hook and hook tilt shall be addressed and approved by the crane manufacturer or, depending on the project, by a third party.

Lifting rigging angle and tugger line angle, each with the horizontal plan, should be properly considered in the lift point design and planning.

Off-lead and side-lead forces shall be maintained below crane design specification or below 2°, whichever is less. Any value in excess shall be justified by detailed calculations on the basis of vessel motions, environmental and operational loads on the object and the resulting inclination of the hoisting line from the vertical as relevant to the installation methodology.

19.3 Actions and action effects

In accordance with common terminology in the field of reliability of structures that is used in this document, basic variables are assigned nominal, representative and design values.

The representative actions (loads) on the crane hook, and the representative action effects (forces) in the slings and on the lift points are determined in accordance with [19.4](#) to [19.8](#). Design values of actions and action effects are given in [19.10](#).

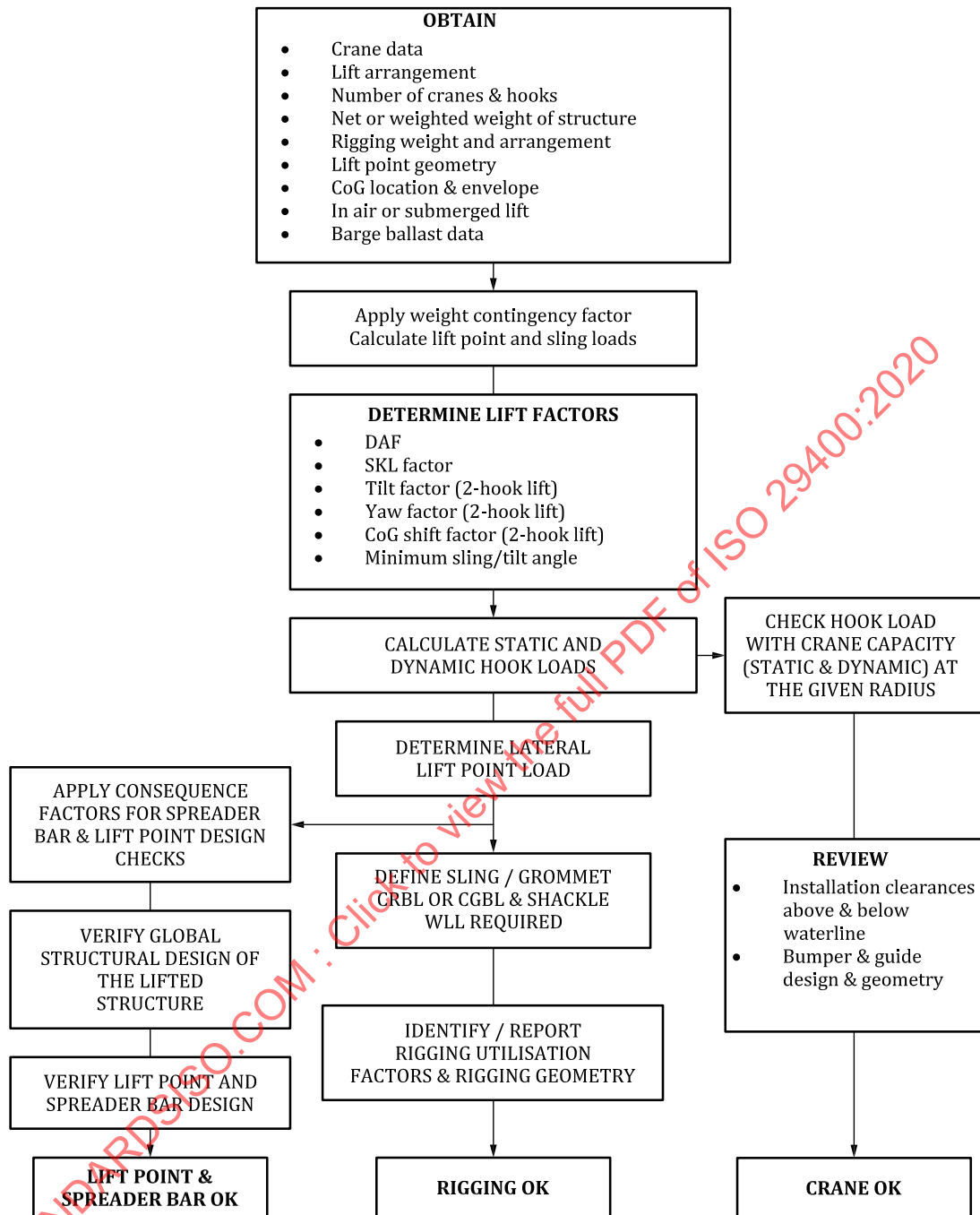
The forces on a lift point are governed by the lift weight, W_{lw} , while the forces in slings and the load on the crane are governed by the hook load, F_{hl} ; the difference between these two being the weight of the rigging, W_{rw} , between lift point(s) and crane hook. Both lift weight and hook load are subject to dynamic amplification resulting from movements of the lifted object and/or the crane. Therefore, a distinction should be made between “static” and “dynamic” lift weights, and between “static” and “dynamic” hook loads. The lift weight, W_{lw} , in this document is the “dynamic” lift weight. Further, in accordance with common terminology in this document, W_{lw} is, henceforth, referred to as the nominal

lift weight. Analogously, the hook load, F_{hl} , in this document is the “dynamic” hook load, and F_{hl} is, henceforth, referred to as the nominal hook load. The reference point to derive the nominal lift weight for the permissible hook load should be established, in some cases this is at the hook and in others at the boom head pulleys.

