BRITISH STANDARD

BS EN ISO 19901-6:2009

Incorporating corrigendum December 2011

Petroleum and natural gas industries — Specific requirements for offshore structures

Part 6: Marine operations (ISO 19901-6:2009)

ICS 75.180.10

British Standards

National foreword

This British Standard is the UK implementation of EN ISO 19901-6:2009 incorporating corrigendum December 2011.

The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/12, Design of offshore structures.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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English Version

Petroleum and natural gas industries - Specific requirements for offshore structures - Part 6: Marine operations (ISO 19901-6:2009)

Industries du pétrole et du gaz naturel - Exigences spécifiques relatives aux structures en mer - Partie 6: Opérations marines (ISO 19901-6:2009)

Erdöl- und Erdgasindustrie - Spezielle Anforderungen für Offshore-Anlagen - Teil 6: Mariner Betrieb (ISO 19901-6:2009)

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Foreword

This document (EN ISO 19901-6:2009) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

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Endorsement notice

The text of ISO 19901-6:2009 has been approved by CEN as a EN ISO 19901-6:2009 without any modification.

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 19901-6 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 7, *Offshore structures*.

ISO 19901 consists of the following parts, under the general title *Petroleum and natural gas industries — Specific requirements for offshore structures*:

— *Part 1: Metocean design and operating considerations*

— *Part 2: Seismic design procedures and criteria*

— *Part 4: Geotechnical and foundation design considerations*

— *Part 5: Weight control during engineering and construction*

— *Part 6: Marine operations*

— *Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

The following part is under preparation:

— *Part 3: Topsides structure*

ISO 19901 is one of a series of International Standards for offshore structures. The full series consists of the following:

— ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

— ISO 19901 (all parts), *Petroleum and natural gas industries — Specific requirements for offshore structures*

— ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*

— ISO 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*

— ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Monohulls, semi-submersibles and spars*

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

— ISO/TR 19905-2, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary* [1)]

— ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures* [1)]

1) Under preparation.

Introduction

The series of International Standards applicable to types of offshore structure, ISO 19900 to ISO 19906, constitutes a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum, petrochemical and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature or combination of materials used.

It is important to recognize that structural integrity 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 offshore structural systems.

The series of International Standards applicable to types of offshore structure 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 these International Standards.

This part of ISO 19901 was developed to provide requirements and guidance for the planning, engineering and safe execution of marine operations for all types of offshore structures except for drilling rigs, pipe-laying barges and diving support vessels. Marine operations for offshore structures are parts of the construction, transportation and installation phases when the structure is at risk from the marine environment. Marine operations can extend to decommissioning, redeployment, removal, etc.

This part of ISO 19901 describes the principles of and provides requirements and guidance for marine operations associated with fixed and floating offshore structures, from the point of view of planning, engineering, implementation and documentation. Alternative requirements, methods and provisions can fulfil the intention of this part of ISO 19901 and may be applied, provided it can be demonstrated that they achieve at least the same level of confidence. The overall objective of this part of ISO 19901 is to ensure that marine operations are conducted within defined and recognized safety/confidence 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 marine operations are performed.

It is not the intent of this part of ISO 19901 to govern the design of structures, systems and components used in 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.

Annex B provides regional information on the application of the document to certain specific offshore areas.

Petroleum and natural gas industries — Specific requirements for offshore structures —

Part 6:
Marine operations

1 Scope

This part of ISO 19901 provides requirements and guidance for the planning and engineering of marine operations, encompassing the design and analysis of the components, systems, equipment and procedures required to perform marine operations, as well as the methods or procedures developed to carry them out safely.

This part of ISO 19901 is applicable to marine operations for offshore structures including

- steel and concrete gravity base structures (GBS);
- piled steel structures and compliant towers;
- tension leg platforms (TLP);
- deep draught floaters (DDF), including spars or deep draught caisson vessels (DDCV);
- floating production semi-submersibles (FPSS);
- floating production, storage and offloading vessels (FPSO);
- other types of floating production systems (FPS);
- mobile offshore units (MOU);
- topsides and components of any of the above;
- subsea templates and similar structures;
- gravity, piled, drag embedded and suction or other anchors;
- tendon foundations;
- associated mooring systems.

This document is also applicable to modifications of existing structures, e.g. installation of additional topsides modules.

This part of ISO 19901 is not applicable to the following marine operations:

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

b) drilling, processing and petrochemical activities;

c) routine marine activities during the service life of the structure;

d) drilling from mobile offshore drilling units (MODU);

e) installation of pipelines, flowlines, risers and umbilicals;

f) diving.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19900:2002, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1:2005, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19901-4:2003, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations*

ISO 19901-7:2005, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 15544, *Petroleum and natural gas industries — Offshore production installations — Requirements and guidelines for emergency response*

ISO 17776, *Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment*

IMCA M 179, *Guidance on the Use of Cable Laid Slings and Grommets*. The International Marine Contractors Association

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900, ISO 19901-1, ISO 19901-4, ISO 19901-7 and ISO 19904-1 and the following apply.

NOTE Other terms and definitions relevant for the use of this part of 19901 are also found in ISO 19901-5[28], ISO 19902[29], ISO 19903[35] and ISO 19904-1[30].

3.1
action
external load applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

EXAMPLE An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

NOTE An earthquake typically generates imposed accelerations.

[ISO 19900:2002, 2.1]

3.2
action effect
effect of actions on structural components

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

[ISO 19904-1:2006, 3.5]

3.3
air cushion
air pumped into underbase compartments of the structure

NOTE Normally applied in order to reduce the draught and increase the freeboard and/or to alter the structural loading.

[ISO 19903:2006, 3.10]

3.4
assembly
designed and fabricated group of bulk and equipment items that form one unit

[ISO 19901-5:2003, 3.1.1]

3.5
ballast
variable solid or fluid content in order to change the draught, stability, trim and/or heel of a structure afloat

NOTE Adapted from ISO 19901-5:2003, 3.1.2.

3.6
ballast system
system used to change the draught, stability, trim and/or heel of a structure afloat

3.7
barge
simple floating vessel, normally non-propelled, on which a structure is transported

3.8
basic variable
one of a specified set of variables representing physical quantities that characterize actions, environmental influences, geometrical quantities or material properties, including soil properties

[ISO 19900:2002, 2.5]

3.9
bending efficiency factor
factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in strength caused by bending around a shackle, trunnion, padear or crane hook

3.10
bollard pull
towing or manoeuvring action that can be generated by a tug for an indefinite period of time with its propulsion system running at operational, as opposed to maximum revolutions per minute

NOTE Bollard pull is expressed in kilonewtons.

3.11
bridging document
document that aligns and co-ordinates the requirements and responses of various parties in relation to a specific aspect of a project

NOTE Commonly used to align and co-ordinate the emergency response procedures for owner and contractors.

3.12
bumper
temporary structure designed to protect structures or modules during the initial fitting stage of an installation operation

3.13
characteristic value
value assigned to a basic variable associated with a prescribed probability of not being violated by unfavourable values during some reference period

NOTE The characteristic value is the main representative value. In some design situations, a variable can have two characteristic values, an upper and a lower value.

[ISO 19900:2002, 2.7]

3.14
CoG envelope
defined constraint volume within which the centre of gravity (CoG) of an assembly or a module shall remain

NOTE Adapted from ISO 19901-5:2003, 3.1.8.

3.15
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 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 WSD analysis of the lifted object. They are, accordingly, applied to lift points, their attachments to the object and components in the object supporting lift points. They are not intended for application to slings, grommets and shackles.

3.16
construction afloat
addition of material or outfitting to the structure while afloat

NOTE Adapted from ISO 19903:2006, 3.17.

3.17
crane vessel
vessel, ship or barge on which lifting equipment is mounted

NOTE For the purpose of this document, this term includes crane barges, crane ships, derrick barges, shear-leg barges and semi-submersible crane vessels.

3.18
cribbing
arrangement of timber baulks, secured to the deck of the barge or vessel, designed to support the cargo

NOTE Cribbing is generally arranged at strong points of the deck and/or cargo.

3.19
deadweight
total carrying capacity of a floating structure

NOTE 1 This includes cargo weight, deck cargo, snow and ice, marine growth, ballast water, consumables and crew onboard a floating unit.

NOTE 2 Adapted from ISO 19901-5:2003, 3.1.11.

3.20
deck mating
marine operation in which the platform topsides is floated into position and connected to the support structure

NOTE This operation is normally conducted by ballasting and deballasting of the support structure.

[ISO 19903:2006, 3.18]

3.21
decommissioning
process of shutting down a platform and removing hazardous materials at the end of its production life

[ISO 19900:2002, 2.10]

3.22
design criterion
quantitative formulation that describes the conditions that shall be fulfilled for each limit state

NOTE Adapted from ISO 19900:2002, 2.11.

3.23
design situation
set of physical conditions representing potential conditions during a certain time interval for which the design is expected to demonstrate that relevant limit states are not exceeded

NOTE Adapted from ISO 19900:2002, 2.13.

3.24
design value
value derived from the representative value for use in the design verification procedure

[ISO 19900:2002, 2.14]

3.25
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

3.26
displacement
weight of the volume of water displaced by a floating structure

NOTE 1 The weight of the water displaced is the sum of the lightship weight, deadweight and mooring system load including vertical component of the mooring pre-tension and/or riser action.

NOTE 2 Adapted from ISO 19901-5:2003, 3.1.12.

3.27
dunnage
arrangement of timber on deck of a barge or vessel laid out to support the cargo

3.28
dynamic action
action that induces acceleration of a structure or a structural component of a magnitude sufficient to require specific consideration

[ISO 19901-7:2005, 3.8]

3.29
dynamic amplification factor
DAF
ratio of a dynamic action effect to the corresponding static action effect

NOTE An appropriately selected dynamic amplification factor can be applied to static actions to simulate the effects of dynamic actions.

[ISO 19902:2007, 3.16]

3.30
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 Each combination of yarn and type of construction normally results in different properties and characteristics.

3.31
fibre rope grommet
FRG
endless loop-shaped sling made up from a single length of fibre rope

NOTE A fibre rope grommet is of similar construction to a steel wire rope grommet.

3.32
fibre rope sling
FRS
sling made from a single fibre rope, usually with spliced eye end terminations

3.33
fixed structure
structure that is bottom founded and transfers all actions on it to the seabed

[ISO 19900:2002, 2.17]

3.34
float-off
offloading an object from a submersible transport vessel or barge 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

3.35
float-on
loading an object onto a submersible transport vessel or barge 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 The object is then lifted from the water and onto the vessel/barge deck by deballasting the vessel/barge to its seagoing condition.

3.36
float-out
transfer of a floating structure out of a flooded dry dock

NOTE Adapted from ISO 19903:2006, 3.28.

3.37
float-over
transfer of a major assembly supported on barge(s) on to its temporary or permanent structure 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

3.38
grillage
steel structure, secured to the deck of a barge or vessel, designed to support the cargo and distribute the loads between the cargo and the barge or vessel

NOTE Adapted from ISO 19901-5:2003, 3.1.19.

3.39
grommet
endless loop-shaped sling made up from a single length of (fibre or steel wire) rope

See also **fibre rope grommet** (3.31) and **steel wire rope grommet** (3.89).

3.40
gross weight
calculated or weighed weight of the structure being lifted, including a weight contingency factor

NOTE Sometimes the gross weight is referred to as a not-to-exceed (NTE) weight.

3.41
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

3.42
hook load
sum of the rigging weight, including the DAF, and the lift weight

3.43
indeterminate lift
any lift where the sling forces are not statically determinate

3.44
launching
offloading an object into the water from a barge or other floating unit by means of sliding the object longitudinally, or less commonly, sideways along the floating unit

3.45
lift point
connection between the rigging and the structure being lifted

NOTE Lift points include padears, padeyes and trunnions.

3.46
lift weight
gross weight times the DAF

3.47
lightship weight
dry and invariable weight of a floating unit

NOTE Adapted from ISO 19901-5:2003, 3.1.27.

3.48
limit state
state beyond which the structure no longer fulfils the relevant design criteria

[ISO 19900:2002, 2.21]

3.49
link beam
connecting beam between the quay and the barge

NOTE The link beam can provide a structural connection, or can solely provide a smooth path for skidding or trailers.

3.50
load case
compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent actions and fixed variable actions for a particular design or verification

[ISO 19902:2007, 3.29]

3.51
loadout
transfer of a major assembly or a module from land onto a barge or vessel by horizontal movement or by lifting

NOTE 1 The following types of loadout operation can be distinguished:

— floating: loadout from the quay onto a floating barge;

— grounded: loadout from the quay onto a grounded barge;

— lifted: loadout performed by crane;

— skidded: loadout where the structure is skidded, using a combination of skidways, skidshoes or runners, propelled by towing engines, jacks or winches;

— trailer: loadout where the structure is wheeled onto the barge using trailers or SPMTs.

NOTE 2 Adapted from ISO 19901-5:2003, 3.1.30.

3.52
marine operation
planned and controlled vertical or horizontal movement of a structure or component thereof over, in or on water

[ISO 19903:2006, 3.36]

3.53
marine spread
fleet of vessels assembled to perform a marine operation

3.54
mating
transfer of a major assembly supported on barge(s) or vessel(s) to a temporary or permanent support structure

NOTE 1 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 fixed structure: transfer of the barge supported major assembly to a fixed structure by means of manoeuvring it over the structure, 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.

NOTE 2 Adapted from ISO 19901-5:2003, 3.1.31.

3.55
minimum breaking strength
MBS
certified strength of a chain, wire rope, fibre rope or accessories

NOTE Adapted from ISO 19901-7:2005, 3.15.

3.56
mooring component
general class of component used in the mooring of floating structures

EXAMPLE Chain, steel wire rope, synthetic fibre rope, clump weight, buoy, winch/windlass or anchor.

3.57
nominal value
value assigned to a basic variable determined on a non-statistical basis, typically from acquired experience or physical conditions

[ISO 19900:2002, 2.22]

3.58
not-to-exceed weight
NTE weight
maximum acceptable weight of the structure, with an associated limiting CoG envelope

NOTE Adapted from ISO 19901-5:2003, 3.1.34.

3.59
offload
transfer of a major assembly or a module from a barge or transport vessel to land or to a self-floating condition by horizontal movement or by lifting

3.60
operational duration
planned duration of a marine operation, which includes a contingency time

3.61
owner
representative of the company or companies which own a development, who can be the operator on behalf of co-licensees

[ISO 19901-7:2005, 3.20]

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

3.63
padeye
lift point consisting essentially of a plate, reinforced by cheek plates if necessary, with a hole through which a shackle can be connected

3.64
platform
complete assembly including structure, topsides and, where applicable, foundations

[ISO 19900:2002, 2.23]

3.65
point of no return
PNR
point during an operation that represents the final opportunity to reverse, delay or abandon the operation

3.66
recognized classification society
RCS
member of the international association of classification societies (IACS), with recognized and relevant competence and experience in floating structures for marine operations, and with established rules and procedures for classification/certification of installations used in petroleum or natural gas activities

NOTE Adapted from ISO 19904-1:2006, 3.29.

3.67
representative value
value assigned to a basic variable for verification of a limit state

[ISO 19900:2002, 2.26]

3.68
reserve buoyancy
contingency buoyancy expressed in percentage of the nominal total intact buoyancy of self-floating steel structures

3.69
resistance
capacity of a structure, component or a cross-section of a component to withstand action effects without exceeding a limit state

[ISO 19904-1:2006, 3.32]

3.70
return period
average period between occurrences of an event or of a particular value being exceeded

NOTE 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.

[ISO 19901-1:2005, 3.23]

3.71
rigging
slings, shackles and other devices including spreader bars/frames used to connect the structure being lifted to the crane

3.72
rigging weight
total weight of rigging, including contingency

3.73
safe haven
sheltered location at which a tow or transport can seek refuge from inclement weather

3.74
seabed
materials below the sea in which the structure is founded, whether of soils such as sand, silt or clay, cemented material or of rock

NOTE 1 The seabed can be considered as the half-space below the sea floor.

NOTE 2 Adapted from ISO 19901-4:2003, 3.6.

3.75
sea fastening
temporary fastening items which keep movable items in position during transportation at sea

NOTE Adapted from ISO 19901-5:2003, 3.1.38.

3.76
sea floor
interface between the sea and the seabed

[ISO 19901-4:2003, 3.5]

3.77
semi-submersible
floating structure normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns connected to submerged pontoons

[ISO 19904-1:2006, 3.36]

3.78
skew load factor
SKL
factor by which the load on any lift point, or pair of lift points, is multiplied to account for sling length mismatch in a statically indeterminate lift

3.79
skidshoe
bearing pad attached to the structure that engages in the skidway and carries a share of the vertical load

3.80
skidway
system of structural beams (concrete or steel) or rails, on the quay and on the barge, on which the structure is loaded out via the skidshoes

3.81
skirt
structure constructed at or below the base of a structure that extends downwards from the bottom of the foundation plate, penetrating into the seabed

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

NOTE 2 Adapted from ISO 19903:2006, 3.49.

3.82
sling eye
loop at each end of a sling, either formed by a splice or by a mechanical termination

3.83
splash zone
area of a structure that is frequently wetted due to waves and tidal variations or during lift operations

NOTE 1 Refers to the wave-affected zone of the water column surrounding a structure.

NOTE 2 Adapted from ISO 19900:2002, definition 2.31.

3.84
splice
that 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

3.85
spreader bar
spreader frame
structure 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 into a vertical plane

NOTE The usual purpose of a spreader bar or frame is to avoid a clash between the rigging and the structure, which would result if the rigging were connected directly from the lift point to the hook.

3.86
squat effect
tendency of floating objects or vessels to undergo an increase in draught when underway

3.87
steel cable-laid sling
SCLS
assembly of several (usually six) round stranded steel wire ropes (referred to as unit ropes), laid helically around a core (usually a seventh rope)

NOTE 1 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 See IMCA M 179 for construction and use of cable-laid slings.

3.88
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 Each combination of material and type of construction normally results in different properties and characteristics.

3.89
steel wire rope grommet
SWRG
endless loop-shaped sling made up from a single length of round stranded steel wire rope

NOTE 1 As for cable-laid slings, the steel wire rope used in a grommet is also referred to as a unit rope.

NOTE 2 A steel wire rope grommet is constructed from one continuous length of stranded wire rope and consists of a body composed of six strands around a strand core. The rope is spirally wound around the core rope in six loops. During the production of grommets a temporary rigid core is used, which is replaced by the first half loop and the last half loop of the stranded wire rope. At the start of looping, the core rope changes into an outer rope, and at the end the sixth outer rope changes back into the core rope. When removing the temporary rigid core, the ends of the stranded wire are tucked into the body core, with the tuck position diametrically opposite to the core butt position.

NOTE 3 See IMCA M 179 for construction and use of steel wire rope grommets.

3.90
steel wire rope sling
SWRS
sling made from a single steel wire rope with various possible end terminations

NOTE Terminations include spliced eyes, Flemish eye with swaged steel sleeve (also known as super loop), spelter sockets, resin sockets, etc.

3.91
strength
mechanical property of a material indicating its ability to resist actions, usually given in units of stress

[ISO 19902:2007, 3.49]

3.92
structure
organized combination of connected parts designed to withstand actions and provide adequate rigidity

[ISO 19900:2002, 2.35]

3.93
termination efficiency factor
factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in strength caused by a splice or other end termination

3.94
topsides
structures and equipment placed on a supporting structure (fixed or floating) to provide some or all of a platform's functions

NOTE 1 For a ship-shaped floating structure, the deck is not part of the topsides.

NOTE 2 For a jack-up, the hull is not part of the topsides.

NOTE 3 A separate fabricated deck or module support frame is part of the topsides.

[ISO 19900:2002, 2.38]

3.95
tow
marine transportation of an object or its supporting barge by being pulled or pushed by tow vessel(s)

NOTE 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.

3.96
trailer
system of steerable wheels, connected to a central spine beam by hydraulic suspension that can be raised or lowered

3.97
trunnion
lift point on a structure consisting of a tubular member or cast cantilever with a stopping plate at the end, around which a sling or grommet can be passed

NOTE 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.

3.98
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

3.99
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, e.g. of a flare.

3.100
verification
examination made to confirm that an activity, product, or service is in accordance with specified requirements

3.101
watertight
capability of preventing the penetration of water into or through the structure with a water pressure head corresponding to that for which the surrounding structure is designed

[ISO 19904-1:2006, 3.50]

3.102
weather-restricted operation
marine operation that can take place safely within the limits of a favourable weather forecast

NOTE 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.

3.103
weathertight
capability of preventing the penetration of water into the structure during temporary exposure to water

NOTE A watertight closing appliance is also considered weathertight.

[ISO 19904-1:2006, 3.51]

3.104
weather-unrestricted operation
marine operation that can take place safely in any weather condition that can be encountered during a season

NOTE The statistical extremes for the area and seasons are considered in the design weather criteria.

3.105
weather window
period of time, sufficient in length to safely carry out a marine operation, for which forecast environmental conditions remain below prescribed limiting operational environmental criteria

3.106
working load limit
WLL
maximum load that can safely be applied to a rope, sling, grommet, shackle or lift point

3.107
50/50 weight estimate
value representing the median value in the probability distribution of weight estimates

[ISO 19901-5: 2003, 3.1.54]

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

NOTE 2 The 50/50 weight estimate is used as the basis for weight budgeting.

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 2 and 3)
b	breadth, expressed in metres
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
D	minimum diameter over which a sling or grommet is bent, expressed in millimetres
f_{fr}	calculated percentage friction force
f_{SF}	safety factor (in WSD method)
$f_{SF, sh}$	safety factor for a shackle (in WSD method)
$f_{SF, Y}$	safety factor for component Y (in WSD method) Y = SWRS; SCLS; FRS; SWRG or FRG
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
$F_{dsf, 2 parts}$	design sling force for each part of a two-part sling
F_{min}	minimum value of the breaking strength of a steel wire rope, expressed in kilonewtons
F_{hl}	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
$F_{rsf, 2 parts}$	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

$F_{CS,X}$ calculated strength (CRBL) of the body of component X in force terms, where X is a sling or one leg of a grommet (see 18.4.2)

X = SWRS; SCLS; FRS; SWRG, 1 or FRG, 1

$F_{CS,X}$ calculated strength (CGBL) of a complete grommet of type X in force terms (see 18.4.2)

X = SWRG, 2 or FRG, 2

$F_{DS,sh}$ 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, see 18.4.6)

Y = SWRS; SCLS; FRS; SWRG or FRG

F_{min} minimum value of the breaking strength of a steel wire rope, expressed in kilonewtons

F_{PR} minimum towline pull required, expressed in kilonewtons

$F_{RS, sh}$ representative strength of a shackle in force terms

$F_{RS,Y}$ representative strength of component Y in force terms, where Y is a sling or a grommet (see 18.4.5)

Y = SWRS; SCLS; FRS; SWRG or FRG

$F_{WLL, sh}$ 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, see 18.4.6)

Y = SWRS; SCLS; FRS; SWRG or FRG

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
K	empirical factor for the minimum breaking strength for a given rope class and core type
l_{freebd}	effective freeboard, expressed in metres
L_{OA}	length over all, expressed in metres
$\max(a_{i,j})$	largest value of a for all i and all j
$\min(a, b)$	lower value of a and b
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
R_{t}	rope grade (tensile strength grade of the wires in the rope), expressed in newtons per square millimetre
T_{eff}	tug efficiency in the considered sea conditions, expressed in percent
W	gross weight
W_{c}	cargo weight, expressed in kilonewtons
W_{cw}	calculated weight
W_{lw}	nominal lift weight
$(W_{\text{rlw}})_{\text{one crane}}$	representative lift weight on a lift point for one-hook lifts by one crane
$(W_{\text{rlw}})_{\text{two cranes}}$	representative lift weight on a lift point for lifts by two cranes
W_{rw}	rigging weight
$W_{\text{rw},i}$	rigging weight associated with crane hook i (i = 1, 2)
W_{s}	weight of the sling
$W_{\text{srlw},i}$	statically resolved lift weight for crane hook i (i = 1, 2)
$W_{\text{srlw},j}$	statically resolved lift weight acting on lift point j
$W_{\text{srlw},i,j}$	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
α	heeling angle where the maximum hydrostatic righting moment occurs, expressed in degrees
β	sum of the static wind heeling angle and the maximum roll angle, expressed in degrees

γ_f	partial action factor (in PFD method)
$\gamma_{f,hl}$	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)
$\gamma_{R,sh}$	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

CGBL	calculated grommet breaking load (see 18.4.1)
CoG	centre of gravity
COLREGS	Convention on International Regulations for Preventing Collisions at Sea, 1972, as amended
CRBL	calculated rope breaking load (see 18.4.1)
CSBL	calculated sling breaking load (see 18.4.1)
DAF	dynamic amplification factor
DDCV	deep draught caisson vessel
DDF	deep draught floater
DP	dynamic positioning
EPBD	emergency preparedness bridging document
FMEA	failure modes and effects analysis
FPS	floating production system
FPSO	floating production, storage and offloading vessel
FPSS	floating production semi-submersible
FRG	fibre rope grommet (see 18.1)
FRS	fibre rope sling (see 18.1)
GBS	gravity base structure
HAZID	hazard identification study

HSE	health, safety and environment
IACS	International Association of Classification Societies
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
IOPP	international oil pollution prevention
ISM	international safety management
ISO	International Organization for Standardization
ISPS	international ship and port facility security
IWRC	independent wire rope core
MARPOL	international convention for the prevention of pollution from ships
MBS	minimum breaking strength
MOU	mobile offshore unit
NDT	non-destructive testing
NTE	not-to-exceed
PFD	partial factor design
PMS	positioning monitoring system
PNR	point of no return
QRA	quantitative risk analysis (or assessment)
RCS	recognized classification society
ROV	remotely operated vehicle
SCLS	steel cable-laid sling (see 18.1)
SKL	skew load factor
SMC	safety management certificate
SOLAS	International Convention for the Safety of Life at Sea, 1974, as amended
SPMT	self-propelled modular transporters: a trailer system having its own integral propulsion, steering, jacking, control and power systems
SSCV	semi-submersible crane vessel
SWL	safe working load
SWRG	steel wire rope grommet (see 18.1)
SWRS	steel wire rope sling (see 18.1)
TLP	tension leg platform
UHC	ultimate holding capacity of drag anchors
ULS	ultimate limit states

WLL working load limit (see 18.4.1)

WSD working stress design

5 General considerations

5.1 Introduction

5.1.1 General

Marine operations for offshore installation include transient marine movements and other activities where the structure or the operation is at risk from the marine environment. Such operations can include

- loadout from shore to barge or vessel;
- launching from shore to water;
- float-out from dry docks;
- wet or dry towage and other marine transportations;
- temporary moorings and stationkeeping during construction;
- construction and outfitting afloat;
- installation by means of launching or float-off, upending, lowering by ballasting, float-over or lifting;
- installation of anchor foundations;
- installation of permanent moorings, including tendons;
- connection to permanent moorings and tendons;
- scour protection;
- decommissioning and total or partial removal of the structure.

This part of ISO 19901 gives requirements and guidance on the planning and execution of marine operations during the temporary phases of construction, transportation and installation of the various structures and their components.

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.

5.1.2 Safety requirements

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 operation is designed taking into account the statistical weather extremes for the area and season;
- the operational weather conditions, chosen at values smaller than the specified limiting conditions, are forecast 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 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.

5.2 Jurisdiction

5.2.1 Introduction

Platform construction 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, the jurisdiction of the flag state applies.

5.2.2 Life at sea

In order to respect 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 recommendatory 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 identified in References [1] to [7]. 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 [1] to [7] do not necessarily apply to domestic voyages. In such cases, national standards offering equivalent levels of safety should be applied.

References [8] to [18] 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

The legislation for the protection of the environment is evolutionary and covers various purposes. 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 [19] to [24].

5.3 HSE plan

A HSE plan shall be established. The objectives of the plan shall be

— to document the HSE standards, processes and procedures that apply to the work;

— to identify, assess and manage hazards and risks arising from the work, reducing them to as low as reasonably practicable;

— to ensure that safety is inherent in planning and design of the work;

— to ensure minimal impact on the environment;

— to protect the health of the workforce.

The plan shall include HSE activities during all phases of the work, from planning and design through to execution of the operation.

Selected activities are described in 5.4 to 5.10.

The use of alcohol, drugs or narcotics by personnel involved in marine operations is not permitted.

5.4 Risk management

5.4.1 Introduction

For risk management, ISO 17776 and the provisions of 5.4 and 5.5 apply.

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 to avoid hazards wherever possible;

— control to reduce the potential consequences of unavoidable hazards;

— measures to mitigate the consequences of an incident, should one occur.

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

Personnel and organizations involved in 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

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

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

5.4.2.2 QRA techniques can be used

- to compare levels of risk between alternative proposals or between known and novel methods; and
- 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 marine contractor as a basis for the method statement for the operation. 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.

5.6 Environmental impact study

An environmental impact study should be carried out, where appropriate, to identify and deal with generally recognized risks to the environment (e.g. waste management, disposal at sea) or to personnel, and to population and wildlife (e.g. toxicity, explosives, radiation, noise, vibrations and other disturbances).

5.7 Manning, qualifications, job and safety training

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

Qualification requirements for job categories critical to safe operations shall be specified. See Reference [25] for regulations on safe manning. Before commencement of an operation, personnel involved should 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.

Job-specific training should 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 plant and equipment.

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

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

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

Finally, an up-to-date list with information of next of kin should be maintained.

5.8 Incident reporting

During marine operations, incident reporting depends on the contract requirements and governmental regulations and can include

— periodic reports;

— incident, accident and near-miss accident reports;

— pollution or substantial threat of pollution reports.

5.9 Personnel tracking

A suitable security and tracking system should be in use to

— record the presence of personnel on the installation and supporting vessels;

— track their whereabouts;

— restrict access to certain areas to authorized personnel only, if required.

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 marine operations are outlined in 6.2 to 6.7. The degree 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, illustrating how the 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

— owner's organization and project management for the project;

— contractor's project management for the project;

- engineering design;
- procurement;
- construction;
- marine operations;
- HSE;
- project controls;
- quality;
- interface management.

6.2.2 Operational organization

Separate organization charts shall be drawn up for each 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;
- towing vessels;
- mooring systems and marine spread;
- ballast system operation;
- weather forecasting;
- support services;
- advisory panel providing expertise as required;
- HSE;
- 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 period from one organization to another (e.g. fabrication to marine operations, or onshore to offshore) should be identified.

During ongoing marine operations, the selection of site team members shall be limited to those persons with defined roles during the operation. Any organizational 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, 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 a marine operation shall communicate in one language.

NOTE For preparation of appropriate operational manuals, see 6.5.2.

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 [26], or any other equally acceptable system, may be used.

Operators of vessels shall have a management system in compliance with the ISM Code [9], verified by valid ISM certificates; see 6.6.2.

6.4 Technical procedures

Technical procedures shall be set up to control the design and engineering related to marine activities.

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 criteria;

— design premises;

— metocean criteria;

— calculation procedures;

— response forecasting.

Design premises are defined as the fundamental principles and philosophy upon which the outline and detailed design of a marine operation are based; design premises include, among others, design criteria, methods of analysis and a description of software used.

Marine operations involving complex procedures that are not proven by past experience shall require analysis and/or the performance of simulations and/or model tests in order 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 marine operations.

6.5 Technical documentation

6.5.1 Document numbering system

The document numbering system used for 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.

Marine operations documents shall be clearly identified by number, revision and date, type of document, discipline involved and review status.

6.5.2 Marine operations documents

6.5.2.1 Documents relating to marine operations should be grouped into levels according to their status, for example

— design basis and criteria documents;

— marine operations procedures documents;

— supporting documents, including definitions of actions, structural and naval architectural calculations, systems operational manuals, equipment specifications and decommissioning reports.

Procedure documents that are intended for use as an active tool during marine operations should include a section that clearly shows their reference to higher and lower level documents and should list interrelated documents.

Documents listed in a marine operations procedures document should be available and accessible on board or on-site close to the operation for reference by anyone that is involved.

6.5.2.2 Elements that are considered essential and that should be included in, or referred to by, a marine operations document are the following:

— introduction;

— reference documents;

— outline execution plan;

— organigram and lines of command;

— job descriptions for key personnel;

— safety plan, including a description of safety equipment, the location and signalization of safety routes, and requirements for personnel training;

— information on authorities and permits, including notification requirements;

— contractual approvals and hand-over;

— environmental criteria, including design and operational criteria;

— operational bar chart, showing the anticipated duration of each activity, interrelated activities, key decision points and hold points;

— preparations, surveys and outline check lists;

— specific step-by-step instructions for each phase of the operation, including sequence, timing and resources;

— contingency plans;

— results of related calculations, e.g. environmental actions, moorings, ballast, stability, bollard pull;

— appendices listing more detailed information, such as drawings, calculations, equipment specifications, site information, dimensional control, operational monitoring and control systems, logging of operational control parameters, communication systems, ROV procedures, check lists;

— EPBD.

6.5.3 Operational schedule

A detailed activity schedule should be established showing how the marine operation is planned. The schedule should be presented as an operational bar chart, showing the duration of each activity, interrelated activities, key decision points and hold points.

For weather-restricted activities, the duration shall be set equal to the planned duration plus estimated contingency time. Risk analysis should be used as an assisting tool to establish realistic contingency times.

6.5.4 Contingency philosophy

Marine operations shall include contingency and back-up plans.

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, even if a breakdown occurs to any system or equipment.

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, back-up or redundancy may 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 should 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 apply.

Contingency and emergency planning shall form part of the general operational procedures. Plans shall be developed for foreseeable emergencies that can be identified by a risk assessment, which can include

- 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 or compressed air system;
- failure of equipment, such as lift system;
- loss of communication;
- loss of vessel or barge control;
- loss of electrical power;
- fire;
- collision;
- pollution;

— leakage;

— structural failure;

— mooring line failure;

— man overboard;

— personnel accidents or medical emergencies;

— medical evacuation from remote locations;

— grounding;

— unexpected water depth limitations or sea floor hazards;

— piracy, mutiny, terrorism, or other unauthorized intervention.

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

The procedures should 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 preparedness bridging document

Procedures issued by parties involved in a marine operation should be compatible with each other, and gathered in an emergency preparedness bridging document (EPBD).

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

The EPBD should also include a flow chart outlining the responsibility for notifying a maritime rescue co-ordination centre and, if necessary, onshore base organizations, 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 EPBD should define which emergency response organization among the involved parties takes primacy in the organization of the onshore support.

6.6 Certification and documentation

6.6.1 General

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 it is required to carry on board ships is given in Reference [27]. A review of the required and recommended documents is given in 6.6.2 and in A.2.

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

Table 1 lists the documentation that is either required or recommended for transportation of various types of vessels and floating structures.

For marine operations in general, at least some, if not all, of the documentation listed in Table 1 is mandatory for compliance with international legislation. Specialist advice should be obtained regarding required documentation.

Vessels involved in the performance of marine operations should be in possession of a certificate of compliance with the ISM Code [9], demonstrating that the company owning the vessel(s) has developed and put into effect a vessel safety management system in line therewith.

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

6.7 Systems and equipment

6.7.1 General

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

Vessels, systems and equipment required for installation operations should be in good condition with appropriate certification (see also Table 1), and fit for the purpose for which they are intended. They should have the capability and capacity to operate effectively under the environment and actions for which the operation is designed. They should 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.

6.7.2 Marine vessels

Marine vessels and their equipment should be inspected prior to the operation to confirm their suitability and validity of certification, as applicable for the type of vessel and voyage planned; see 6.6.

Vessel stability should be in accordance with Clause 9 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.