The representative values of actions and action effects are derived from the statically distributed nominal actions or action effects, multiplied by a variety of factors that account for uncertainties in geometry, uncertainties in the position of the CoG, contingencies and other circumstances. These factors are identically applied in PFD and WSD methods. Consequence factors are an exception to this rule. They are part of the WSD method and are used on the resistance (strength) side of design checks for the lifted object to selectively enhance the safety margin for critical structural components; they are not applied to slings, grommets and shackles. In the PFD method, the resistance (strength) side of design checks is not altered and the consequence factors are, instead, applied as partial action factors; see also the discussion on WLL in [19.11](#) and on structural analysis by the WSD method in [19.12](#).

In a PFD method, the representative values of actions are multiplied by partial action factors in order to obtain design values of actions and action effects. In a WSD method, the representative actions serve directly as design actions without factoring them. Design values of actions and action effects for both methods are given in [19.12.3](#).

The various factors and their application are illustrated in [Figure 8](#). This flowchart is for guidance only and is not intended to cover every case. In case of any conflict between the flowchart and the text, the text shall govern.

Figure 8 — Example lift calculation flowchart^[56]

19.4 Weight contingency factors

For the weight contingency factors, reference shall be made to [Clause 12](#). ISO 19901-5^[11] should also be consulted.

For class A, B and C structures, weight control, weight contingency factors k_{wcf} for calculated and weighted weights shall be applied according to [12.2](#).

The gross weight is the calculated or weighed weight including the weight contingency factors. The gross weight, W , is determined from [Formula \(10\)](#) using the calculated weight and $k_{wcf} \geq 1,05$, or from [Formula \(11\)](#) using the weighed weight and, generally, $k_{wcf} \geq 1,03$ (see [12.2](#)):

$$W = k_{wcf} \times W_{cw} \quad (10)$$

$$W = k_{wcf} \times W_{ww} \quad (11)$$

where

k_{wcf} is the weight contingency factor;

W_{cw} is the calculated weight;

W_{ww} is the weighed weight.

19.5 Dynamic amplification factors (DAFs)

19.5.1 Introduction

The gross weight from [Formula \(10\)](#) or [Formula \(11\)](#) is the static weight at rest of the object being lifted. However, the lift weight experienced by the crane during lifting is larger as a result of dynamic effects caused by movements of the lifted object and/or the crane; this is accounted for by multiplying the gross weight by a dynamic amplification factor (DAF), denoted by k_{DAF} .

DAF values differ with circumstances and apply to lifts made in air and in water alike.

There are two possibilities to determine which the DAF to be used:

- Possibility 1: DAF values for lifts from cranes, whether onshore, inshore or offshore, are provided in [19.5.2](#). DAF values for offshore lifts made by cranes on two or more vessels are provided in [19.5.3](#);
- Possibility 2: DAF is calculated through dynamic analyses, depending on the metocean conditions.

If any part of the lifting operation includes lifting or lowering through water, including passing through the splash zone, analyses shall be submitted according to one of two methods, which shall:

- show how the total in-water lifting actions are derived, taking into account weight, buoyancy, entrained mass, boom-tip velocities and accelerations, hydrodynamic inertia and drag actions; or
- calculate the dynamic sling forces and hook loads to document that slack slings do not occur in sea states that do not exceed sea state limitations for the offshore operation to be performed.

19.5.2 Lifts by a crane

A DAF shall be applied to account for the dynamic effects of the crane taking up the weight, and for movements of the crane or the lifted object during lifting. Unless operation-specific calculations show otherwise, the nominal lift weight, W_{lw} , shall be derived using [Formula \(12\)](#) with a dynamic amplification factor, k_{DAF} , from [Table 13](#) or [Table 14](#), as applicable:

$$W_{lw} = k_{DAF} \times W \quad (12)$$

where W is the gross weight.

The DAF in [Table 13](#) and [Table 14](#) shall only be used when the effect of all variables influencing dynamic loads are well understood.

DAF values in air for lifts from onshore or from floating crane vessels excluding lifts from elevated jack-ups are given in [Table 13](#) referring to the following lifts:

- lifts with a single crane on a floating vessel;
- lifts with two cranes on the same vessel;
- on-shore lifts by two or more cranes;
- lifts by two or more hooks on the same crane boom excluding offshore lifts;
- inshore lifts in totally sheltered waters, by cranes on two or more vessels.