Table 1 — Required or recommended documentation for the transportation of various types of vessels and floating structures [27],[36]

Document [a]		Cargo vessel	Offshore construction vessel/ supply/tug	All towage (manned)	Barge towage (unmanned)	FPSO towage (unmanned)	Other towage (unmanned)
Required documents							
1	Certificate of registry	✓	✓	✓	—	—	—
2	Certificate of class (hull)	✓	✓	✓	✓	✓	—
3	Certificate of class (machinery)	✓	✓	✓	✓	—	—

Table 1 (*continued*)

	Document [a]	Cargo vessel	Offshore construction vessel/ supply/tug	All towage (manned)	Barge towage (unmanned)	FPSO towage (unmanned)	Other towage (unmanned)
4	International tonnage certificate	✓	✓	✓	✓	—	—
5	Cargo ship safety construction certificate	✓	✓	✓	—	—	—
6	Cargo ship safety equipment certificate	✓	✓	✓	—	—	—
7	Certificates for navigation lights and shapes	—	—	—	✓	✓	✓
8	Load line certificate	✓	✓	✓	✓	—	—
9	Load line exemption	—	—	—	✓	✓	✓
10	MARPOL and IOPP[b] certificate	✓	✓	✓	—	—	—
11	Safety management certificate (SMC)	✓	✓	✓	—	—	—
12	Customs clearance	✓	✓	✓	✓	✓	✓
13	De-rat certificate, or exemption	✓	✓	✓	—	—	—
14	Safety radio certificate	✓	✓	✓	—	—	—
15	Stability booklet	✓	✓	✓	✓	✓	✓
16	ISPS certificate	✓	✓	✓	✓	✓	✓
17	Bollard pull certificate	—	✓	—	—	—	—
18	Certificates for bridle, tow wires, pennants, stretchers and shackles	—	✓	✓	✓	✓	✓
19	Suez or Panama Canal documentation (if relevant)	✓	✓	✓	✓	✓	✓
20	Certificates for life saving appliances	✓	✓	✓	—	—	—
21	Minimum safe manning document	✓	✓	✓	—	—	—
22	Muster list	✓	✓	✓	—	—	—
Recommended documents, where applicable							
23	Medicine certificate	✓	✓	✓	—	—	—
24	POB list	✓	✓	✓	—	—	—
25	Installation certificate for gas welding equipment	✓	✓	✓	✓	✓	✓
26	Lift certificate	✓	✓	✓	✓	✓	✓
27	Certificate for transportation of dangerous cargoes/chemicals, etc.	✓	✓	✓	✓	✓	✓

Table 1 (*continued*)

Document [a]		Cargo vessel	Offshore construction vessel/ supply/tug	All towage (manned)	Barge towage (unmanned)	FPSO towage (unmanned)	Other towage (unmanned)
28	Damage control plans and booklets	✓	✓	✓	✓	✓	✓
29	Certificate of class (DP systems if applicable)	—	✓	—	—	—	—
30	Certificate of class (propulsion systems)	—	✓	—	—	—	—
31	Certificate of class (safety construction)	—	✓	—	—	—	—
32	Certificate of class (safety equipment)	—	✓	—	—	—	—

[a] See A.2 for guidance.

[b] Not required for unmanned towages unless fitted with machinery.

NOTE 1 Smaller vessels (cargo vessels and offshore construction vessels, including supply vessels and tugs) can be exempt from some certification requirements.

NOTE 2 Some documents are not required for inland voyages or inland towages.

7 Metocean and earthquake requirements

7.1 Introduction

It can be impractical and/or uneconomical to plan to perform marine operations in extreme environmental conditions. Consequently, marine operations are generally weather-sensitive, requiring weather windows of minimum duration with specified limits on the metocean parameters during which the marine operations can be performed. Setting the limits too high can lead to unacceptable risk, whereas setting the limits too low can lead to excessive waiting times.

Metocean parameters limiting environmental conditions shall comply with ISO 19901-1. With regards to marine operations, reference shall be made specifically to ISO 19901-1:2005, 5.9, which deals with metocean parameters for short-term activities.

Metocean criteria for marine operations shall provide a realistic evaluation of the sensitivity of a marine operation to meteorological and oceanographic conditions. These criteria are a major step to ensuring the safe execution of a marine operation. The metocean criteria shall be obtained by establishing limiting criteria for the metocean parameters by which the meteorological and oceanographic conditions are characterized. The response characteristics of particular installation vessels to specific aspects of the metocean environment shall be considered when establishing these limiting criteria.

A set of limiting metocean criteria that is dependent on the type and duration of the operation shall be established. Such criteria shall include, but not be limited to,

— wind magnitude and direction,

— wave height and period,

— current magnitude and direction,

— swell magnitude and direction.

Operations can be defined as weather-restricted or weather-unrestricted; see 7.2.

The risk of subjecting a marine operation to an extreme event exceeding the defined metocean criteria varies with location, and regard should be paid to local codes of practice. The meteorological conditions that are specific to particular geographical areas (such as arctic, temperate, tropical and equatorial areas) should be considered. Oceanographic conditions that are swell-dominated or swell-protected and have significant currents due to tide, ocean circulation and local rivers should also be considered.

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

Some consideration to earthquakes is given in 7.8.

7.2 Weather-restricted/weather-unrestricted operations

7.2.1 Weather-restricted operations

A weather-restricted operation is a marine operation that can be completed within the limits of a favourable weather forecast. The reliability of weather forecasts is such that weather-restricted operations should generally be completed within 72 h.

7.2.2 Weather-unrestricted operations

Weather-unrestricted operations can safely take place in any weather condition that can be encountered during a season. The weather condition(s) shall reflect the statistical extremes for the area and season concerned.

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 is made to ISO 19901-1.

7.3.2 Wave and swell conditions

Wave conditions shall be considered in the planning and engineering of marine operations. For the description of the wave and swell parameters, reference is 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, lateral surge motions due to shoaling swell and second order wave drift actions should be considered.

For operations involving phases that are sensitive to large or extreme wave heights, such as temporary on-bottom stability, the maximum wave height and associated period should be used.

For precise 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.

Attention should also be paid to particular site conditions that are prone to current acting against the waves, which can amplify wave steepness.

7.3.3 Current

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

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

7.3.3.2 Current can be divided into six different components:

— wind-generated current, which is typically a surface current in the direction of the wind;

— ocean currents (for example the Gulf Stream), which can have homogenous flow down to several hundred metres;

— tidal current, which can also be felt down to a considerable depth below the surface although the velocities normally decrease with depth;

— freshwater outflow (river generated), which is typically a surface current;

— local current phenomena, such as loop (inertial), soliton (internal) and topographical currents;

— bottom currents.

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

— for sites where tidal current dominates, measurement during at least one complete lunar cycle during the same season of the year as the actual planned operation;

— for sites where the complexity of the bathymetry (topographical current) can generate unstable flow, real-time current measurements with devices that record the current velocity and direction, with 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 include

— combinations of wind, wave and current;

— water level, including tide and surge;

— 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 Annex B.

7.3.5 Temperature

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

7.3.6 Marine growth

The effect of marine growth on corrosion, weight, effective diameter and surface roughness shall be considered.

7.4 Metocean criteria

7.4.1 Design and operational criteria

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

— The design criteria are that set of values for the metocean parameters (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 metocean parameters, the directionality of waves, wind and current shall be considered.

— For weather-unrestricted operations, the operational metocean criteria are the same as the design criteria, although lower values can be set for practical reasons.

— For weather-restricted operations, the operational metocean criteria are that set of values for the metocean parameters (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 forecast not to be exceeded for the duration of the operation, allowing for contingencies.

7.4.2 Return periods

Metocean criteria for marine operations depend on the planned duration of the operation including contingency. Generally, operations with a planned duration of up to three days may be considered as weather-restricted operations for which a specific weather window may be defined, while operations with a planned duration of more than three days should be considered as weather-unrestricted operations. Return periods of the metocean parameters for weather-unrestricted operations may be estimated as a multiple of the operational duration; a minimum 10 times the duration of the operation may be used.

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.

The choice of return periods should be based on the consequence of failure of the operation. The regional hazard curve of the sea state should also be considered. As general guidance, the periods in Table 2, which are based on North Sea weather conditions, may be applied. Return periods can depend on location.

Table 2 — General guidance for return periods of metocean parameters for weather-unrestricted operations (based on North Sea conditions)

Duration of the operation	Return periods of metocean parameters
Up to 3 days	Specific weather window to be defined
3 days to 1 week	1 year, seasonal
1 week to 1 month	10 year, seasonal
1 month to 1 year	100 year, seasonal
More than 1 year	100 year, all year

7.4.3 Response-based analysis

For critical, long-duration marine activities, or operations in complex offshore environments 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 frequency 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 Weather windows

7.5.1 Weather-restricted operations

Weather-restricted operations shall be planned using reliable time history data that indicate not only the probability of not exceeding the limiting criteria but also the persistence of such conditions for the season considered.

In mature areas like the North Sea, this information is normally available, but in other areas it does not always exist or can be difficult to obtain. In some cases, limitations in the availability of data can be compensated for, achieving the same level of confidence, by applying statistical extrapolation methods. The quality of data available can influence the assessment of overall risk.

Consideration shall be given to applying a reduction factor to the limiting criteria in order to account for remaining uncertainties. The reduction factor should be determined as a function of the duration of the operation, the number of data sources and the quality of the available data.

Weather windows should be developed based on thresholds of the key sensitive parameters of the operation. For example, based on known limiting thresholds for wind and wave, the duration statistics for favourable conditions should be computed.

7.5.2 Impact on design

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

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

7.5.3 Margins on weather

A margin shall be added to the design weather criteria, if these are based on statistical maxima. The margin accounts for inaccuracies in the calculation model and the probability of exceeding the maxima. For precise operations, a margin of 20% on critical parameters is recommended. For other operations, it is a matter of judgement.

7.6 Operational duration

7.6.1 Time schedule

7.6.1.1 For defining the weather window required for a time-critical marine operation, the scheduled plan of the operational duration shall be as realistic as possible.

The window duration shall have necessary margins for

- inaccuracy in operational schedule;
- technical or operational delays;
- uncertainty in the environmental statistics;
- accuracy of the metocean forecast.

7.6.1.2 The forecast window duration shall be in excess of the total critical operational schedule. This should be evaluated against a background of the planned operation and the consequences of exceedance. As a guideline, the following points should be considered:

- 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.

7.6.2 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 criteria 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.

7.7 Metocean forecast

7.7.1 General

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.

For complex and/or long weather-restricted operations, forecaster(s) with local experience shall preferably be present on-site to check the local situation and provide regular weather briefing based on forecasts from two independent sources. This applies to major marine operations such as

- float-over topsides;
- float-out;
- GBS tow out;
- offshore installation and lifting;
- sensitive barge towing.

7.7.2 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 heights above sea level; the wind speed should indicate 1 min and 1 h means and also indicate wind gusts;

— waves and swell, including significant and maximum height, direction and period;

— loop currents and wind squalls;

— visibility, rain, snow, sleet, icing and sea ice;

— confidence level of the forecast.

7.7.3 On-site monitoring

Where operations are sensitive to local (near-site or on-site) environmental conditions or to changes in these, real-time measurement, as well as regular forecast, both prior to start and during operations, shall be considered.

7.8 Earthquake

Possible effects of earthquakes (not metocean effects as tsunamis) on structures during marine operations, if applicable, should be taken into account.

8 Weight control

8.1 Introduction

Weight control should be performed by means of a well defined procedural system, such as that described in ISO 19901-5[28].

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

8.2 Weight control classes

In relation to weight control classes, ISO 19901-5[28] states 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.”

8.3 Contingencies for class A

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[28] 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.

— 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 a certificate is produced from a competent body stating, for the specific case in question, that the weighing accuracy is better than 3 %.

The application of weight contingency factors for lift purposes is given in 18.3.2.

8.4 Weight and CoG constraints

For the purpose of planning marine operations, the 50/50 weight estimate method 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.

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

8.5 Weight control audits

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 9.12.

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 9.12.

8.6 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 to an appropriate level of accuracy.

9 Stability

9.1 Introduction

The general stability requirements for floating objects, with comments on the stability criteria for particular types of structure where they differ from the general requirements, are set out in 9.2 to 9.12. Further information on stability can be found in ISO 19904-1:2006[30], Clause 15.

9.2 General requirements

Sufficient stability and reserve buoyancy shall be demonstrated for floating objects during all stages of the marine operations.

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 9.4 and 9.5 shall be applied to floating objects. Exceptions and alternatives are dealt with separately.

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

9.3 Stability calculations

An allowance shall be included in the stability calculations to account for uncertainty in mass, buoyancy, location of CoG, density of ballast and ballast water, and density of sea water. Allowance for ice accumulation on exposed structures should be taken into account.

NOTE 1 For some deepwater structures, it can be necessary to consider the compressibility of the structure.

The results of the weight control programme (see Clause 8) shall be taken into account in stability calculations.

If motion responses in various floating stages (such as construction afloat, towage and installation) can cause loss of freeboard, stability or stationkeeping, or can become critical for other considerations, model tests should be used in combination with dynamic analyses.

The intact metacentric height, GM, together with the displacement and added mass 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 should be carried out.

NOTE 2 For some self-floating structures, longitudinal stability can be more critical than transverse stability.

The buoyancy of cargo compartments (such as overhanging legs of structures and hulls of mobile drilling units) can contribute to the intact stability (see 9.4).

9.4 Intact stability

9.4.1 Introduction

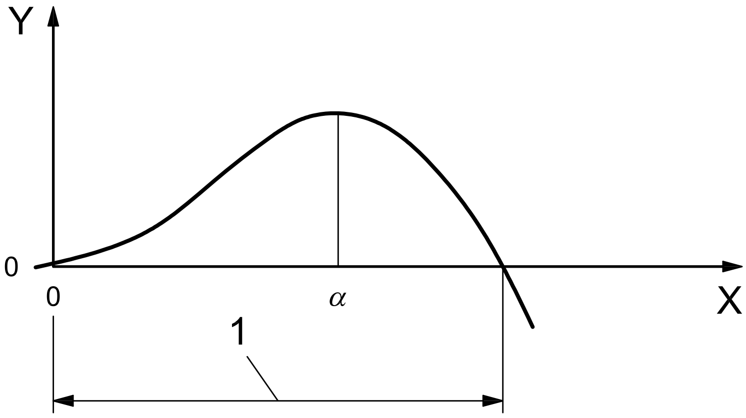
The intact stability range is the range between 0° heel or trim and the heeling angle at which the righting arm (GZ) becomes negative, as indicated in Figure 1.

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 1 shows both the initial linear and the subsequent non-linear 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 shall be satisfied, unless satisfying other safe stability criteria can be demonstrated and proven as exemptions gained from the flag state.



Key

X heeling angle, expressed in degrees

Y righting arm, expressed in metres

1 intact stability range

Figure 1 — Illustration of stability terms

9.4.2 Intact stability requirements

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see Figure 2) 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 of progressive flooding;
- 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 IMO Resolution A.749(18) [14].

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 TLPs) 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 and TLPs) as given in the relationships in Equation (1) for column-stabilized structures and Equation (2) for other structures:

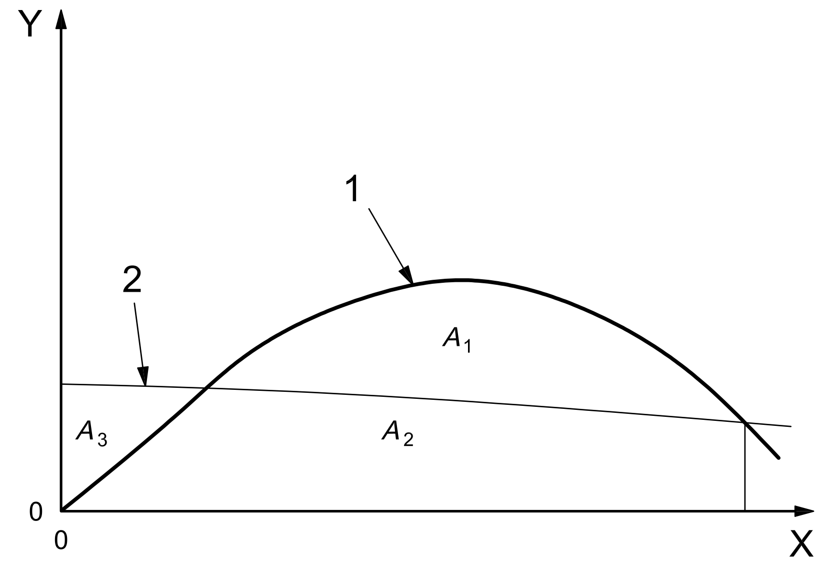
$$(A_1 + A_2) \geqslant 1{,}3\ (A_2 + A_3) \qquad (1)$$

$$(A_1 + A_2) \geqslant 1{,}4\ (A_2 + A_3) \qquad (2)$$

where A_1, A_2 and A_3 are the areas defined as indicated in Figure 2.

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 2 — Intact stability requirement [31]

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 12.7.5.

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 stability range shall never be less than 15°.

9.5 Damage stability

9.5.1 Introduction

9.5.1.1 Damage stability shall be evaluated by considering the operational procedures and duration, environmental actions and responses, and the consequences of possible damage.

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 intact 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.

9.5.1.2 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.

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

- compartments separated by a horizontal watertight bulkhead within $^{+5}_{-3}$ m of the intact waterline shall be considered as one compartment;
- penetration of not less than 1,5 m, unless it can be demonstrated that such penetration is unlikely to occur;
- 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 intact waterline, including, for instance, caissons or cargo compartments, the buoyancy of which is required to meet the intact stability requirements of 9.4, should be considered as a damage case.

The emptying of a full compartment to the damaged waterline 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.

9.5.2 Damage stability requirements

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see Figure 3) 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 of progressive flooding;
- 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 [14].

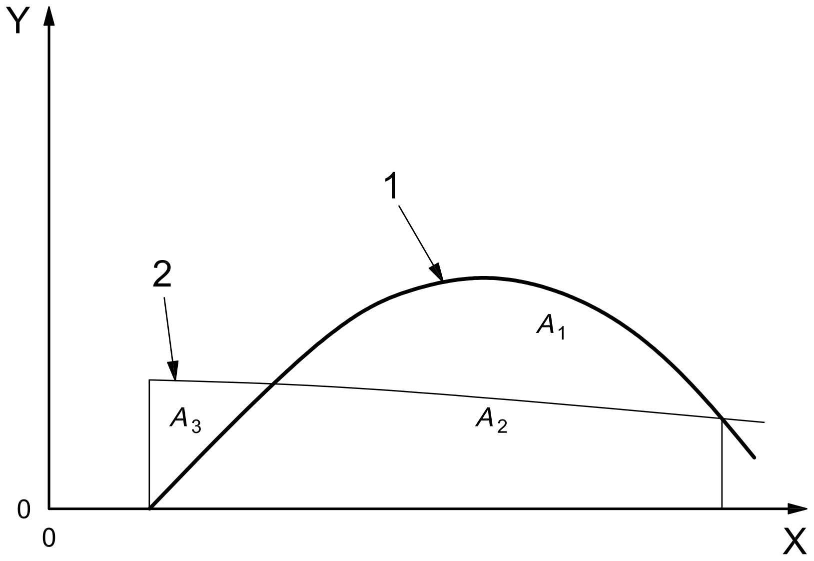
The area under the righting moment curve shall not be less than 1,4 times the area under the wind heeling moment curve as given by Equation (3):

$$(A_1 + A_2) \geqslant 1{,}4\,(A_2 + A_3) \tag{3}$$

where A_1, A_2 and A_3 are the areas defined as indicated in Figure 3.

NOTE 1 See 9.8 for ocean going classed trading vessels.

NOTE 2 This criterion has been found inadequate for jack-ups, and is likely to be inadequate also for barges with limited freeboard carrying cargoes [32].



Key

X heeling angle, expressed in degrees

Y moment, expressed in kilonewton-metres

1 righting moment

2 wind overturning moment

Figure 3 — Damage stability requirements [31]

The 1 min wind speed used for overturning moment calculations in the damage condition shall be the smaller of 25 m/s or the wind speed used for the intact condition.

Where it is impractical to comply with damage stability requirements, a risk assessment shall be carried out, and the following precautions taken.

a) Reinforce or fender vulnerable areas to withstand collision from the largest towing or attending vessel, at a speed of typically 2 m/s.

b) Protect projecting hatches, pipework and valves against collision or damage from towing and handling lines.

c) Provide emergency towlines with trailing pick-up lines to minimize the need for vessels to approach the structure closely during the tow.

d) Provide emergency pumping equipment.

e) Minimize the potential for leaks via ballast or other systems.

f) 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.

g) Conspicuously mark vulnerable areas and make masters of all towing or attending vessels aware of these.

h) Provide a guard vessel to warn off other approaching vessels.

9.6 Single-barge transports

Single-barge transports should conform to the requirements set out in 9.4 and 9.5.

9.7 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 9.4 and 9.5, with the following additional recommendations.

— Barges that are totally immersed in the intact condition should be classed as submersible barges. Submersible barges are normally classed as such by the RCS. If not classed, they should be subject to appropriate project-specific structural, equipment and machinery checks.

— 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.

9.8 Classed vessels

The requirements of 9.4 also apply to classed vessels.

NOTE 1 For vessels that carry offshore or similar cargoes, reference is made to the IMO instruments in References [14] and [6].

The damage stability requirements in Clause 9 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 instrument [33] for further details.

9.9 Self-floating structures

9.9.1 General

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, self-floating steel structures, spars and TLPs).

Because of the diversity of self-floating structures, where compliance with the general requirements and guidance in Clause 9 is not applicable or practical, other arrangements that offer no greater overall risk may be considered.

9.9.2 Intact and damage stability

9.9.2.1 Unless existing IMO regulations are applicable, the requirements of 9.4 and 9.5 shall apply with the additional criteria specified in this subclause.

The initial intact metacentric height (GM), after correction for free surface and air cushion effects, shall not be less than 1 m.

Where the intact stability range required by 9.4 cannot be achieved, it shall be demonstrated that

— ϕ_{max}, the value of the maximum dynamic heeling angle due to wind and waves, expressed in degrees, is at least half that of the heeling angle, α, expressed in degrees, where the maximum hydrostatic righting moment occurs; see Figure 1;

— the area ratio required in 9.4.2 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.

9.9.2.2 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 5 m above and 5 m below the intact waterline, in order to withstand collision from the impact of the largest towing or attending vessel;

— developing rigorous procedures 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.

9.9.3 Upending and installation of self-floating and launched steel structures

The following apply for the upending and installation of self-floating and launched steel 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 no single failure of a component or system can 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 metacentric height (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 Equation (4):

$$B_r = 100\,(B_0 - W_0)/B_0 \qquad (4)$$

where

B_0 is the total available buoyancy of the structure;

W_0 is the weight of the structure in air.

Table 3 — Recommended reserve buoyancy based on nominal total intact buoyancy

Case	Intact %	Damage %
Structure after launch	10	5
During upending by ballasting, without crane assistance	Sufficient to maintain required bottom clearance	

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
After launch, transverse and longitudinal	1,0	0,2
During upending, transverse	1,0	0,2
During upending, longitudinal [a]	> 0	> 0
After upending, before final positioning, both directions	1,0	0,2

[a] A limited period during upending, when the steel 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 metacentric height (GM) after launch and during upending with the top of steel 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 9.9.2 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.

9.10 Loadout operations

The stability requirements for loadouts of objects onto barges or vessels (see Clause 11) 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 metacentric height (GM) adequate for the operation and shall take account of the CoG changes as the cargo crosses the quay edge. Normally, metacentric height (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 metacentric height (GM) during the loadout operation should be considered.

The area ratio requirements of 9.4.2 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 Equation (5):

$$l_{freebd} \geqslant 0{,}5 + H_{max}/2 \quad (5)$$

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 attitude. 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 11.12.

9.11 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 weathertight. Weathertight 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.

9.12 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 [14].

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, such as installation of topsides. The necessity for such tests should be determined by the sensitivity of the planned operation, the accuracy of the calculated metacentric height (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.

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.

For floating objects with a large metacentric height (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.

10 Ballasting operations

10.1 Introduction

In this subclause and 10.2 to 10.10 are considered the ballasting operations of offshore structures, including steel structures, GBSs, compliant towers, barges, TLPs, DDFs, FPSSs, FPSs and FPSOs, and, in particular, temporary or one-off ballasting requirements for transient marine operations rather than routine service life operations.

Attention should be paid to regulations or requirements relating to the transfer and/or treatment of ballast water locally and at destination.

Ballasting operations typically control

— the draught, heel and trim of floating structures (or tendon force distributions for TLPs);

— 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:

a) lift-off or float-out from construction docks;

b) immersion, trim and stability control during construction while afloat;

c) load transfers from shore to barges (float-out operations);

d) mating operations;

e) launching operations;

f) upending operations;

g) steel structure setting operations;

h) gravity structure installation operations;

i) subsea immersion operations;

j) float-on and float-off operations;

k) decommissioning.

10.2 Ballast system

10.2.1 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

— 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.

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 8.

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.

10.2.2 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 RCS.

The transfer of sea 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 steel 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.

10.3 Protection against damage and deterioration

10.3.1 General

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 launch. 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 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.

10.3.2 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.

10.4 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 should be designed to prevent accidental cross-flooding and uncontrolled ingress of water in likely operational conditions and in the designed damage cases.

10.5 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. It should be provided with the following control and indicating systems where applicable:

- 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.

Valves and operational controls should be clearly marked to identify the function they serve.

Means to indicate whether a valve is open or closed should be provided at each location from which the valve is controlled. The indication should rely on movement of the valve spindle. Remotely operated valves should 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.

10.6 Pumps

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.

10.7 Valve arrangements

Where valves are arranged with remote control and are power operated, a secondary means of operating the valves, which can be manual control, should be provided. Any automatic or radio-controlled system should be provided with a manual override system.

The valve system should 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) should be provided with an independent secondary means of closure. Sea inlet and submerged ballast discharge valves should 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 should 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.

10.8 Vent systems

Ballast tanks should be provided with air vents. The size of the vent pipes should be sufficient to prevent excess overpressure of the tanks from rapid filling.

Vent openings that can become intermittently immersed in a damaged condition should be self-closing in the event of immersion, or the vent system should 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.

10.9 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.

NOTE Guidance on the required design capacity for ballasting and de-ballasting rates and quantities is given in Clause 11.

10.10 System testing

Where possible, the commissioning of pumps and/or compressor systems should include both functionality and capacity trials. 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 should 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.

11 Loadout

11.1 Introduction

Clause 11 applies to the loadout of various types of structure, including, but not limited to, steel and concrete structures, TLPs, spars, FPSs, modules, components and bridges onto floating or grounded barges and ships. Loadout (float-on) of floating cargoes onto submersible barges and ships is covered in 11.12. Additional information can be found in ISO 19902:2007 [29], Clauses 8 and 22.

Due to the wide range of structures, loadout methods and transport vessels, Clause 11 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.

Clause 11 applies particularly to skidded and trailer-transported floating loadouts in tidal waters. Recommendations for grounded loadouts or loadouts accomplished by lifting are also included.

Loadouts involve the use 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. 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 Clause 11.

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 Clause 11 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.

11.2 Categories of loadout

The loadout operation can be categorized according to tidal conditions as indicated in Table 5. The category does not reflect local weather conditions, which are accounted for elsewhere. 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

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.

11.3 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, the structure, including the lift points, should be analysed for the support conditions proposed during the lift; see Clause 18.

Consideration should also be given to lifting off construction supports, or lifting onto sea fastening supports, where these operations form an integral part of the loadout operation.

Weight control shall conform to the requirements of Clause 8. For class A loadouts, pre-loadout weighing should be considered, in particular for more complex systems such as topsides, in lieu of depending on calculated predictions.

When the support geometry is sensitive to a shift of CoG, a stability sensitivity study evaluating an envelope of possible CoG shifts should be performed.

If weighing takes place shortly before loadout, the effect on the loadout procedures of any weight changes should be assessed.

11.4 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.

Compatibility between quay strength and elasticity, and the support conditions used for analysis of the structure, should be demonstrated, where appropriate.

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 during 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.

For tidal loadouts, an easily readable tide gauge should be provided adjacent to the loadout quay. The water line level should be monitored prior to, during and after loadout.

The approval of port and coastal state authorities should be obtained, as necessary, for the operation and for the institution of any necessary controls on marine traffic.

11.5 Barge

The barge shall be classed by an RCS.

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 9.10.

Suitable survey should 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.

11.6 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.

11.7 Moorings

11.7.1 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 criteria shall be lower than the design criteria; see 7.4.

11.7.2 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 11.7.1 and Clause 7.

— 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 11.11) 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).

11.8 Grounded loadouts

A survey of ground levels over the area covered by the bottom of the barge shall be carried out, showing suitable support conditions for the barge.

A survey shall be made shortly before the barge is positioned to ensure that no debris is located where it can damage the bottom plating of the barge.

If evenly distributed support over the bottom plating of the barge cannot be achieved, either calculations shall be prepared and documented 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, both 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.

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 barge.

Final skidway levels shall be compatible with the requirements of 11.3.

The ballast shall be adjusted during loadout, where necessary, to avoid barge settlement or overstress.

The plan for refloating of the barge shall be updated and, if necessary, revised in line with any changes in barge orientation not fully anticipated before the loadout. The plan for refloating the barge should include consideration of the moorings that are required, verification that the barge is undamaged and inspections or actions necessary to ensure that the barge remains in class following the grounding.

11.9 Pumping and ballasting

11.9.1 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 and pipeline losses.

11.9.2 Recommended pump capacity

Pump capacity shall be provided as given in Table 6, depending on the category of loadout as defined in Table 5 and to satisfy each case as defined below:

a) case a: the nominal maximum pump capacity computed for the loadout as planned, to compensate for tidal changes and weight transfer, with no contingencies;

b) case b: 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;

c) case c: the computed pump capacity required, as a contingency, to provide the requirements of either case a or case b, whichever is the greater, in the event of the failure of any one pump, component or pumping system; 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 should 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 it is necessary to reverse in order to function as part of the back-up capacity shall be capable of such reversal within 10 min, and adequate resources shall be available to perform this operation.

Table 6 — Recommended pump capacity for each case and category [34]

Category[a]		Case	Pump capacity recommended, as a percentage of capacity calculated for each requirement %
1	Tidal window	a	150%
		b	150%
		c	120%
2	Constant deck level > 24 h	a	150%
		b	120%
		c	100%
3	Little tide	a	100%
		b	No requirements
		c	75%
4	Grounded and pumping	a	120%
		b	120%
		c	100%
5	Grounded	All	No requirements

[a] See Table 5.

Pumps that it is necessary to move around the barge 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 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 taken into account, as should any limitations of the barge and structure.

Where a safe loadout plan is demonstrated, with reserve pumping capacity provided in accordance with Table 6, the reserve capacity may be used to enable the loadout to proceed faster, provided it can also be demonstrated that this is safe.

Table 7 gives an example for a category 2 loadout that assumes that the worst single system failure reduces the pumping capacity, expressed in any unit, to 80 % of the full capacity.

Table 7 — Example of required capacity calculation for a category 2 loadout

Case	Nominal capacity m^3/hr	Factor %	Recommended capacity m^3/hr
a	1 000	150	1 500
b	1 100	120	1 320
c	1 100/0,8 = 1 375	100	1 375
Required	—	—	1 500 (case a)

11.10 Loadouts by trailers, SPMTs or hydraulic skidshoes

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.

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.

11.11 Propulsion system design, redundancy and back-up

11.11.1 Propulsion system

The propulsion system, including back-up and contingency systems, shall be designed according to the category of loadout as defined in 11.2, and as shown in Table 8. 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 recommendations of 11.11.2 apply, and the reversibility of motion should be demonstrated.

11.11.2 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 8 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.

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 9, unless justification for a lower value can be provided. The typical values shown are for information only and should be justified if used.

Table 8 — Propulsion system design [34]

Category	System requirement	Skidded loadouts	Trailer loadouts	
			Non-propelled	SPMT
1	Slope capacity	Design slope + 3 %	Design slope + 3 %	Design slope + 3 %
	System redundancy	Required	Required	Required
	Braking system	Required	Built-in	Built-in
	Pull-back system	Required	Required	Built-in
2	Slope capacity	Design slope + 2 %	Design slope + 2 %	Design slope + 2 %
	System redundancy	Recommended	Recommended	Recommended
	Braking system	Required	Built-in	Built-in
	Pull-back system	Not required	Built-in	Built-in
3	Slope capacity	Design slope + 1 %	Design slope + 1 %	Design 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	Design slope	Design slope	Design 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	Design slope	Design slope	Design 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

Table 9 — Coefficients of friction for the design and sizing of the propulsion system [34]

Level surfaces	Static		Moving	
	Typ.	Max.	Typ.	Max.
Sliding				
Steel on steel	0,15	0,30	0,12	0,20
Steel on teflon	0,12	0,25	0,05	0,10
Stainless steel on teflon	0,10	0,20	0,05	0,07
Teflon on wood	0,14	0,25	0,06	0,08
Steel on waxed wood	0,10	0,20	0,06	0,12
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 gravel	0,03	0,04	0,03	0,04

The design action on winching systems shall not exceed the certified safe working load (SWL), after allowance for splices, bending and sheave losses; see Clause 18. 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 rerigging. If rerigging 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 rerigging.

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 9.

11.12 Float-on onto submersible barges or vessels

Floating transfers onto submerged barges or vessels should be accomplished by one of two methods.

a) Stability is maintained by submerging the stern to the sea floor, whilst 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.

b) 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 deballasted to induce sufficient reaction to ensure no further movement of the cargo and then further deballasted to the voyage waterline.

In either method, minimal stability phases can be encountered during ballasting and deballasting. Sometimes submergence of the unloaded vessel, when no cargo water plane area is present, causes a phase of minimal stability. During deballasting, 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 that wind and current action on the cargo during positioning are within the capacity of the handling and guidance systems.

The stability caution in 9.10 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 9.10, 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, 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 9.10, to demonstrate that any sliding of the cargo cannot occur. It is recommended that 50 % of the minimum values shown in Table 9 be used for this value, based on observed operations; see also both 11.13 and 12.7.5 on sea fastening.

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 the deballasting operation, and during the 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.

11.13 Barge reinstatement and sea fastenings

Sea fastening work shall be started as soon as possible after positioning the structure on the barge. Sea fastening shall be designed to minimize offshore cutting, to provide restraint after cutting and to allow lift-off without fouling.

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.

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 sea fastenings fully in accordance with the provisions of this subclause, then friction may be taken into account to contribute to the sea fastenings. It is recommended that the coefficient of friction be 50 % of the minimum listed in Table 9 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 sea fastening 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.

11.14 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.

11.15 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 should be avoided. If such a shift change cannot be avoided, 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 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 sea fastening is completed.

Fit-for-purpose safety procedures shall be in effect.

11.16 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 necessary to include in the loadout manual and supporting documents are listed in Clause A.3.

12 Transportation

12.1 Introduction

Cause 12 applies to offshore transportation, inshore transportation and transportation in sheltered areas, using either wet tow or dry tow. Additional information can be found in ISO 19902:2007[29], Clauses 8 and 22, and in ISO 19903:2006[35], Clause 11.

12.2 General considerations

12.2.1 Manned tows

For information on manned tows, see Reference [18].

12.2.2 Unmanned tows

For unmanned tows, access to the towed object shall be provided 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.

12.2.3 Navigation lights and day shapes

For information on navigation lights and day shapes, reference is made to COLREGs regulations [4]. Navigation lights shall have their own power supply and an emergency power supply.

12.2.4 Contingency

Contingency plans shall conform to 6.5.

12.2.5 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. For detailed information on the analysis methods, see 13.3.1 and ISO 19901-7:2005, 8.3.

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 (see 9.4), the dynamic behaviour should be verified by model testing or non-linear analysis.

If neither a motion study nor a model test programme is performed for standard configurations and subject to satisfactory marine procedures, the motion criteria given in Table 10 may be used as guidance. The default values given in Table 10 are from Reference [36]. Alternative default motion criteria, as set out, for example, in References [37] or [38], may also be used as guidance.

Table 10 — Default values of motion response for standard transportation analysis [36]

Type of vessel	**Vessel dimensions LOA** and b[a] m	**Roll amplitude** degrees	**Pitch amplitude** degrees	**Heave acceleration** m/s^2
Large vessels	$L_{OA} \geqslant 140$ and $b \geqslant 30$	20	10	0,2 g
Medium vessels	$L_{OA} \geqslant 76$ and $b \geqslant 23$	20	12,5	0,2 g
Small vessels	$L_{OA} < 76$ or $b < 23$	30	15	0,2 g
Large cargo barges	$L_{OA} \geqslant 76$ and $b \geqslant 23$	20	12,5	0,2 g
Small cargo barges	$L_{OA} < 76$ or $b < 23$	25	15	0,2 g

[a] L_{OA} indicates the length overall; b indicates the breadth, both expressed in metres.

The motion default values presented in Table 10 should be used in conjunction with the following provisions.

a) The roll and pitch values relate to a 10 s full cycle period of motion for vessels and barges with $b \geqslant 23$ m. For vessels and barges with $b < 23$ m, the roll period can be shorter.

b) The roll and pitch axes pass through the centre of floatation.

c) The phasing considered combines, as separate load cases, the most severe combinations of

   1) roll and heave,

   2) pitch and heave.

d) For inland and sheltered water transportation, the greatest effect of the following cases is taken into account:

   1) the static loads caused by an acceleration of 0,1 g applied parallel to the deck in both directions,

   2) the static inclination caused by the design wind,

   3) the most severe inclination in the one compartment damage condition.

e) The additional heel or trim caused by the design wind is taken into account.