Table 13 — DAF in air for lifting from onshore or floating crane vessels (excluding elevated jack-ups)^[56]

Static hook load (SHL) (tonnes)			k_{DAF}		
			Onshore ^{b, c, g}	Inshore ^{d, f}	Offshore ^{e, f}
3 ^a	< SHL ≤	100	1,10	$1,07 + 0,05 \sqrt{100/SHL}$	$1 + 0,25 \sqrt{100/SHL}$
100	< SHL ≤	300	1,05	1,12	1,25
300	< SHL ≤	1 000	1,05	1,10	1,20
1 000	< SHL ≤	2 500	1,03	1,08	1,15
SHL > 2 500			1,03	1,05	1,10
^a For lifted items weighing less than 3 tonnes, it is recommended to assume that the item weighs 3 tonnes and this is used throughout the calculations for the rigging design. ^b For onshore crawler cranes travelling with load, possible dynamic effects should be evaluated thoroughly. Crane speeds and surface conditions should be considered. If not documented, the factors for “inshore lifts” should be used. ^c Onshore is also applicable to a lift to/from a vessel moored alongside a quay using a land-based crane. If a ship’s crane is used, inshore factors apply. ^d Inshore is applicable to a lift with a crane vessel to/from a vessel in sheltered waters and is also applicable to lifting from the deck of a crane vessel onto a fixed platform at an offshore location. ^e Offshore is applicable to a lift by a crane vessel from another vessel to a fixed platform. ^f SHL refers to the static hook load (see 19.15.4). ^g For onshore lifts, where the crane can move horizontally, the “onshore” column shall apply					

For DAF in air for a crane lifts from a jack-up vessel in an elevated mode, see [Table 14](#).

Table 14 — DAF in air for lifting from elevated jack-ups^[56]

Static hook load (SHL) (tonnes)			k_{DAF}			
			Inshore ^b		Offshore ^b	
			Own deck to/from FIXED structure	To/from FLOATING structure	Own deck to/from FIXED structure	To/from FLOATING structure
3 ^a	< SHL ≤	100	1,10	$1,05 + 0,05 \sqrt{100/SHL}$		$1,10 + 0,05 \sqrt{100/SHL}$
100	< SHL ≤	300	1,05	1,10		1,15
300	< SHL ≤	1 000	1,05	1,10		1,12
1 000	< SHL ≤	2 500	1,03	1,08		1,10
SHL > 2 500			1,03	1,05		1,10
^a For lifted items weighing less than 3 tonnes, it is recommended to assume that the item weighs 3 tonnes and this is used throughout the calculations for the rigging design. ^b SHL refers to the static hook load (see 19.15.4).						

19.5.3 Offshore lifts by cranes on two or more vessels

For offshore lifts by cranes on two or more vessels, whether similar or with different natural periods, the k_{DAF} should be determined by operation-specific analysis or, if due to project-specific requirements, by model testing.

19.6 Representative hook load

19.6.1 One-hook lifts by a single crane

The forces on a lift point of the lifted object are governed by the lift weight, W_{lw} , given by [Formula \(12\)](#) with the dynamic amplification factor, k_{DAF} , given in [19.5](#). However, forces in slings and the total load on the crane are governed by the nominal hook load, F_{hl} , given by [Formula \(13\)](#):

$$F_{hl} = W_{lw} + k_{DAF} \times W_{rw} \quad (13)$$

where

W_{lw} is the nominal lift weight;

W_{rw} is the rigging weight.

For one-hook lifts by a single crane, the representative hook load, F_{rhl} , is equal to the above nominal hook load as given in [Formula \(14\)](#):

$$F_{rhl} = F_{hl} \quad (14)$$

19.6.2 Two-hook lifts by two cranes

For a two-hook lift, the nominal hook load, F_{hl} , from [Formula \(13\)](#) represents the total hook load on the two cranes together. The nominal load on each crane hook is found by distributing the total F_{hl} statically between the two hooks, based on the location of the CoG of the lifted object with associated rigging between the hooks. The statically resolved nominal hook load on each hook is denoted by $F_{srhl,i}$ with i equal to 1 or 2, indicating the number of the crane hook.

Lifts by two hooks can be performed with two cranes on the same vessel and with two cranes on two vessels (one crane per vessel), in offshore, inshore and onshore conditions. The hooks can be from either revolving or from sheer-leg cranes. In all these situations, a CoG shift factor, k_{sf} , and a tilt factor, k_{tf} , shall be applied to the resolved hook loads $F_{srhl,i}$.

The two-hook lift factors k_{sf} and k_{tf} account for uncertainty in the position of the CoG of the lifted object, for possible uneven heights of the crane hooks and/or for uneven hoisting speeds.

The representative hook load on crane hook i for a two-hook lift, $F_{rhl,i}$, for i equal to 1 or 2, is given by [Formula \(15\)](#):

$$F_{rhl,i} = k_{sf} \times k_{tf} \times F_{srhl,i} \quad (15)$$

where

- $F_{\text{srl},i}$ is the nominal hook load, F_{hl} , from [Formula \(13\)](#), statically resolved between crane hooks 1 and 2;
- k_{sf} is the CoG shift factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the total hook load between the two hooks, guidance for calculation of k_{sf} can be found in Annex P1 of Reference [\[56\]](#);
- k_{tf} is the tilt factor, the value of which reflects the effect of uneven heights of the crane hooks and/or uneven hoisting speeds when statically distributing the total hook load between the two hooks, guidance for calculation of k_{tf} can be found in Annex P1 of Reference [\[56\]](#).