For many instances of transportation, however, the effects of direct wind action when calculating the actions on the cargo may be neglected.

As noted in 9.4.1, a further limiting heeling angle shall be determined to account for structural design limitations of, for instance, the topsides modules and the structural design constraints associated with the sea fastening. In other words, if the integrity of the sea fastening is compromised at 10°, it is irrelevant that the hull can heel 15°.

12.2.6 Structural 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 12.7.5.

12.2.7 Bunker ports

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 should be capable of holding tow as recommended in 12.3.

12.2.8 Weather forecast

The transportation shall not start unless the forecast is for stable weather, predicting favourable environmental conditions for a period of 48 h as recommended in Clause 7. 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 tow.

The forecast should show the operational weather conditions, taking into account the margin defined in 7.5.3. 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.

12.3 Towline pull required, fleet composition and towing arrangement

12.3.1 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, 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, including, as appropriate, the tow to the inshore construction site or holding area, the F_{PR} should be based on the operational metocean criteria given in Clause 7 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 Equation (6):

$$F_{PR} = \sum \left(F_{BP} \times \frac{T_{eff}}{100} \right) \tag{6}$$

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;

$\left(F_{BP} \times \frac{T_{eff}}{100} \right)$ 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 11.

Table 11 — Estimation of the tug efficiency (based on experience from the North Sea environment)

Continuous static bollard pull F_{BP} kN	**Tug efficiency for various sea conditions** T_{eff} %		
	Calm	H_s = 2,0 m [a]	H_s = 5,0 m [a]
$F_{BP} \leqslant 300$	80	$50 + F_{BP}/10$	$F_{BP}/10$
$300 < F_{BP} < 900$	80	80	$30 + 0{,}75\ [(F_{BP}/10) - 30]$
$F_{BP} \geqslant 900$	80	80	75

[a] H_s indicates the significant wave height.

12.3.2 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 as well as the certificates listed in Table 1. 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 requires assistance.

Stern tugs should not be considered when calculating the total effective bollard pull.

12.3.3 Towing arrangement

The MBS of the towline shall be related to the continuous static bollard pull, F_{BP}, of the tug given in Table 12.

Table 12 — MBS of the towline [36]

Bollard pull F_{BP} kN	**Benign areas** kN	**Other areas** kN
$F_{BP} \leqslant 400$	2,0 F_{BP}	3,0 F_{BP}
$400 < F_{BP} \leqslant 900$	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, chain pennants and fairleads, where fitted, 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 12. The emergency towline shall be fitted with a pick-up line.

12.3.4 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.

12.4 Tow out from dry dock

12.4.1 General

Guidelines are given in 12.4.2 to 12.4.7 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.

12.4.2 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.

12.4.3 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.

12.4.4 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.

12.4.5 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 13.4.

12.4.6 Navigation systems

Two independent positioning systems should be provided. The position 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.

12.4.7 Survey requirements

For the tow out operation from the dock sill to the holding area for hand-over for inshore 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.

12.5 Inshore tow

12.5.1 Tow route and towing clearances

The minimum under-keel clearance for inshore tow should not be less than 2 m or 10 % of the maximum draught, whichever is greater, after deduction of effects due to roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the structure.

The minimum channel width along the inshore leg of the tow route 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 tug configuration.

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.

When passing under bridges and power cables, the overhead clearance should be adequate and should consider tidal variations and changes in draught of the towed object. Where clearance is limited, 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.

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.

12.5.2 Survey requirements

For areas where the under-keel or side clearance can be critical, a recent survey report (not older than three months) should be obtained. Alternatively, the inshore tow route should be surveyed with a width of five times the beam of the object, with a minimum of 500 m. Sidescan sonar and bathymetric data should be obtained. The sidescan equipment used should be of recognized industry standard.

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 requirements may be relaxed if it can be shown that the on-board bathymetry measurement systems and PMS systems are of sufficiently high precision.

12.5.3 Navigation systems

Guidelines for navigation systems are given in 12.4.6.

12.6 Offshore tow

12.6.1 Holding areas and contingency plans for routing

Suitable holding areas or safe havens shall be identified along the tow route to hold the transport when waiting on weather or tide. An offshore holding area near the installation site should also be identified. All necessary permits and agreements shall be arranged in advance.

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.

12.6.2 Under-keel clearance

The minimum under-keel clearance during an offshore tow should allow for 5 m above lowest astronomical tide (LAT) level, after deductions for the effects of roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the structure.

12.6.3 Special considerations

Special considerations should be given to transits in limited areas with small under-keel clearances subject to weather-restricted conditions, tidal windows and accuracy of the survey data.

12.6.4 Navigation systems

Navigation data shall be provided by two independent on-board systems and suit the navigational constraints of the tow route.

12.6.5 Survey requirements

In areas where the water depth is less than the structure draught plus 10 m, the offshore tow route should be surveyed over a width of 1 000 m. The tow route survey should provide sidescan sonar and bathymetric data.

12.7 Transport by dry tow or onboard a heavy transport vessel

12.7.1 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.

12.7.2 Stability

For stability requirements, see Clause 9.

12.7.3 Under-keel clearance

The minimum under-keel clearance for offshore transportation should be 5 m after considering the effects of roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the vessel.

12.7.4 Special considerations

Special considerations should be given to transit in limited areas with smaller under-keel clearances subject to weather-restricted conditions, tidal windows and accuracy of the survey data.

12.7.5 Sea fastening

12.7.5.1 For sea fastening of objects for dry tow on a barge or aboard a heavy transport vessel, the following considerations apply.

— The provisions of 12.2.5 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, 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 13 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 13, which presents the maximum coefficients of friction and the minimum force, expressed as a percentage of cargo weight.

12.7.5.2 When using the information in Table 13, 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 Equation (7):

$$f_{\mathrm{fr}} = \frac{900 - H_{\mathrm{c}}}{3} \tag{7}$$

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 13 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 may be considered. It should be demonstrated that all parts of the load path, including the potential sliding surfaces, are capable of withstanding these forces. For additional information, see 11.12 and 11.13.

Table 13 — Allowance of friction in sea fastening design [36]

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
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

a ⩾ $15 - W_c/40\,000$.
b ⩾ $7{,}5 - W_c/40\,000$.
c ⩾ $3{,}5 - W_c/200\,000$.

12.7.6 Navigation systems

Requirements for navigation systems are given in 12.6.4.

12.8 Transport manual

A transport 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 necessary to include in the transport manual and supporting documents are given in Clause A.4.

13 Temporary mooring and stationkeeping for marine operations

13.1 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 Clause 13.

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.

— Inshore construction moorings: These moorings are used to hold a structure during its construction and outfitting afloat, are generally suitable for long periods of operations in sheltered waters and are generally catenary moorings.

— Moorings alongside quays: These moorings are used to hold a low draught or slender structure during its inshore construction and outfitting, are most commonly used for ship-shaped structures and are generally treated as conventional berthings with a combination of spring and breast lines.

— Standby moorings: These moorings are used to hold the main structure or one of its components (e.g. topsides on a barge prior to float-over) 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.

— Position keeping moorings: These moorings are used as a positioning aid during precise operations, such as inshore loadout, inshore deck mating or offshore installation.

Inshore construction moorings are generally set up in areas where deep water is available at the construction site, and along the tow route toward the field, in order to accommodate the deep draught of GBSs, or of permanent floaters such as spars or FPSs. These areas often require specific development to accommodate the temporary mooring of such units.

13.2 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 typhoons, 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.

13.3 Determination of mooring response

13.3.1 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 19901-7:2005, 8.3.

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 19901-7:2005, 7.4.

13.3.2 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.

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.

13.4 Sizing of mooring lines

13.4.1 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.

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.

13.4.2 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 ISO 19901-7:2005, 10.2, Table 5, which is reproduced as Table 14. The corresponding design safety factors are also listed.

Table 14 — ULS line tension limits and design safety factors[a]

Analysis condition	Analysis method	Line tension limit % of MBS	Design safety factor
Intact	Quasi-static	50	2,00
	Dynamic	60	1,67
Redundancy check	Quasi-static	70	1,43
	Dynamic	80	1,25
Transient	Quasi-static or dynamic	95	1,05

[a] From ISO 19901-7:2005, Table 5.

13.4.3 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.

13.5 Sizing of anchors

Temporary mooring systems normally include drag anchors, the holding capacity of which depends upon their correct embedment into the soil.

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.

Alternatively, other means for anchoring, such as gravity anchors, suction anchors, vertically loaded anchors or anchor piles, can be used for specific applications. In such a case, the design safety factors used for the sizing of the anchors shall comply with the requirements given in ISO 19901-7:2005, 10.4, for mobile mooring systems.

Calculations of anchor UHC should 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 certifying authority.

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.

Alternatively, vertically loaded anchors, gravity anchors, suction anchors or anchor piles can be considered.

13.6 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, see also 12.3.3.

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.

13.7 Sizing of mooring line components

Mooring line components should be sized following the principles listed in 13.4, 13.5 and 13.6.

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 18.4.

Other components used to connect or lead the mooring line, e.g. fairleaders, winches, stoppers, etc., should have a design strength in accordance with 13.6.

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.

13.8 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.

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 a subsea asset, 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.

For guidance on horizontal clearances during deck mating operations, see 15.4.

For clearances for crane vessels, their associated mooring system and lifted objects, see 18.7.

13.9 Tensioning of moorings

After laying, drag anchors should be tested to the 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 19901-7:2005, 10.4.6.

If this tensioning test is impractical for large anchors, the test load should be individually determined after considering the actual anchor design and the soil conditions.

In such a case, the test load applied should be as large as is practical, and provisions should be made in the mooring arrangement to recover any slack in the line in the event of further embedment or drag after completion of the test and throughout the construction stages of the structure.

When mooring piles or suction anchors are used, proof tests are not normally required as long as the installation records show that the soil conditions are in accordance with the soil design data. However, a pull-out test should be undertaken in order to recover the slack in the part of the chain embedded in the soil during anchor or pile installation.

13.10 Other stationkeeping means

13.10.1 General

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.

13.10.2 DP systems

DP systems should be designed, equipped and operated in accordance with References [39] and [40].

Guidance on the vertical and horizontal clearances for DP crane vessels is given in 18.7.3

13.10.3 Purpose-built mooring arrangements

Where the stationkeeping system is not an integral part of the vessel's equipment, but is purpose-built for the installation operation (winches, jacks, fenders, etc.), it should be sized to hold station when subjected to the design metocean criteria for the operation.

13.10.4 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.

14 Construction and outfitting afloat

14.1 Introduction

Clause 14 covers marine operational aspects encountered during construction and outfitting afloat. It is also intended to apply to quayside operations in sheltered water locations, such as at quaysides in an existing yard or newly constructed quay. This includes activities on the structure, starting with tow out from the construction site, mooring at the outfitting site (if different from the construction site) and activities on the structure at the outfitting site until departure for the offshore site.

NOTE Deck mating activities, although often carried out during construction afloat, are covered separately in Clause 15, which deals with float-over topsides installation operations.

Documentation and procedures for construction afloat shall comply with the general requirements of Clause 6. When developing these procedures, it shall be ensured that those responsible for planning, authorizing and carrying out the work are fully informed about any limitations and constraints that can be placed on the work by factors that can be outside their own discipline.

Unlike traditional onshore construction work, activities related to construction and outfitting afloat can be constrained by parameters that can change on a daily basis, such as

— marine spread requirements;

— draught, displacement, ballast condition and stability;

— weather conditions;

— direct actions and structural resistances;

— mooring actions and resistance;

— restrictions by port authorities;

— other simultaneous ongoing activities and related access restrictions.

NOTE Some of these aspects are inter-related.

14.2 Structural strength and stresses

14.2.1 Structural strength

Determination of structural strength and stresses during construction afloat shall take into account

— static actions;

— hydrostatic actions;

— stationkeeping actions;

— environmental and environmentally-induced actions;

— tidal level changes;

— differential ballasting;

— actions resulting from the construction spread;

— vessel impact actions;

— actions due to construction activities, with particular attention to lifting;

— contingencies, including accidental flooding, mooring line breakage and dropped objects, as appropriate.

14.2.2 Structural limitations

Any structural limitations imposing constraints on operations shall be clearly defined and written into the relevant operational procedures. These can include

- maximum and minimum draught;
- differential ballast levels in adjacent buoyancy compartments;
- overall weight distribution;
- structural limitations on heel or trim with consequent limitations imposed on draught, stability or environmental conditions;
- phases during which one compartment damage stability requirements are not met, and the structural requirements or the alternatives given in Clause 9 apply.

Aging of time-sensitive construction materials, such as concrete, should be taken into account in the calculations.

14.3 Construction spread

The construction spread can include barges and other floating equipment moored alongside or near the structure, and can serve the following functions:

- storage for construction materials and equipment;
- base for a concrete mixing plant;
- temporary power supply;
- temporary ballast control;
- offices;
- workshops;
- personnel reception area and security;
- bridges/gangways;
- temporary stairs;
- berthing and unloading area for ferries, transport barges and vessels;
- safety and emergency facilities.

In general, the number of vessels moored alongside the structure should be kept to a minimum. Where practical, any redundant equipment should be removed from the spread.

The mooring and fendering system for each item of the spread should be designed in accordance with Clause 13.

Where such a design is impractical, e.g. in locations prone to tropical cyclones, the limiting design and operational metocean parameters for the moorings shall be clearly defined. An emergency preparedness plan and related detailed procedures shall be developed to discontinue use of the affected equipment and remove it to a place of safety before the operational limit is reached. Adequate tugs and safe moorings should be made available to perform this operation.

Equipment and material on barges should be secured to minimize the risk of falling overboard or sliding laterally.

Floating equipment moored adjacent to the structure should satisfy the one compartment damage stability requirements in accordance with the damage stability criteria established for the project.

The requirement for contingency pumping equipment on-site should be evaluated.

A HAZID shall be carried out for the entire spread involved during the construction and outfitting afloat.

14.4 Welding

Welding during construction and outfitting shall be performed in accordance with the welding and NDT procedures established for the project.

If welding is performed on the structure with the power source located on an attendant vessel, precautions shall be taken to eliminate the return of stray welding currents. Appropriate recommendations on welding and NDT techniques can be found in ISO 19902[29]. Welding cables (both positive and negative leads) shall be insulated and no portion of any welding cable shall be suspended in or near the water.

Instrumentation can be installed on the attending vessel to check for the presence of stray welding currents. If stray welding currents are detected, an immediate investigation to determine the cause should be conducted and the situation rectified. If the problem is not rectified in a reasonable period of time, welding operation shall be discontinued until the problem is corrected.

The minimum structural welding required to ensure seaworthiness of a vessel while performing partial lift and set procedures during construction or outfitting should be determined ahead of time and recorded in the operation plans.

15 Float-over topsides installation

15.1 Introduction

Clause 15 contains guidelines for float-over installation of topsides onto structures either floating or fixed to the seabed. Additional information on float-over installation can be found in ISO 19902:2007[29], Clause 22. Guidelines for lift-based installation are provided in Clause 18.

15.2 Environmental considerations

Float-over installations are weather-restricted marine operations. Appropriate design environmental parameters shall be developed in accordance with Clause 7.

15.3 Structural considerations

15.3.1 General

The topsides and its transportation vessel, the structure and the installation equipment are subjected to a variety of actions during installation. The adequacy of global and local strength shall be documented.

15.3.2 Design situations and actions

The design situations can include the following types of actions:

— permanent actions;

— variable actions;

- environmental actions;
- dynamic actions;
- manoeuvring and positioning actions;
- hydrostatic and ballasting actions;
- indirect actions from deformations, misalignments and out-of-levelness;
- accidental actions.

When topsides are installed onto a floating structure, the horizontal restraint of the topsides prior to making a permanent connection should be checked against the worst inclination resulting from the design situations (induced by wind, by waves or by mooring lines). Friction can be taken into consideration using the friction coefficients given in Table 13.

15.3.3 Temporary connection points

Temporary connection points can be used for the attachment of stationkeeping, positioning and guidance systems, such as tugger lines, winches, winch wires or mooring wires, or other devices. Connection point design should consider directions from which the action can be applied, and the design strength should be at least 1,3 times the breaking strength of the wire or the rope to be attached to it; see 13.6.

Where connection points become submerged during the operation, they should be designed so that failure of a connecting point does not lead to the loss of the watertight integrity of the submerged structure.

15.3.4 Topsides supports

Topsides supports, such as transportation vessel grillage and permanent support stools, should have sufficient strength to withstand actions imparted on them during the operation. Deflections of the topsides and the barge during the load transfer operation for the defined sequencing of lift-off from the supports should also be considered.

15.3.5 Floating structures

Floating structures shall be designed so that a pre-defined stand-by draught can be maintained prior to topsides installation. Any structural limitations on the length of time the structure can remain at deep submergence draught should be quantified and considered in the operational procedures.

15.4 Clearances

15.4.1 General

During the float-over operation, appropriate clearances shall be maintained between the relevant structures, equipment and the sea floor in order to avoid unintended impacts and damage. When setting these clearances, consideration shall be given to the influence of factors such as relative motions, tide, current effects, water density, wind heel, bathymetry and draught measurement tolerances, as well as to deflections of structures. Minimum required clearances are given in 15.4.2 to 15.4.4.

15.4.2 Floating structures — Under-keel clearance

Under-keel clearances for floating structures are given in 13.8.

15.4.3 Floating structures — Minimum freeboard

For floating structures, the minimum freeboard should take into account the details of the installation operation, including the effects mentioned in 15.5.1, as appropriate, and the controllability of the load transfer.

For GBSs, the minimum freeboard should not be less than 6,0 m, unless a lower value can be justified.

For installation vessels, the minimum freeboard shall not be less than 0,5 m.

15.4.4 Clearances during float-over

Where the topsides installation method involves manoeuvring alongside or between the structure's legs or columns in very close proximity of the structure, the minimum horizontal clearance between each side of the transportation vessel and the structure should be dependent upon the installation system utilized. As a guiding principle, the minimum clearance should be sufficient to allow unimpeded operation of the installation system and should be based on motion analysis of the two bodies being positioned.

Where there is a risk of heavy contact between structures, a suitable fendering system should be installed. Fender dimensions should be taken into account when determining minimum clearances.

As a guide, the minimum vertical clearance between any part of the topsides and the structure's legs or columns should not be less than 0,5 m for sheltered inshore locations, with due consideration of the local environmental conditions.

For offshore locations, the minimum vertical clearances should take account of the operability requirements and of the relative motions between the topsides and structure under the design environmental conditions.

15.5 Guidance systems for topsides set-down

15.5.1 General

Guidance systems shall be provided to ensure precise positioning, within specified tolerances, of the topsides when set-down on the structure and to protect adjacent structures and equipment from damage during the installation operation. Such systems can consist of

- passive guidance systems, such as bumpers and guides, pins and buckets, stabbing cones, stopper plates and fenders, that are designed so that the topsides can be manoeuvred against them; these guidance systems can be fitted with elastomers for load absorption;
- active guidance systems, such as jacking or winching systems, that are connected to the topsides or transportation vessel to guide the topsides into position and to effect a load transfer from the transport barge to the structure;
- a combination of both passive and active guidance systems.

15.5.2 Passive guidance systems

Passive guidance systems should be designed for impact and for frictional forces from any direction and in any combination in which they can occur. Where passive guidance systems use temporary structures, they should be designed to fail before overstress or damage is caused to any permanent structure to which they are attached. Determination of design actions and layout of the passive guidance system should include consideration of

- installation method and equipment;
- design and operational environment;
- vulnerability of surrounding structure;
- ease of removal following topsides installation.

Prior to the start of the topsides installation, an as-built dimensional survey of the guides should be carried out to ensure that they are within acceptable tolerances for achieving precise topsides positioning.

15.5.3 Active guidance systems

Active guidance systems should be designed to achieve and maintain a final position within the recommended tolerances given in the design report, which defines the limiting environmental conditions appropriate to each phase of the operation. These systems should have a range of movement sufficient to enable connection and activation when the positioning tolerance limits of the stationkeeping systems are reached.

For offshore operations, it can be necessary to incorporate damping to control vertical motions during the final positioning phase.

15.6 Operational aspects

15.6.1 Planning and scheduling

For floating structures requiring minimum freeboard for topsides installation, the operation should be planned to minimize the time spent at deep draught. In the event of delays, the structure should be deballasted to a safe (stand-by draught) condition.

An appropriate procedure should be established to allow a stand-by draught in a safe condition for the float-over spread whilst waiting for acceptable weather, e.g. when experiencing operational delays before the start of the installation.

15.6.2 Pre-operational preparations

For floating structures that require deep draught submergence for topsides installation, both inclining and deep draught submergence tests should be performed as separate marine operations prior to the topsides installation. Ballasting rates should be consistent with those being used for the actual topsides installation. The trial submergence should include hold points to allow for checks of systems and structure.

The float-over operation should not commence until the results from the inclining and/or deep submergence tests are known.

Paint identification and draught marks for the various steps of the operation shall be made on the floating structures.

15.6.3 Removal of sea fastenings

The PNR for cutting sea fastenings shall be clearly defined. The cutting of sea fastenings shall not start until the decision to proceed with the installation operation is made. In cases where the transportation sea fastening system is designed for transportation environmental conditions significantly more onerous than those prevailing at the installation location, partial removal of the sea fastenings may be considered upon arrival of the transport at location.

15.6.4 Final approach to the structure

Where the topsides installation requires the transportation vessel to work in very close proximity to the structure, particular attention should be given to means of controlling the vessel speed during the final approach. This is normally achieved by use of winches and lines, with further assistance from tugs, pre-laid moorings, fenders, etc., as required.

15.6.5 Load transfer

An appropriate load transfer system should be provided to handle repeated impacts, taking into account the relative motions between the topsides, structure and transportation vessel, and the speed with which load transfer (ballasting, de-ballasting) can take place. A hydraulic load transfer system or passive elastomers shall be considered to reduce the exposure to impacts.

Where impacts are likely to occur, the topsides and the structure shall be designed for impact effects.

The position of the topsides shall be verified when either sufficient weight of the topsides has been transferred to the structure to prevent any further movement or the topsides is engaged in the final guidance system, such that its accuracy of position is guaranteed upon set-down.

Where load transfer involves significant ballasting operations, the sequencing of such ballasting should be pre-determined to keep heeling and bending moments within acceptable ranges while minimizing the duration of the load transfer operation.

Where multiple barges support the topsides, the final load transfer sequences should be planned to maintain positive contact between each barge and the topsides until the scheduled removal stage.

Removable or collapsible supports or jacks can be used to gain clearance rapidly and minimize secondary contacts. The reliability of such devices shall be appropriately confirmed.

The load transfer operation shall be designed to ensure completion without serious consequences, even in case of failure of any one system or component.

15.6.6 Barge or vessel removal

When adequate clearance has been achieved following transfer of the topsides from the barge or vessel to the structure, the barge or vessel should be removed from the immediate location in a controlled manner. Guides and fenders should be pre-installed, as necessary.

15.6.7 Return to stand-by draught

For floating structures, deballasting should continue following barge or vessel removal until a safe draught is reached, at which time permanent connection of the topsides should commence.

15.6.8 Operational control parameters

The following parameters shall be considered, monitored and controlled during the operation, as appropriate:

a) in general:

   1) relative position, orientation and clearance of structure and topsides,

   2) parameters for active guidance systems (oil pressure, stroke, etc.),

   3) environmental conditions and forecast;

b) on transportation vessels or barges:

   1) vessel(s) or barge(s) trim, heel and draught,

   2) water level in vessel and/or barge ballast cells,

   3) ballast control status;

c) on floating structures:

   1) draught, heel and trim,

   2) water level in ballast cells,

   3) air pressures in cells,

4) ballast control status,

5) leakage.

15.7 Float-over manual

Float-over is a marine operation and, as such, detailed procedures should be established and implemented.

A float-over manual and supporting documentation should be prepared for the operation and issued for information and approval, as appropriate. The items listed in 6.5.2 and in 17.18 shall be included in the float-over manual and supporting documents.

Towing, mechanical handling and ballast operations should be considered during HAZID or similar sessions; see 5.4.2.

All personnel vital to the performance of this operation should participate in these sessions.

16 Pre-laid mooring including foundation

16.1 Introduction

16.1.1 General

The installation of pre-laid position mooring systems, including foundations for offshore floating structures, shall be in accordance with ISO 19901-7, as applicable, and with the provisions presented in 16.1.2 to 16.13. Spread mooring systems, single point mooring systems and vertical tension leg systems are addressed. For additional guidance, see ISO 19902:2007[29], Clause 22.

16.1.2 Mooring system components

The anchor point and the mooring line or tendon are the major components of a mooring system.

Anchor types include fluke, plate, suction, pile or gravity.

Catenary or taut mooring lines are generally composed of several components and segments that can be of different materials, characteristics, weight and appearance, including

— connectors;

— stud or studless chain;

— steel wire rope, sheathed or unsheathed;

— synthetic wire rope;

— weight or buoyancy components.

TLP mooring systems are generally composed of tendons that form a link between the structure and the foundation system(s) on the sea floor. A typical tendon design generally includes

a) the main body, made up of individual tendon segments with similar or identical geometric properties, and which can take a variety of forms, such as

   1) tubulars,

   2) solid rods or bars,

3) stranded construction such as parallel or helical wire rope,

4) fibre rope;

b) connectors, which connect the tendon to the platform hull (top connector) and to the foundation system(s) (bottom connector);

c) couplings, which connect one tendon segment to another or to a specialty component.

16.2 Installation planning

16.2.1 General

Relevant marine operations shall be considered at the design stage of the mooring system.

Regardless of the type of mooring system being installed, mooring system installation operations shall be subject to a thorough risk assessment and the operations shall be designed and planned taking account of the assessment results.

The operations plans shall be documented in a set of installation procedures or of instructions for the installation crew.

16.2.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— mooring configuration, component specifications and special design features incorporated to facilitate deployment;

— relevant owner and regulatory requirements for the as-laid mooring;

— existing installation units, subsea equipment, supporting vessels and other activities planned or in progress in the vicinity of the field;

— environmental conditions, such as local seasonal data (wind, waves, swell and current) and hurricanes or typhoons (known as cyclones or typhoons in other areas), as applicable;

— specific design criteria for weather-restricted operations;

— seabed soil conditions at anchor and mooring line locations;

— the existence of nearby obstacles, especially those on the sea floor.

16.2.3 Mooring equipment documentation

Components of the mooring system shall have valid certificates and/or design documentation and should be uniquely identifiable.

The following documentation should be available for the design, planning and execution of the operations:

— dimensions with tolerances;

— material specifications;

— weight;

— length;

- strength (as certified or otherwise documented);
- special considerations;
- load-elongation properties: initial permanent elongation and stiffness of fibre ropes;
- axial stiffness (steel wire rope);
- torque and twist behaviour (steel wire rope and fibre rope);
- resistance to mechanical and chemical attacks;
- fabricator's guidelines or instructions, if any;
- minimum bending radius (as a function of rope tension, as applicable);
- anchor particulars.

Relevant documentation should be available during pre-installation operations and temporary phases.

16.2.4 Pre-installation activities

Activities carried out prior to the start of installation operations shall include

- inspection and certification of mooring components;
- survey of mooring line corridors and anchor location areas;
- trial fitting of components, where practical, to verify tolerances;
- calibration of positioning systems.

ROV surveys shall be performed in search of obstructions along planned mooring line lay routes and at anchor location areas that can interfere with installation work. A mooring line shall not be installed unless a sea floor survey provides evidence that a lay corridor at least 20 m wide is free of obstructions. The surveyed corridor width shall take account of the accuracy of the intended survey procedure.

EXAMPLE If the survey accuracy is ± 15 m, it is necessary to survey an additional width of 5 m to ensure a 20 m obstacle free corridor.

The use of a sea floor acoustic array positioning system shall be considered, depending on the specified tolerances for the as-laid position and the orientation of anchors and mooring lines, and on water depth. Target buoys indicating anchor locations and the position of the floating structure shall be installed.

ROV instrumentation shall be capable of using the survey system to determine the actual location, radial orientation and verticality.

16.2.5 Sequence of mooring component installation

The mooring system configuration generally dictates the sequence of installation of its components. Efforts should be made to determine a safe and controlled sequence for the handling of components and personnel, and to make optimum use of available installation vessels and facilities.

The platform chain end of the mooring line laid on the sea floor shall be terminated with an abandonment and recovery system to ensure that it can be easily located and recovered to the surface without delay or damage. The location of each mooring line termination on the sea floor shall be recorded. The abandonment and recovery system shall include a secondary recovery method as a contingency so that, if the primary recovery system is unable to retrieve the mooring line, the secondary system can be utilized. This termination system shall be designed such that the mooring line can be retrieved by use of a line lowered from a floating vessel and shall also be designed such that it can be activated by the use of ROV-assisted tools.

16.2.6 Post-installation activities

Following installation of the mooring system, a post-installation visual survey of the mooring system should be performed. The survey should be documented and taped on video. Positions of anchor points should be stated together with a recording of the level of accuracy provided by the deployed survey system. The survey should record, as a minimum,

— the as-laid configurations of the mooring lines;

— the positions of anchor points and of pre-laid mooring lines;

— the condition, shape and position of aids for use during temporary phases, final pick-up or hook-up (buoys, grommets, etc.);

— any damage, twist, etc., that has occurred during installation.

16.3 Fluke anchor installation

16.3.1 General

Installation of drag embedment fluke anchors shall generally follow the procedures developed by the anchor manufacturer with modifications, as necessary, to suit the actual installation, and shall be approved by all parties.

Adequate mooring system holding capacity shall be demonstrated by load testing, see ISO 19901-7:2005, 10.4.6.

16.3.2 Operational aspects

In addition to the items listed in 16.2.2 and 16.2.3, aspects for consideration during planning and design shall include, as appropriate,

— monitoring of anchor installation;

— line tension during installation;

— line angle outside stern roller;

— anchor drag;

— final installation measurements;

— minimum test tension for a 15 min holding time;

— final anchor drag;

— final penetration depth (best estimate);

— installation tolerances;

— requirements to as-laid documentation;

— requirement for ROV assistance to verify position and orientation during deployment.

16.3.3 Anchor installation vessel

Available bollard pull, winch capacity and MBS of the installation wire onboard the actual installation vessel(s) should be such as to ensure that the minimum required test load can be applied to the mooring system.

Friction resistance at the stern roller, weight of mooring lines (in deep waters) and line angle should be taken into consideration.

16.4 Plate anchor installation

16.4.1 General

The embedment of plate anchors can be achieved by dragging (like a fluke anchor), pushing, driving or by the use of suction.

Installation shall generally follow the procedures developed by the plate anchor manufacturer with modifications, as necessary, to suit the actual installation, and shall be approved by all parties.

Adequate mooring system holding capacity shall be demonstrated by load testing, see ISO 19901-7:2005, 10.4.6.

16.4.2 Operational aspects

For drag-in plate anchors, see 16.3. For plate anchor embedment using suction piles, see 16.5.

In addition to the items listed in 16.2.2 and 16.2.3, aspects for consideration during planning and design shall include, as appropriate,

— triggering and rotation of the anchor;

— verification by measurements that the anchor has rotated to its intended installation position;

— confirmation of anchor holding capacity by full load testing.

16.4.3 Anchor installation vessel

For anchor-installation vessels, see 16.3.3.

16.5 Suction anchor installation

16.5.1 General

Suction anchors should be purpose-built for a specific installation method.

Marine operations shall be considered at the design stage so as to obtain a design optimum with respect to logistics, handling, deployment and insertion of the anchors.

Anchors are normally transported offshore on the installation vessel or on a separate barge. In the case of multi-caisson suction anchors, self-floating transportation can be feasible.

The anchors are either lifted by crane or launched by skidding from the transportation vessel, and lowered to the sea floor. During lowering, there should be free movement of water between the interior of the anchor and the sea through open valves in the roof of the anchor.

When the mooring line is attached to the anchor before anchor launching, the installation procedure shall ensure that the integrity of the mooring line is maintained throughout anchor submergence and insertion.

The anchor penetrates to an initial depth under its own weight. Sufficiently large water evacuation ports shall be provided to allow water to escape quickly during this self-weight penetration without disturbing the upper soil layer. Further penetration to final depth is accomplished by closing the evacuation valves and pumping out water to create suction. Soil data shall be used to determine the required pump capacity (i.e. necessary and permissible underpressure) to enable the anchor to penetrate to its required depth.

To generate the underpressure, a remotely controlled hydraulic pump can be fixed to the anchor prior to launching. Alternatively, a pump can be docked underwater by pre-rigged guide wires or by ROV.

After installation, the mooring line shall be pre-tensioned to prevent unacceptable slackening of the embedded section following floater mooring system hook-up; see ISO 19901-7:2005 10.4.6.

16.5.2 Operational aspects

In addition to the items listed in 16.2.2 and 16.2.3, aspects for consideration during planning and design shall include, as appropriate,

- anchor weight and dimensions;
- location of padeye (depth below mudline);
- mooring line configuration;
- geotechnical parameters;
- expected self-weight penetration depth;
- required suction pressure;
- limiting suction pressure;
- installation tolerances on verticality, orientation of padeye and penetration depth;
- lifting and repositioning in case of penetration failure;
- requirements for as-installed documentation;
- lifting/lowering capacity of marine equipment;
- requirements for ROV assistance.

16.5.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during installation:

- anchor position;
- anchor heading during lowering, upon initial stabbing and once installed;
- penetrated depth;
- internal suction pressure;
- padeye orientation;
- anchor verticality during lowering, upon initial stabbing and once installed.

16.6 Anchor pile installation

16.6.1 General

Anchor piles can be launched, lifted or upended, and are normally lowered to the sea floor by crane. During lowering, the anchor pile shall be lowered by a method that restrains the pile from rotating about the lowering line.

When the mooring line is attached to the pile before launching, the installation procedure shall maintain the integrity of the line throughout pile submergence and insertion.

The pile penetrates to an initial depth under its own weight. Penetration to final depth is generally accomplished by the use of a pile hammer mounted on the top of the pile. In other cases, the pile can be drilled and grouted in place, or the pile can be dropped from a calculated height above the sea floor using gravity to reach the design penetration.

After installation, the mooring line shall be pre-tensioned to prevent unacceptable slackening of the embedded section following the floater mooring system hook-up; see also ISO 19901-7:2005, 10.4.6.

16.6.2 Operational aspects

In addition to the items listed in 16.2.2 and 16.2.3, aspects for consideration during planning and design shall include, as appropriate,

— pile weight and dimensions;

— location of padeye;

— mooring line configuration;

— geotechnical parameters;

— expected self-weight penetration depth;

— requirement for sea floor support frame;

— selection of pile hammer or drilling and grouting equipment;

— installation tolerances on verticality, orientation of padeye and final penetration depth;

— potential for pile and connector fatigue during driving;

— requirements for ROV-assisted instrumentation to determine pile penetration immediately after lowering of the pile.

16.6.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

— pile position;

— padeye orientation;

— penetrated depth;

— pile hammer or drilling and grouting equipment performances;

- blow counts;
- pile verticality during lowering, upon initial stabbing and throughout installation until full penetration is achieved;
- pile refusal;
- pile soak.

16.7 Gravity anchor installation

16.7.1 General

Gravity anchors are deadweight anchors that commonly consist of solid blocks or containment structures with high density material ballast.

Both solid block anchors and containment structure anchors are normally transported on a vessel and lifted in place by crane. Self-floating containment structures are also used.

The ballast material can be concrete or steel blocks, scrap metal or rock. Ballast material is normally put in after installation of the containment structure and lifted into place or, in the case of rock, dumped through a fall pipe from the installation vessel.

After installation, the mooring line shall be pre-tensioned to demonstrate adequate holding capacity and to prevent unacceptable slackening following the floater mooring system hook-up, see also ISO 19901-7:2005, 10.4.6.

16.7.2 Operational aspects

In addition to the items listed in 16.2.2 and 16.2.3, aspects for consideration during planning and design shall include, as appropriate,

- anchor weight and dimensions;
- locations of padeyes;
- tolerances on orientation of padeyes;
- requirement for ROV assistance;
- sea floor bathymetry;
- seabed soil conditions.

16.7.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during installation:

- anchor position;
- padeye orientation;
- ballast weight.

16.8 Mooring system connectors

16.8.1 General

Connectors are used to join mooring system segments and components. Shackles and links, triangle plates and spelter sockets (open or closed) of various types are the most commonly used connectors in catenary and taut mooring systems.

Top and bottom connectors for TLP tendons are uniquely designed for each particular application. Generally, tendons have intermediate connections along their length. Tendon connections can take the form of mechanical couplings (threads, clamps, bolted flange, etc.), girth-welded joints or other types of structural connections.