19.7 Representative lift weight per lift point

19.7.1 One-hook lifts

For a one-hook lift, the nominal lift weight, W_{lw} , is given by [Formula \(12\)](#). The distribution between the lift points is obtained by statically distributing W_{lw} between the lift points to which the hook is connected. The result is denoted by $W_{\text{srlw},j}$, where $j = 1, 2, \dots$, indicates the number of the lift point. The largest statically resolved lift weight per lift point is $\max(W_{\text{srlw},j})$.

The static distribution of the lift weight takes into account only the geometry of the lifting arrangement and the position of the CoG of the lifted object. To account for uncertainty in the position of the CoG, a CoG factor, k_{CoG} , shall be applied. Where the allowable CoG position is specified as a cruciform, or another geometric shape, the most conservative CoG position within the allowable area shall be taken and $k_{\text{CoG}} = 1,0$ shall be applied. If no CoG envelope is used, a factor of $k_{\text{CoG}} = 1,02$ shall be applied.

For one-hook lifts made by a single crane, the representative lift weight on all lift points for one-hook lifts by one crane, $(W_{\text{rlw}})_{\text{one crane}}$, shall be taken in accordance with [Formula \(16\)](#):

$$(W_{\text{rlw}})_{\text{one crane}} = k_{\text{CoG}} \times \max(W_{\text{srlw},j}) \quad (16)$$

where

- k_{CoG} is the CoG factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the lift weight between the lift points;
- $\max(W_{\text{srlw},j})$ is the largest value for all j of the statically resolved lift weight, $W_{\text{srlw},j}$, acting on lift point j .

19.7.2 Two-hook lifts

For a two-hook lift by two cranes, the statically resolved lift weight on crane hook i , $W_{\text{srlw},i}$, for i equal to 1 or 2, can be derived from the equivalent of [Formula \(13\)](#), applied in reverse to the hook load and rigging weight on crane hook i , as given in [Formula \(17\)](#):

$$W_{\text{srlw},i} = F_{\text{srl},i} - k_{\text{DAF}} \times W_{\text{rw},i} \quad (17)$$

where

- $F_{\text{srl},i}$ is the nominal hook load on hook i from [Formula \(15\)](#) statically resolved between crane hooks 1 and 2;
- $W_{\text{rw},i}$ is the rigging weight associated with crane hook i ;
- k_{DAF} is the dynamic amplification factor from [19.5.2](#), including the multiplier from [19.5.3](#), where applicable.

$W_{\text{srlw},i}$ is distributed between the lift points, j , to which crane hook i is connected. The largest statically resolved lift weight for crane hook i and lift point j is $\max(W_{\text{srlw},i,j})$.

In addition to the uncertainties described in 19.7.1, for a two-hook lift, yawing of the lifted object can also occur, causing an increase in individual lift point actions. To account for this effect, the statically resolved lift weight per lift point shall further be multiplied by a yaw factor, k_{yaw} .

For a two-hook lift by two cranes, with two slings to each hook, the representative lift weight for all lift points, $(W_{\text{rlw}})_{\text{two cranes}}$, shall, therefore, be taken in accordance with Formula (18):

$$(W_{\text{rlw}})_{\text{two cranes}} = k_{\text{CoG}} \times k_{\text{yaw}} \times \max(W_{\text{srlw},i,j}) \quad (18)$$

where

k_{yaw} is the yaw factor, the value of which reflects the effect of yawing during lifting with two cranes when statically distributing the lift weight between the lift points, and should be set equal to 1,05 for all lifts;

$\max(W_{\text{srlw},i,j})$ is the largest value, for all i and all j , of the statically resolved lift weight, $W_{\text{srlw},i,j}$, for crane hook i acting on lift point j .

The value of the yaw factor, k_{yaw} , may be reduced if other values can be shown to provide similar levels of safety.

Yaw factors for two-hook lifts with a rigging arrangement other than two slings to each hook require special consideration.

19.8 Representative forces on a lift point

19.8.1 Representative vertical force

The lift weight per lift point is a vertical force acting on the lift point. The representative value of the vertical force on a lift point is equal to the representative lift weight per lift point, W_{rlw} , from Formula (16) or Formula (18), as applicable, multiplied by a SKL, k_{skl} . The SKL reflects the unequal load sharing in an indeterminate lift between slings that differ in length as a result of manufacturing tolerances.

The representative vertical force on a lift point, P_{rvf} , is accordingly given by Formula (19) for one-hook lifts by one crane or by Formula (20) for two-hook lifts by two cranes:

$$P_{\text{rvf}} = k_{\text{skl}} \times (W_{\text{rlw}})_{\text{one crane}} \quad (19)$$

$$P_{\text{rvf}} = k_{\text{skl}} \times (W_{\text{rlw}})_{\text{two cranes}} \quad (20)$$

The difference in length for a matched pair of slings shall not exceed $0,5d$, where d is the diameter of the sling according to IMCA LR 008, M 179. The value of k_{skl} also depends on whether or not a rigging arrangement contains elements capable of redistributing unequal sling forces due to sling length deviations, e.g. floating spreader bars.