16.8.2 Operational aspects

16.8.2.1 In addition to the items listed in 16.2.2 and 16.2.3, the following considerations apply, as appropriate, during planning and design.

— Each connector should have a valid certificate with a unique identifier.

— Connectors should be used and assembled in accordance with manufacturer’s instructions.

— Items that can work loose, such as nuts and bolts, should be properly secured.

— MBS or WLL of connectors should be considered in conjunction with the representative strength of connected components in determining the safety level for the total mooring system.

16.8.2.2 During temporary phases, limitations shall be set for actions and handling, such as

— impact or snap actions;

— bending actions, for example over the stern roller, around guiding pins, on winch drums or in bends;

— tension actions;

— torsion actions;

— cyclic actions;

— mechanical abrasion;

— combinations of the above.

16.8.3 Post-installation inspection

After their installation, connectors should be inspected to verify that they are intact and undamaged before further installation of the mooring system.

16.9 Chain

16.9.1 General

Both stud link chain and studless link chain are used in mooring systems. The chains shall be handled and installed in accordance with the manufacturer’s instructions and guidelines.

16.9.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— chain segments having a valid certificate that uniquely identifies each chain segment;

— position of each uniquely identified chain segment in the mooring line;

— adequacy of stopping off equipment and tools to sustain installation actions;

— suitability of the sizes of gypsies, winch pull capacities and brake capacities;

— avoiding chain segment twist;

— checking compatibility of design actions and design resistances throughout all phases of installation;

— avoidance of mechanical damage to chain links.

16.9.3 Post-installation inspection

A post-installation survey shall be performed to verify that chain segments are not twisted beyond their limiting criteria and that no mechanical damage has occurred.

16.10 Steel wire rope

16.10.1 General

Due to the various constructions of steel wire rope, each type can behave differently when handled and subjected to a load. This can apply, in particular, to bending and torque properties. Wires for long-term mooring systems should be coated or sheathed.

Steel wire rope shall be handled and installed in accordance with the manufacturer's instructions and guidelines.

16.10.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— wire rope segments with a valid certificate that uniquely identifies each wire rope segment;

— methods for stopping off actions during installation;

— load-elongation properties (axial stiffness);

— twist and torque of wire rope when loaded and, in particular, its effect on adjacent mooring system components;

— planning the handling of sheathed wire rope to avoid damage to wire rope sheathing and, if sheathing damage occurs, its adequate repair on deck;

— compliance with minimum bend radii on winch reels, over fairleads and stern rollers, in particular near wire rope terminations;

— protection from mechanical damage or weld spatters, in particular when the wire rope is sheathed;

— other hazards with respect to the integrity of the wire sheathing;

- avoiding kinks or loops during wire handling and in the as-laid configuration;
- fatigue during the pre-installation period;
- minimum tension to avoid over-bending.

16.10.3 Post-installation inspection

A post-installation survey should be performed to document the as-installed configuration and to verify that the wire is not twisted beyond its acceptance criteria, that it is not damaged and that no kinks or loops have occurred.

16.11 Synthetic fibre rope

16.11.1 General

Fibre rope can be of various material(s) and constructions. Each combination can have different characteristics and properties that should be taken into account when handling, when subjected to actions and when stored temporarily. The manufacturer's instructions and guidelines shall be followed.

NOTE For further information, see ISO 18692:2007, Annex D [41].

16.11.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

a) rope construction, rope material, protective cover and particle ingress protection;

b) MBS;

c) load-elongation properties: initial permanent elongation and stiffness;

d) fabrication tolerances (length);

e) weight, submerged and in air;

f) hoop actions;

g) cyclic actions;

h) compression actions (lack of tension);

i) bend radii (over the inner diameter of the winch drums, guiding pins, stern roller, etc.);

j) bending combined with tension;

k) minimum tension and over-bending;

l) heat and UV radiation;

m) methods for stopping off loads;

n) potential for mechanical wear and damage (sharp steel edges, vessel deck, stern roller, handling equipment);

o) avoiding contact with chemicals (oil, solvent, etc.);

p) avoiding contact with sea floor and exposure to water-borne particles;

q) attachment of buoyancy elements;

r) motions and fatigue experienced during temporary phases;

s) environmental effects during installation and during the pre-installed period.

Any rope without ingress protection shall not be allowed to contact the sea floor nor be exposed to water-borne particles and shall be discarded if dropped onto the sea floor.

16.11.3 Post-installation inspection

A post-installation survey should be performed to document the as-installed condition and configuration, to verify that no damage has occurred and to compare actual conditions with the acceptance criteria.

16.12 TLP tendons

16.12.1 General

Long, slender pipe (tubular) or rod structures are most often used for TLP tendons. Chain, steel wire rope, synthetic fibre rope and other composite material can also be used. Their installation requirements are addressed in 16.9, 16.10 and 16.11, respectively.

The material used in pipe or rod structures is high-strength steel or composite materials. Tendons can be towed to the site, upended and installed, assembled on-site or installed from reels on-site.

16.12.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— bending, maximum bending stresses and accumulated bending strain;

— compression loads and buckling;

— fatigue incurred during temporary phases;

— buoyancy requirements;

— environmental effects during temporary phases;

— minimum tension requirements;

— vortex induced vibrations (VIV).

Threaded joints should be specifically considered with the aim to enhance resistance to bending and to facilitate handling operations.

16.12.3 Pre-installed phase

Pre-installed tendons should be continuously monitored during the period from pre-installation to structure hook-up. In particular, precaution should be taken to ensure that

— interference from other vessels is avoided;

— interference with other pre-installed tendons is avoided;

— tension is always maintained in the tendons.

16.13 Mooring installation manual

A mooring installation manual and supporting document should be prepared for the operation and issued for information and approval, as appropriate. The items found in 6.5.2 and 17.18 shall be included in the mooring installation manual and supporting documents.

17 Offshore installation operations

17.1 Introduction

17.1.1 General

The requirements, guidance and recommendations for marine operations involved in the offshore installation of structures, topsides, subsea templates and similar objects are provided in 17.1.2 to 17.18. Additional information can be found in ISO 19902:2007[29], Clause 22.

17.1.2 Design

Operations shall be designed in accordance with the contents of Clause 17. Results from analyses, tests and any other required design activities shall be documented. Minimum requirements on tolerances of installation shall be defined.

17.2 Installation site

17.2.1 Sea floor survey

A bathymetric survey of the site sea floor area shall be carried out to determine bottom topography, confirm cleanliness of the site and provide up-to-date and accurate information for the installation design.

Measurements locating pre-existing structures shall be performed.

17.2.2 Soil survey

Site-specific geophysical and geotechnical data shall be made available to design and plan the installation operations.

17.3 Actions on and motions of floating units

The following aspects shall be considered, as appropriate:

— environmental actions and induced motions of floating units;

— actions resulting from external or internal hydrostatic pressures;

— actions imposed from translation and rotation of the object;

— actions resulting from earth pressure;

— actions from lifting operations;

— actions imposed during set-down;

— actions imposed when passing through the splash zone.

Model tests can be considered as part of the design to substantiate analytical results to alert the designer to unanticipated responses and to indicate the levels of design margins for the findings of computer modelling assessment.

17.4 Systems and equipment

17.4.1 General

Guidelines for the selection of operational systems and equipment in general are given in Clause 5 and Clause 6. Considerations regarding specific items of systems and equipment are given in 17.4.2 to 17.4.6.

17.4.2 Vessels

The installation operation can be a direct continuation of the offshore transportation, using the transportation fleet as the core of the installation fleet.

17.4.3 Position monitoring system

Normally, two independent on-board positioning monitoring systems (PMSs) shall be utilized for operational monitoring and control purposes. 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.

Where underwater accuracy is important, at least one PMS shall be an underwater, hydro-acoustic reference system.

17.4.4 Ballast systems

Ballast systems shall be considered as the prime operational systems on floating units for installation purposes, where draught, trim, heel and stability are vital for a successful operation; see Clause 10 for further guidelines.

17.4.5 Transport vessel interface with marine equipment

If the transport vessel is a launch barge, cargo barge or motor vessel, consideration shall be given to handling and positioning during the installation activity.

17.4.6 Floating structure interface with marine equipment

The floating structure can be level, inclined or horizontal with respect to its final attitude, and consideration shall be given to the methods for handling the marine equipment.

17.5 Launching

17.5.1 General

Launching can be performed by means of either longitudinal or, less commonly, sideways sliding of the structure from a barge or other floating unit.

17.5.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— stability (see also 9.9.3), strength and hydrodynamic characteristics of the launch barge or unit and the launched object;

— ranges of both weight and CoG position;

- water depth at the launch site;
- sea floor clearance;
- launch barge stern submergence and tilt beam reactions;
- skidway friction, at rest and moving;
- anti-self launch plates;
- minimization of sea fastening to simplify launch procedures;
- method of initiating launch;
- contingencies for failure modes;
- weather restrictions;
- boarding of launch barge during operation.

17.5.3 Preparations at fabrication yard

Activities for consideration at the fabrication yard shall be

- installation of pre-installed handling and positioning lines;
- pre-installation of installation aids;
- fastening of pre-installed rigging, handling and positioning lines, etc., so that it can withstand transportation and launch actions;
- commissioning of operational systems and equipment;
- checking of launch barge systems;
- provision of temporary access for installation activities;
- verification that operational systems and closures are in the proper condition/orientation;
- leak testing of all intact compartments and closure devices;
- provision of positive pressure in all intact compartments.

17.5.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

- position of barge and tugs in attendance;
- launch direction relative to the wind and current directions;
- environmental conditions;
- draught, heel, trim and stability of the launched object.

Prior to initiation of the jacking operations that lead to free sliding of the object being launched, draught, trim, ballast and stability of the launch barge are adjusted and set.

17.6 Float-off

17.6.1 General

For the float-off of an object from a transport barge or vessel, the transport barge or vessel shall be ballasted so that the object can be floated off. The transport barge or vessel can be level or inclined in this operation, the latter tending towards a launch, but controlled to avoid dynamic effects.

17.6.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

- stability, strength and hydrodynamic characteristics of the float-off barge or vessel and the object being floated off;
- ranges of both weight and CoG position;
- water depth at offload site;
- barge draught and submergence required for float-off;
- object/barge or object/vessel interaction during float-off, including friction forces;
- structure floating stability, including damage cases;
- release and recovery of sea fastening;
- position control of object and barge or vessel throughout;
- contingencies for failure modes.

17.6.3 Preparations at the fabrication yard

Activities for consideration at the fabrication yard shall include, as appropriate,

- installation and checking of rigging;
- installation of pre-installed handling and positioning lines;
- fastening of pre-installed rigging, handling and positioning lines, etc., so that they can withstand transportation and launch actions;
- commissioning of float-off systems and equipment;
- checking of float-off barge systems.

17.6.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

- barge trim and draught;
- barge ballast and stability parameters;
- all intact compartments, for example by means of air pressure;
- position of barge and tugs in attendance;

— orientation in relation to wind and current directions;

— environmental conditions;

— draught, heel, trim and stability of the offloaded object.

17.7 Upending

17.7.1 General

Upending of a horizontally floating object to the vertical can be carried out in a number of ways, such as

— no intervention during upending, in a self-upend, after initiation of gravity flooding;

— with intervention during upending, by controlled gravity flooding, or by pumped flooding, or a combination of both;

— with intervention during upending, by crane assisted control alone or in combination with controlled gravity flooding.

17.7.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

— stability (see also 9.9.3), strength and hydrodynamic characteristics of the upended object throughout the operation;

— water depth at upending location;

— bottom clearance during the upending;

— clearance from underwater objects and mooring lines of other vessels;

— provision of accessible control systems for flooding;

— system operation during all stages of upending;

— safe access to work locations;

— provision of accessible fill lines for external ballasting system;

— failure modes and effect analysis (damaged tank scenarios);

— compartmentation and contingencies.

17.7.3 Preparations at the fabrication yard/offload location

Preparations should be considered at the fabrication yard and offload location for the commissioning and checking of operational systems and equipment.

17.7.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

— draught, heel, trim and stability of the upended object;

— sea floor clearance;

— ballasting rate;

— ballasted weight;

— mode of operational valves;

— crane hook load;

— environmental conditions;

— position of the upended object, tugs and command vessel in attendance;

— provision of a tug control line or lines to mitigate lack of stability, if appropriate.

17.8 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 10.

17.9 Lifting and lowering by external means

17.9.1 General

Lifting and lowering operations are generally carried out by derrick barge cranes, but can also be achieved by numerous types of equipment using specially rigged rotary, traction and linear winch systems. The lifting systems should conform to accepted classification standards.

For detailed information on lifting operations, see Clause 18.

17.9.2 Operational aspects

17.9.2.1 Aspects for consideration during planning and design shall include, as appropriate,

— interaction between the lift vessel, crane(s), lift rigging, structure being lifted and transport barge or vessel during the lift, until the structure being lifted is free of the barge or vessel;

— structure weight and CoG and sensitivity to variations in these parameters;

— dynamic actions if the structure passes through the wave zone;

— added mass effects and dynamics of the lowering system, in the case of lowering an item to the sea floor;

— hook load and lowering system capacity;

— lift rigging specification, testing and design; see Clause 18;

— positioning;

— provision of anti-twist systems or suitable arrangements to overcome problems due to the natural rotation induced by the lay of wire ropes.

For detailed operational aspects, see Clause 18.

17.9.2.2 Twisting of hoist wire depends on

— geometry of reeving (spacing between individual falls);

— construction of wire rope;

— length of wire rope;

— length of suspended reeving.

17.9.3 Fabrication yard

Rigging and equipment for lifting shall be prefitted. 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.

17.9.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during lifting and lowering:

— hook load;

— hook lowering 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, above water and under water.

17.10 Lowering by ballasting

17.10.1 General

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.

17.10.2 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 deballasting methods if required;

— 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.

17.10.3 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.

17.11 Precise positioning on the sea floor by active and passive means

17.11.1 General

For precise positioning of objects on the sea floor (close to existing structures), active 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.

17.11.2 Operational 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;

— structural and geotechnical design of docking pile(s) and bumpers, where appropriate;

— operational and accidental actions on docking pile(s) and bumper(s), where appropriate;

— applicable procedure for touchdown, e. g. using a small inclination to aid precise positioning of the object;

— on-bottom stability of the object at set-down and prior to fixing it in place, e. g. using a large inclination at the initiation of set-down to maintain stability of the object during the final lowering period.

17.11.3 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 lines;
- dynamic behaviour of the lowered object.

17.12 Skirt penetration

17.12.1 General

For general information and design issues of skirts, see ISO 19901-4, ISO 19902[29] and ISO 19903[35].

17.12.2 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.

17.12.3 Suction penetration

Suction penetration is achieved by creating an underpressure in the skirt compartments to generate a downward action.

17.12.4 Operational 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;
- 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.

17.12.5 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.

17.13 Underbase grouting

17.13.1 General

The voids within the skirt compartments between the base of a gravity structure and the sea floor are commonly filled with grout to improve the structure's foundation capacity.

17.13.2 Operational 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.

17.13.3 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.

17.13.4 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.

17.14 Piling

17.14.1 General

Guidance is provided in 17.14 on the installation of piles securing structures to the seabed. For the installation of anchor piles, see 16.6.

Steel structures are generally secured to the seabed by open-ended tubular steel piles that are welded, grouted or swaged 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; see ISO 19902[29].

Piles are normally lowered from above the water to the sea floor by stabbing them through a leg, or 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.

17.14.2 Operational 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 equipment for piles;

- free head for handling of piles and piling equipment;
- guiding system 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 swaging piles to the structure, if applicable.

17.14.3 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;
- 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.

17.15 Attachment to pre-laid mooring system

17.15.1 General

Pre-laid mooring systems can be used with various types of floating structures, such as FPSOs, FPSs, FPSSs, and DDFs, whether or not designed as weathervaning.

17.15.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

- survey of the pre-laid mooring system immediately prior to hook-up;
- recovery of attachment points to the pre-laid mooring system;
- temporary and/or permanent connections along the mooring lines;
- access to messenger lines (wires and chains), and their storage on drums or in lockers;
- failure modes and effects analysis;
- tugs and stationkeeping configuration;
- stationkeeping tolerances;
- direct tension measurement system with adequate accuracy (as opposed to indirect tension measurement through hydraulic pressure, etc.);
- management of twist in lines during installation, including procedure to remove twist in a practical manner;
- presence of other marine vessels and equipment;
- requirements for temporary power and control capabilities on the floating structure being connected to the pre-laid mooring system;
- components of the pre-laid mooring system used during attachment of the floating structure;
- interface of pre-laid mooring system with other marine operations;
- minimum number of mooring lines required to make the floating structure safe against a storm;
- connection sequence to the pre-laid mooring system, taking account of forecast environmental conditions;
- spares, repair kits and contingency plans for connection, as applicable.

17.15.3 Preparation at the fabrication yard

Activities for consideration at the fabrication yard shall include

- pre-fitting of forerunners, messenger lines and temporary structures assisting the attachment;
- installing back-up systems for critical handling and holding systems;
- checking, testing and commissioning of equipment.

17.15.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during the connection operation:

- environmental conditions, during the operation and as forecast;
- speed of paying out or retracting wires and chain;
- handling time to make connections;
- position of the floating structure;
- tension in attached mooring lines;
- post-installation inspection.

17.16 Connection to a tendon system

17.16.1 General

TLPs are commonly attached to the seabed using a tendon system. TLP tendons are either pre-installed as described in Clause 16 or assembled on-site by lowering and connecting tendon segments.

17.16.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate,

- towing and positioning of the marine spread assembled for the connection of the TLP, as applicable;
- transfer of the TLP from towing mode to stationkeeping mode;
- equipment for handling and joining segmented tendons;
- equipment for handling and lowering tendon segments;
- protection of unconnected tendons;
- protection of tendons during installation;
- make-up method for the connection of tendon segments and possible handling restrictions;
- make-up method for connecting tendons to the foundation and to the hull of the TLP;
- downflooding points on or inside the TLP hull;
- stability and positioning of the TLP during the connection of the tendons;
- stationkeeping method and associated tolerances;
- tendon tensioning equipment, including jacking and ballasting/deballasting systems;
- duration of tendon connection operations versus available weather window;
- number of tendon connections required to make the structure safe against a storm.

17.16.3 Preparation at the fabrication yard

Actions for consideration at the fabrication yard shall include

— prefitting towlines and positioning lines;

— checking, testing and commissioning of equipment.