For statically indeterminate 4-sling lifts using two matched pairs of slings to minimize tilt of the lifted object, a factor of $k_{\text{skl}} = 1,25$ shall be applied to each diagonally opposite pair of lift points in turn, see Reference [35].

For statically determinate lifts, $k_{\text{skl}} = 1,00$ may be used, provided it can be demonstrated that the sling length deviations do not significantly affect the load distribution in the lift system or the lift system geometry.

For a lift system incorporating one or more floating spreader bars that act as a sling force equalizing system, $k_{skl} = 1,1$ is applicable.

When combining new and re-used slings in one arrangement, a significantly higher value of k_{skl} can be applicable to account for differences in elasticity.

19.8.2 Representative force in line with the sling direction

The representative force on a lift point in line with the sling direction, P_{rdf} is given by [Formula \(21\)](#):

$$P_{rdf} = \frac{P_{rvf}}{\sin \theta} \quad (21)$$

where

P_{rvf} is the representative vertical force on a lift point from [Formula \(19\)](#) or [Formula \(20\)](#);

θ is the angle between the sling and the horizontal plane; normally the sling angle is restricted to (a minimum of) 60° .

19.8.3 Representative lateral force

Wherever possible, the orientation of the lift point should be aligned with the direction of the sling attached to the lift point. However, due to tolerances, some unintentional and unknown misalignment between the orientation of the lift point and the direction of the sling can exist, which shall be accounted for by applying a lateral force factor, k_{lf} .

In some cases, it is not possible to align the orientation of the lift point by design with the direction of the sling. In such cases, there is an intentional and known misalignment between the orientation of the lift point and the direction of the sling. The calculated lateral force, P_{clf} resulting from a known misalignment shall be calculated and applied to the lift point.

In order to account for both unknown and known misalignment, where present, between the orientation of the lift point and the actual direction of the sling, the representative lateral force, P_{rlf} given by [Formula \(22\)](#) shall be applied perpendicular to the lift point:

$$P_{rlf} = k_{lf} \times P_{rdf} + P_{clf} \quad (22)$$

where

k_{lf} is the lateral force factor and should be set equal to 0,05;

P_{rdf} is the representative force on a lift point in line with the sling direction given by [Formula \(21\)](#);

P_{clf} is the calculated lateral force on a lift point due to known misalignment between the orientation of the lift point and the sling direction, where applicable.

The representative lateral force shall be assumed to act through the centreline and along the axis of the pinhole in the padeye, or at the trunnion/padear geometric centre; see Reference [\[35\]](#).

In lift systems with one or more floating spreader bars or frames, k_{lf} shall be increased from 0,05 to 0,08 to account for increased horizontal dynamics. However, in lift systems where the spreader bar is connected directly to the lift points, $k_{lf} = 0,05$ may be used.

The lateral force factor may be reduced if a lower value can be shown to provide similar levels of safety.

19.9 Representative force for slings and grommets

The representative sling force, F_{rsf} , for a one-part sling and the representative force for a grommet, F_{rgf} , (the two legs together) are given by [Formula \(23\)](#):

$$F_{rsf} = F_{rgf} = P_{rdf} + \frac{k_{DAF} \times W_s}{\sin \theta} \quad (23)$$

where

- F_{rgf} is the representative grommet force (for a complete grommet);
- P_{rdf} is the representative force on a lift point in line with the sling direction given by [Formula \(21\)](#);
- k_{DAF} is the DAF in accordance with [19.5.2](#), including the multiplier from [19.5.3](#) where applicable;
- W_s is the weight of the sling or grommet;
- θ is the angle between the sling or grommet and the horizontal plane.

Where a two-part sling (a sling consisting of two parallel legs) or a grommet passes over, round or through a shackle, trunnion, padear or crane hook, the representative sling force and the representative grommet force, both from [Formula \(23\)](#), shall be distributed between each part of the sling or grommet in the ratio 45:55 to account for frictional losses over the bending point. The representative sling force for each part of the two-part sling, $F_{rsf,2 \text{ parts}}$, and the representative force for one leg of the grommet, $F_{rgf,1}$, shall, hence, be taken in accordance with [Formula \(24\)](#):

$$F_{rsf,2 \text{ parts}} = F_{rgf,1} = 0,55 F_{rsf} \quad (24)$$

where F_{rsf} is the representative sling force from [Formula \(23\)](#).

The 45/55 split on sling legs is a practical factor to be applied. However, where the sling is required to slide over the bearing surface (e.g. during a jacket upending), this can increase to approximately 67,5/32,5.

Where any wire rope sling or grommet is bent round a shackle, trunnion, padear or crane hook, the breaking load shall be assumed to be the calculated breaking load multiplied by a bending efficiency factor in accordance with [19.11](#).

19.10 Design values of actions and action effects

If the PFD method is used, design values of the actions and action effects are obtained by multiplying the representative values specified in [19.6](#) to [19.18](#) and [19.19](#) by partial action factors as given in [Formulae \(25\) to \(33\)](#):

$$(F_{dhl})_{PFD} = \gamma_{f,hl} \times F_{rhl} \quad (25)$$

$$(F_{dhl,i})_{PFD} = \gamma_{f,hl} \times F_{rhl,i} \quad (26)$$

$$(F_{dsf})_{PFD} = \gamma_{f,s} \times F_{rsf} \quad (27)$$

$$(F_{dsf,2 \text{ parts}})_{PFD} = \gamma_{f,s} \times F_{rsf,2 \text{ parts}} \quad (28)$$

$$(F_{dgr,1})_{PFD} = \gamma_{f,s} \times F_{rgf,1} \quad (29)$$

$$(F_{\text{dgf}})_{\text{PFD}} = \gamma_{\text{f},s} \times F_{\text{rgf}} \quad (30)$$

$$(P_{\text{dvf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rvf}} \quad (31)$$

$$(P_{\text{ddf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rdf}} \quad (32)$$

$$(P_{\text{dlf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rlf}} \quad (33)$$

where the subscript P represents one of three different subscripts depending on the element to which the action or action effect is applied:

- subscript P represents “lp” when applied to lift points and attachment of lift points to the structure;
- subscript P represents “mf” when applied to members directly supporting or framing into the lift points;
- subscript P represents “m” when applied to other structural members.

If the WSD method is used, the design values are equal to the unfactored representative values, as given in [Formulae \(34\) to \(42\)](#):

$$(F_{\text{dhl}})_{\text{WSD}} = F_{\text{rhl}} \quad (34)$$

$$(F_{\text{dhl},i})_{\text{WSD}} = F_{\text{rhl},i} \quad (35)$$

$$(F_{\text{dsf}})_{\text{WSD}} = F_{\text{rsf}} \quad (36)$$

$$(F_{\text{dsf},2 \text{ parts}})_{\text{WSD}} = F_{\text{rsf},2 \text{ parts}} \quad (37)$$

$$(F_{\text{dgf},1})_{\text{WSD}} = F_{\text{rgf},1} \quad (38)$$

$$(F_{\text{dgf}})_{\text{WSD}} = F_{\text{rgf}} \quad (39)$$

$$(P_{\text{dvf}})_{\text{WSD}} = P_{\text{rvf}} \quad (40)$$

$$(P_{\text{ddf}})_{\text{WSD}} = P_{\text{rdf}} \quad (41)$$

$$(P_{\text{dlf}})_{\text{WSD}} = P_{\text{rlf}} \quad (42)$$

where

- F_{dhl} is the design hook load for a one-crane lift;
- $F_{\text{dhl},i}$ is the design hook load on hook i for a two-hook lift;
- $\gamma_{\text{f,hl}}$ is the partial action factor for hook load;
- F_{dsf} is the design sling force for a one-part sling;
- $F_{\text{dsf},2 \text{ parts}}$ is the design sling force for each part of a two-part sling;

$F_{dgf,1}$	is the design force for one leg of a grommet;
F_{dgf}	is the design grommet force (for a complete grommet);
$\gamma_{f,s}$	is the partial action factor for forces in slings, grommets and shackles;
P_{dvf}	is the design vertical force on a lift point;
P_{ddf}	is the design force on a lift point in line with the sling direction;
P_{dlf}	is the design lateral force on a lift point;
$\gamma_{f,lp}$	is the partial action factor for the forces on a lift point when designing the lift points themselves and their attachment to the structure;
$\gamma_{f,mf}$	is the partial action factor for the forces on a lift point when designing the structural members directly supporting or framing into the lift points;
$\gamma_{f,m}$	is the partial action factor for the forces on a lift point when designing other structural members.

Unless operation-specific calculations show otherwise, the partial factors given in [Table 15](#) shall be applied.

Table 15 — Partial action factors, γ_f

Design value/Load case	Partial factor
For hook load	$\gamma_{f,hl} = 1,0$
For design of slings, grommets and shackles	$\gamma_{f,s} = 1,30$
For design of lift points	$\gamma_{f,lp} = 1,30$
For design of attachments of lift points to the structure	$\gamma_{f,lp} = 1,30$
For design of members directly supporting or framing into the lift points	$\gamma_{f,mf} = 1,15$
For design of other structural members	$\gamma_{f,m} = 1,00$

19.11 Strengths of slings, grommets and shackles

19.11.1 Steel cable slings

For information pertaining to the utilization of steel cable-laid, slings and grommets shall be undertaken accounting for their construction, rating, termination, and bending reduction factors, inspection and thorough examination according to IMCA LR 008, M 179.

19.11.2 Fibre rope slings and fibre rope grommets

For fibre rope slings (FRS), the termination efficiency factor shall normally be the value specified by the manufacturer. As grommets are endless, loop-shaped slings without end termination, a termination efficiency factor is not applicable.

For fibre rope slings (FRS) and fibre rope grommets (FRG), the bending efficiency factor, k_{be} , normally may be taken as 1,0, provided the bending diameter, D , is not less than the minimum specified by the manufacturer see References [35], [56]. Alternatively, the bending efficiency factor specified by the manufacturer may be used.

19.11.2.1 Representative strength

The representative strength of a fibre rope sling (FRS), $F_{RS,FRS}$, in force terms, is given by [Formula \(43\)](#):

$$F_{RS,FRS} = \min(k_{te} \times F_{CS,FRS}, k_{be} \times F_{CS,FRS}) \quad (43)$$

where $F_{CS,FRS}$ is the corresponding breaking strength given on the manufacturer's certificate. The values of k_{te} (termination efficiency factor) and k_{be} (bending efficiency factor) shall be taken in accordance with [19.11.2](#).

The representative strength of a fibre rope grommet (FRG), $F_{RS,FRG}$, in force terms, is given by [Formula \(44\)](#):

$$F_{RS,FRG} = k_{be} \times F_{CS,FRG} \quad (44)$$

where $F_{CS,FRG}$ is the corresponding breaking strength given on the manufacturer's certificate. The bending efficiency factor, k_{be} , shall be taken in accordance with [19.11.2](#).

19.11.3 Working load limits and design strengths of fibre slings and grommets

19.11.3.1 Fibre rope slings

The WLL of a fibre rope sling (FRS) (for design verification by the WSD method) and the design strength of a fibre rope sling (for design verification by the PFD method) are given by [Formulae \(45\)](#) and [\(46\)](#), respectively:

$$F_{WLL,FRS} = \frac{F_{RS,FRS}}{f_{SF,FRS}} \quad (45)$$

$$F_{DS,FRS} = \frac{F_{RS,FRS}}{\gamma_{R,FRS}} \quad (46)$$

where

$F_{WLL,FRS}$ is the WLL of a fibre rope sling, in force terms;

$F_{DS,FRS}$ is the design strength of a fibre rope sling, in force terms;

$F_{RS,FRS}$ is the representative strength of a fibre rope sling from [Formula \(43\)](#);

$f_{SF,FRS}$ is the safety factor for a fibre rope sling, which shall be calculated from the product of various partial safety factors according to chapter 16.4.3 of Reference [\[56\]](#);

$\gamma_{R,FRS}$ is the partial resistance factor for a fibre rope sling, which shall be taken as follows:

$$\gamma_{R,FRS} = f_{SF,FRS} / \gamma_{f,s} \text{ with } \gamma_{f,s} \text{ according to } \text{Table 15}.$$

19.11.3.2 Fibre rope grommets

The WLL of a fibre rope grommet (for design verification by the WSD method) and the design strength of a fibre rope grommet (FRG) (for design verification by the PFD method) are given by [Formulae \(47\)](#) and [\(48\)](#), respectively:

$$F_{WLL,FRG} = \frac{F_{RS,FRG}}{f_{SF,FRG}} \quad (47)$$

$$F_{DS,FRG} = \frac{F_{RS,FRG}}{\gamma_{R,FRG}} \quad (48)$$

where

- $F_{WLL,FRG}$ is the WLL of a fibre rope grommet, in force terms;
- $F_{DS,FRG}$ is the design strength of a fibre rope grommet, in force terms;
- $F_{RS,FRG}$ is the representative strength of a fibre rope grommet from [Formula \(44\)](#);
- $f_{SF,FRG}$ is the safety factor for a fibre rope grommet, which shall be taken as equal to or greater than calculated from the product of various partial safety factors according to chapter 16.4.3 of Reference [\[56\]](#);
- $\gamma_{R,FRG}$ is the partial resistance factor for a fibre rope grommet, which shall be taken as follows:
 $\gamma_{R,FRG} = Wf_{SF,FRG}/\gamma_{F,S}$ with $\gamma_{F,S}$ according to [Table 15](#).

19.11.4 Working load limit and design strength of shackles

The minimum breaking strength (MBS) of a shackle is a certified strength that can be taken as its representative strength.

The WLL of a shackle (for design verification by the WSD method) and the design strength of a shackle (for design verification by the PFD method) are given by [Formulae \(49\)](#) and [\(50\)](#), respectively:

$$F_{WLL,sh} = \frac{F_{RS,sh}}{f_{SF,sh}} \quad (49)$$

$$F_{DS,sh} = \frac{F_{RS,sh}}{\gamma_{R,sh}} \quad (50)$$

where

- $F_{WLL,sh}$ is the WLL of a shackle, in force terms;
- $F_{DS,sh}$ is the design strength of a shackle, in force terms;
- $F_{RS,sh}$ is the representative strength of a shackle, which is equal to the MBS of the shackle;
- $f_{SF,sh}$ is the safety factor for a shackle, which shall be taken from the shackle certificate;
- $\gamma_{R,sh}$ is the partial resistance factor for a shackle, which shall be taken as follows:
 $\gamma_{R,sh} = f_{SF,sh}/\gamma_{f,s}$ with $\gamma_{f,s}$ according to [Table 15](#).

19.12 Design verifications

19.12.1 Allowable hook load

For a one-hook lift by a single crane, the design hook load, $(F_{dhl})_{PFD}$ from [Formula \(25\)](#) or $(F_{dhl})_{WSD}$ from [Formula \(34\)](#), shall not exceed the allowable crane capacity at the required radius from the crane's load-radius curve.

For a two-hook lift by two cranes, the design hook load, $(F_{dhl,i})_{PFD}$ from [Formula \(26\)](#) or $(F_{dhl,i})_{WSD}$ from [Formula \(35\)](#), shall not exceed the allowable crane capacity at the required radius from the crane's load-radius curve for both $i = 1$ and $i = 2$.

For a two-hooks lift by a single crane, the design hook loads, $(F_{dhl,i})_{PFD}$ from [Formula \(26\)](#) or $(F_{dhl,i})_{WSD}$ from [Formula \(35\)](#), shall not exceed the allowable crane capacities at the required radius from the crane's load-radius curve, and confirmation shall be obtained from the crane manufacturer that overall crane capacity is sufficient for coping with overall load.

Load-radius curves for cranes are generally given in terms of safe working loads, which term is equivalent to the WLL. Safe working loads are also referred to as static crane capacities.

In some cases, allowable crane capacities on load-radius curves presented by the crane manufacturer include dynamic effects with a stated dynamic factor. If this is confirmed, the design hook load can be checked against the load-radius curves increased by this dynamic amplification factor.

The basis of the load-radius curves shall be carefully reviewed to ensure consistency with the intended application, particularly for offshore operations.

19.12.2 Slings and grommets

19.12.2.1 General

The fundamental requirement is that the design forces for slings and grommets shall not exceed their corresponding design strengths.

19.12.2.2 One-part slings

A one-part sling shall satisfy [Formula \(51\)](#) when designed in accordance with the PFD method, or [Formula \(52\)](#) when designed in accordance with the WSD method:

$$(F_{dsf})_{PFD} \leq F_{DS,Y} \quad (51)$$

$$(F_{dsf})_{WSD} \leq F_{WLL,Y} \quad (52)$$

where

F_{dsf} is the design sling force for a one-part sling from [Formula \(27\)](#) or [Formula \(36\)](#);

$F_{DS,Y}$ is the design strength of a sling of type Y, where Y refers to the sling types SWRS, SCLS or FRS, in force terms;

$F_{WLL,Y}$ is the WLL of a sling of type Y, where Y refers to the sling types SWRS, SCLS or FRS, in force terms.

The corresponding design strengths are given by [Formula \(46\)](#); the corresponding working load limits are given by [Formula \(45\)](#).

19.12.2.3 Two-part slings

By full analogy, a two-part sling shall satisfy [Formula \(53\)](#) when designed in accordance with the PFD method, or [Formula \(54\)](#) when designed in accordance with the WSD method:

$$(F_{dsf,2\text{ parts}})_{PFD} \leq F_{DS,Y} \quad (53)$$

$$(F_{dsf,2\text{ parts}})_{WSD} \leq F_{WLL,Y} \quad (54)$$

where, in addition to the definitions in [19.10](#), $F_{dsf,2\text{ parts}}$ is the design force for each part of a two-part sling from [Formula \(28\)](#) or [Formula \(37\)](#).

The design strengths and WLLs are given by the same formulae as for a one-part sling.

Reference to chapter 19.9 is made regarding the 45/55 split on sling legs.

19.12.2.4 Grommets

The design strengths and WLLs of the two legs of a grommet are identical and equal to half the design strength and WLL of the complete grommet. However, just as for a two-part sling, the two grommet legs can be subjected to different design forces (see 19.9). Design verification shall, therefore, be based on the most heavily loaded leg of a grommet.

One leg of a grommet shall satisfy [Formula \(55\)](#) when designed in accordance with the PFD method, or [Formula \(56\)](#) when designed in accordance with the WSD method:

$$(F_{dgf,1})_{PFD} \leq 0,5 \times F_{DS,Y} \quad (55)$$

$$(F_{dgf,1})_{WSD} \leq 0,5 \times F_{WLL,Y} \quad (56)$$

where

- $F_{dgf,1}$ is the design force for one leg of a grommet from [Formula \(29\)](#) or [Formula \(38\)](#);
- $F_{DS,Y}$ is the design strength of a grommet of type Y, in force terms;
- $F_{WLL,Y}$ is the WLL of a grommet of type Y, in force terms;
- Y is the grommet type, SWRG or FRG.

The corresponding design strengths are given by [Formula \(48\)](#); the corresponding WLLs are given by [Formula \(47\)](#).

19.12.2.5 Shackles

A shackle shall be at least as strong as the design force for the complete sling (a one-part sling or a two-part sling) or the design force for the complete grommet to which the shackle is attached. The design force for a complete two-part sling is equal to the design force for a one-part sling.

A shackle shall satisfy either [Formula \(57\)](#) or [Formula \(58\)](#), as appropriate, when designed in accordance with the PFD method, or either [Formula \(59\)](#) or [Formula \(60\)](#), as appropriate, when designed in accordance with the WSD method:

$$(F_{dsf})_{PFD} \leq F_{DS,sh} \quad (57)$$

$$(F_{dgf})_{PFD} \leq F_{DS,sh} \quad (58)$$

$$(F_{dsf})_{WSD} \leq F_{WLL,sh} \quad (59)$$

$$(F_{dgf})_{WSD} \leq F_{WLL,sh} \quad (60)$$

where