17.16.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during the connection operation:

— environmental conditions, during the operation and as forecast;

— handling time to make tendon connections;

— position of the TLP being connected;

— tension in connected tendons;

— post-installation inspection.

17.17 Offshore completion

17.17.1 General

Completion of the installation of GBSs can require the addition of heavy ballast to internal and/or external compartments, as well as the application of anti-scour measures around the base.

When the installation of the support structure has been finalized, topsides can be installed; see Clauses 15 and 18.

17.17.2 ROV inspection

After completion of the installation, an ROV survey shall be carried out according to an agreed plan to check for possible damage and debris. To facilitate the survey, the structures are generally suitably marked for reference purposes prior to the installation.

The following items, wherever applicable, shall be inspected and checked for damage:

— paint coatings;

— anodes;

— grout outside skirts (for GBSs);

— risers and other pipework;

— temporary, decommissioned underwater systems;

— scouring of the top soil layers.

17.17.3 Removal of temporary equipment

Temporary equipment shall be removed in accordance with plans agreed to as part of the operational planning and design phase.

17.17.4 Anti-scour for GBSs

Depending on the geometry of the base and local current conditions, the foundations of GBSs can require the application of anti-scour measures, such as graded rock, gravel and/or mattresses.

17.17.5 Heavy ballasting offshore

If it is required to add heavy ballast offshore, solid ballast can be pumped dry or as a slurry into internal tanks, or it can be piped or dumped in a controlled manner into external open tanks.

17.18 Installation manual

Before the start of the installation, an installation manual and supporting documentation should be prepared for the operation and should be issued for information and approval, as appropriate. Items included in the installation manual and supporting documents, in addition to those in 6.5.2, are listed in Clause A.5.

18 Lifting operations

18.1 Introduction

Clause 18 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. Onshore lifts by land-based cranes are also included when they form part of a marine operation such as a loadout.

Additional information on lifting operations can be found in ISO 19902:2007[29], Clauses 8 and 22.

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.

a) Lift points can be of various types, including the following:

   1) padeyes (3.63), 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;

   2) trunnions (3.97), 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;

   3) padears (3.62), which are similar to trunnions, but in which rotation of the sling is not intended.

b) Lifting equipment (rigging) between the lift point(s) and the crane hook(s) includes

   1) Slings, which can be divided into three types:

      i) steel slings, which are either

         — steel wire rope slings (SWRS) (3.90) of single wire rope construction, or

         — steel cable-laid slings (SCLS) (3.87) of cable-laid construction;

      ii) fibre rope slings (FRS) (3.32) of various types of construction;

2) Grommets, which can be divided into

   i) steel wire rope grommets (SWRG) (3.89), which are always of cable-laid construction;

   ii) fibre rope grommets (FRG) (3.31), the construction of which can vary;

3) Shackles;

4) Spreader bars and spreader frames (3.85).

Where appropriate, the particular type of sling or grommet is indicated by the abbreviated designation shown above.

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 and 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 details and in terminology used.

Both methods are allowed. The PFD method is the method underlying the entire ISO 19900 series of standards for offshore structures 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 18.3; resistances (strengths) are discussed in 18.4. Design checks according to the PFD and WSD methods are specified in 18.5.

In addition to the design checks for strength, recommendations and guidance on certain design aspects and operational considerations for lifting operations are given in 18.6 to 18.12.

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, WLL) divided by specific safety factors.

18.2 Rigging geometry

In general, the rigging geometry shall be configured such that the maximum tilt of the lifted structure does not exceed 2°. The tangent of the tilt angle is equal to the ratio of the horizontal distance between the hook and the CoG of the lifted structure in plan and the vertical distance between the hook and the CoG of the lifted structure.

In special circumstances, e.g. for lifted flare booms, flare towers and cantilevered modules, the angle of tilt may exceed 2° to permit the effective use of installation aids. Such lifted structures shall be reviewed as special cases.

18.3 Actions and action effects

18.3.1 General

In accordance with common terminology in the field of reliability of structures that is used throughout the ISO 19900 series of standards, basic variables (3.8) are assigned nominal (3.57), representative (3.67) and design values (3.24).

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 18.3.2 to 18.3.7. Design values of actions and action effects are given in 18.3.8.

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 part of ISO 19901 is the "dynamic" lift weight in accordance with 3.46. Further, in accordance with common terminology in the ISO 19900 series of standards, W_{lw} is, henceforth, referred to as the nominal lift weight. Analogously, in accordance with 3.42, the hook load, F_{hl}, in this part of ISO 19901 is the "dynamic" hook load, and F_{hl} is, henceforth, referred to as the nominal hook load.

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 centre of gravity, contingencies and other circumstances. These factors are identically applied in PFD and WSD methods. Consequence factors (3.15) 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 working load limits (WLL) in 18.4.1 and on structural analysis by the WSD method in 18.5.4.3.

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 18.3.8.

18.3.2 Weight contingency factors

18.3.2.1 For the weight contingency factors, reference is made to Clause 8 and to ISO 19901-5[28].

18.3.2.2 For class A weight control (see 8.3), weight contingency factors shall be applied to the following weights.

a) Calculated weight: For a 50/50 weight estimate (3.107) derived in accordance with ISO 19901-5[28], a weight contingency factor, k_{wcf}, of not less than 1,05 shall be applied. The extreme CoG envelope (where applicable) shall be used.

b) Weighed weight: A weight contingency factor, k_{wcf}, of not less than 1,03 shall be applied to the final weighed weight. This value may be reduced if a certificate is produced from a competent body stating, for the specific case in question, that the weighing accuracy is better than 3 %.

The gross weight (3.40) is the calculated or weighed weight including the weight contingency factors given in a) or b) above. The gross weight, W, is determined from Equation (8) using the calculated weight and $k_{wcf} \geqslant 1{,}05$, or from Equation (9) using the weighed weight and, generally, $k_{wcf} \geqslant 1{,}03$:

$$W = k_{wcf} \times W_{cw} \tag{8}$$

$$W = k_{wcf} \times W_{ww} \tag{9}$$

where

k_{wcf} is the weight contingency factor;

W_{cw} is the calculated weight;

W_{ww} is the weighed weight.

18.3.3 Dynamic amplification factors

18.3.3.1 General

The gross weight from Equation (8) or Equation (9) is the static weight at rest of the object being lifted. However, the lift weight (3.46) 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 (3.29), denoted by k_{DAF}.

DAF values differ with circumstances and apply to lifts made in air. DAF values for lifts made by a single crane on a vessel are given in 18.3.3.2. For lifts made simultaneously by two cranes on the same vessel the values given in 18.3.3.2 may be used as a guide, but they should be increased by an operation-specific factor, if appropriate. DAF values for lifts made by more than one crane, with each crane on a separate vessel, are discussed in 18.3.3.3.

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 either

— 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.

18.3.3.2 For lifts by a single crane on a vessel

For offshore lifts with one 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}, (3.46) shall be derived using Equation (10) with a dynamic amplification factor, k_{DAF}, from Table 15:

$$W_{lw} = k_{DAF} \times W \tag{10}$$

where W is the gross weight.

Table 15 — DAF for a single crane on a vessel [42]

Mass of lifted object[a] tonnes	Gross weight, W kN	k_{DAF} in air			
		offshore	inshore	onshore[b]	
				moving	static
⩽ 100	$W \leqslant 1\,000$	1,30	1,15	1,15	1,00
from 100 to 1 000	$1\,000 < W \leqslant 10\,000$	1,20	1,10	1,10	1,00
from 1 000 to 2 500	$10\,000 < W \leqslant 25\,000$	1,15	1,05	1,05	1,00
from 2 500	$25\,000 < W$	1,10	1,05	1,05	1,00

[a] This column is included to facilitate the comparison with weight reporting.

[b] Lifts by land-based cranes involved with marine operations such as loadouts.

For onshore lifts, where the crane can move horizontally, the “moving” column in Table 15 shall apply. The “static” column shall apply only if there is no crane movement other than luffing and slewing. The definitions of the movement of a crane with a suspended load are as follows.

a) “Moving” is horizontal translation of the whole crane, by crawling or other means, without luffing and slewing.

b) “Luffing” is raising the crane boom up and down, without moving and slewing.

c) “Slewing” is rotating the crane on the turntable, without moving and luffing.

18.3.3.3 For lifts by cranes on two or more vessels

Unless operation-specific calculations show otherwise, for offshore lifts by cranes on two or more similar vessels, the k_{DAF} in Table 15 shall be multiplied by a further factor of 1,1. If the crane vessels are not similar and have different natural periods, operation-specific calculations should be carried out.

For inshore lifts by cranes on two or more vessels in totally sheltered waters, the factors in Table 15 shall apply with no further multiplier for the multiple vessel condition.

For onshore lifts by two or more cranes, the k_{DAF} factors in Table 15 shall apply with no further factor for the multiple crane conditions.

18.3.4 Representative hook load

18.3.4.1 For 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 Equation (10) with the dynamic amplification factor, k_{DAF}, given in 18.3.3. However, forces in slings and the total load on the crane are governed by the nominal hook load, F_{hl}, (3.42) given by Equation (11):

$$F_{hl} = W_{lw} + k_{DAF} \times W_{rw} \quad (11)$$

where

W_{lw} is the nominal lift weight;

W_{rw} is the rigging weight (see 3.72).

The rigging weight, W_{rw}, includes all items between the lift points and the crane hook, including slings, grommets, shackles and spreaders, as well as a contingency as appropriate.

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 Equation (11):

$$F_{rhl} = F_{hl} \quad (12)$$

18.3.4.2 For two-hook lifts by two cranes

For a two-hook lift, the nominal hook load, F_{hl}, from Equation (11) 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 Equation (13):

$$F_{rhl,i} = k_{sf} \times k_{tf} \times F_{srhl,i} \quad (13)$$

where

$F_{srhl,i}$ is the nominal hook load, F_{hl}, from Equation (11), 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, and should be set equal to 1,03;

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, and should be set equal to 1,03.

18.3.5 Representative lift weight per lift point

18.3.5.1 One-hook lifts

For a one-hook lift, the nominal lift weight, W_{lw}, is given by Equation (10). 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 $W_{srlw,j}$, where $j = 1, 2, \ldots$, indicates the number of the lift point. The largest statically resolved lift weight per lift point is $\max(W_{srlw,j})$.

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 $k_{CoG} = 1,0$. If no CoG envelope is used a factor of $k_{CoG} = 1,02$ 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, $(W_{rlw})_{one\ crane}$, shall be taken in accordance with Equation (14):

$$(W_{rlw})_{one\ crane} = k_{CoG} \times \max(W_{srlw,j}) \quad (14)$$

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;

$\max(W_{srlw,j})$ is the largest value for all j of the statically resolved lift weight, $W_{srlw,j}$, acting on lift point j.

18.3.5.2 Two-hook lifts

For a two-hook lift by two cranes, the statically resolved lift weight on crane hook i, $W_{srlw,i}$, for i equal to 1 or 2, can be derived from the equivalent of Equation (11), applied in reverse to the hook load and rigging weight on crane hook i, as given in Equation (15):

$$W_{srlw,i} = F_{srhl,i} - k_{DAF} \times W_{rw,i} \quad (15)$$

where

$F_{srhl,i}$ is the nominal hook load, F_{hl}, from Equation (11), statistically resolved between crane hooks 1 and 2;

$W_{rw,i}$ is the rigging weight associated with crane hook i;

k_{DAF} is the dynamic amplification factor from 18.3.3, including the multiplier from 18.3.3.3 where applicable.

$W_{srlw,i}$ is next 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 $\max(W_{srlw,i,j})$.

In addition to the uncertainties described in 18.3.5.1, 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, $(W_{rlw})_{two\ cranes}$, shall, therefore, be taken in accordance with Equation (16):

$$(W_{rlw})_{two\ cranes} = k_{CoG} \times k_{yaw} \times \max(W_{srlw,i,j}) \quad (16)$$

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;

$\max(W_{srlw,i,j})$ is the largest value, for all i and all j, of the statically resolved lift weight, $W_{srlw,i,j}$, 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.

18.3.6 Representative forces on a lift point

18.3.6.1 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 Equation (14) or Equation (16), as applicable, multiplied by a skew load factor, k_{skl}. The skew load factor (3.78) 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 Equation (17) for one-hook lifts by one crane or by Equation (18) for two-hook lifts by two cranes:

$$P_{rvf} = k_{skl} \times (W_{rlw})_{one\ crane} \quad (17)$$

$$P_{rvf} = k_{skl} \times (W_{rlw})_{two\ cranes} \quad (18)$$

The difference in length for a matched pair of slings shall not exceed $0,5d$, where d is the diameter of the sling; see IMCA M179. 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 $k_{skl} = 1,25$ shall be applied to each diagonally opposite pair of lift points in turn, see Reference [42].

For statically determinate lifts, $k_{skl} = 1,05$ may be used, provided it can be demonstrated that the sling length deviations do not significantly affect the force distribution in the lift system.

For a lift system incorporating one or more floating spreader bars that act as a sling force equalizing system, $k_{\text{skl}} = 1{,}1$ 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.

18.3.6.2 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 Equation (19):

$$P_{\text{rdf}} = \frac{P_{\text{rvf}}}{\sin\theta} \qquad (19)$$

where

P_{rvf} is the representative vertical force on a lift point from Equation (17) or Equation (18);

θ is the angle between the sling and the horizontal plane; normally the sling angle is restricted to (a minimum of) 60°.

18.3.6.3 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 Equation (20) shall be applied perpendicular to the lift point:

$$P_{\text{rlf}} = k_{\text{lf}} \times P_{\text{rdf}} + P_{\text{clf}} \qquad (20)$$

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 Equation (19);

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 centre and along the axis of the pinhole in the padeye, or at the trunnion/padear geometric centre; see Reference [42].

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, $k_{\text{lf}} = 0{,}05$ may be used.

The lateral force factor may be reduced if a lower value can be shown to provide similar levels of safety.

18.3.7 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 Equation (21):

$$F_{rsf} = F_{rgf} = P_{rdf} + \frac{k_{DAF} \times W_s}{\sin\theta} \tag{21}$$

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 Equation (19);

k_{DAF} is the DAF in accordance with 18.3.3, including the multiplier from 18.3.3.3 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 Equation (21), 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, $F_{rsf,2\ parts}$, and the representative force for one leg of the grommet, $F_{rgf,1}$, shall, hence, be taken in accordance with Equation (22):

$$F_{rsf,2\ parts} = F_{rgf,1} = 0{,}55 F_{rsf} \tag{22}$$

where F_{rsf} is the representative sling force from Equation (21).

18.3.8 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 18.3.4 to 18.3.7 by partial action factors as given in Equations (23) to (31):

$$(F_{dhl})_{PFD} = \gamma_{f,hl} \times F_{rhl} \tag{23}$$

$$(F_{dhl,i})_{PFD} = \gamma_{f,hl} \times F_{rhl,i} \tag{24}$$

$$(F_{dsf})_{PFD} = \gamma_{f,s} \times F_{rsf} \tag{25}$$

$$(F_{dsf,2\ parts})_{PFD} = \gamma_{f,s} \times F_{rsf,2\ parts} \tag{26}$$

$$(F_{dgf,1})_{PFD} = \gamma_{f,s} \times F_{rgf,\ 1} \tag{27}$$

$$(F_{dgf})_{PFD} = \gamma_{f,s} \times F_{rgf} \tag{28}$$

$$(P_{dvf})_{PFD} = \gamma_{f,P} \times P_{rvf} \tag{29}$$

$$(P_{ddf})_{PFD} = \gamma_{f,P} \times P_{rdf} \tag{30}$$

$$(P_{dlf})_{PFD} = \gamma_{f,P} \times P_{rlf} \tag{31}$$

where the subscript P represents one of three different subscripts depending on the element to which the action or action effect is applied.

a) P represents “lp” when applied to lift points and attachment of lift points to the structure.

b) P represents “mf” when applied to members directly supporting or framing into the lift points.

c) 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 Equations (32) to (40):

$$(F_{\text{dhl}})_{\text{WSD}} = F_{\text{rhl}} \tag{32}$$

$$(F_{\text{dhl},i})_{\text{WSD}} = F_{\text{rhl},i} \tag{33}$$

$$(F_{\text{dsf}})_{\text{WSD}} = F_{\text{rsf}} \tag{34}$$

$$(F_{\text{dsf,2 parts}})_{\text{WSD}} = F_{\text{rsf,2 parts}} \tag{35}$$

$$(F_{\text{dgf,1}})_{\text{WSD}} = F_{\text{rgf,1}} \tag{36}$$

$$(F_{\text{dgf}})_{\text{WSD}} = F_{\text{rgf}} \tag{37}$$

$$(P_{\text{dvf}})_{\text{WSD}} = P_{\text{rvf}} \tag{38}$$

$$(P_{\text{ddf}})_{\text{WSD}} = P_{\text{rdf}} \tag{39}$$

$$(P_{\text{dlf}})_{\text{WSD}} = P_{\text{rlf}} \tag{40}$$

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;

$F_{\text{dsf,2 parts}}$ is the design sling force for each part of a two-part sling;

$F_{\text{dgf,1}}$ is the design force for one leg of a grommet;

F_{dgf} is the design grommet force (for a complete grommet);

$\gamma_{\text{f,s}}$ 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;

$\gamma_{\text{f,lp}}$ is the partial action factor for the forces on a lift point when designing the lift points themselves and their attachment to the structure;

$\gamma_{\text{f,mf}}$ 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;

$\gamma_{\text{f,m}}$ 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 16 shall be applied.

Table 16 — Partial action factors, γ_f

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	$\gamma_{f,m} = 1,00$

18.4 Strengths of slings, grommets and shackles

18.4.1 General

For design verification, strengths (resistances) are assigned a representative value (3.67). If available data allow the determination of a characteristic value (3.13) for strength, this is the preferred representative value; otherwise, a nominal value (3.57) for strength serves as the representative value. In design verification by the PFD method, design values (3.24) for strength (resistance) are derived from the corresponding representative value by dividing the latter by a partial resistance factor. In design verification by the WSD method, design values for strength are referred to as working load limits (see following); they are derived from the corresponding representative strength value by dividing this by a safety factor.

As noted in 18.1, the WSD method is the method normally used for design verification of lifting operations. For consistency with existing practice, a number of terms that are in common use in practical applications are defined as follows and hereafter maintained in the discussion:

a) F_{min}:

The value F_{min} is a specified value, expressed in kilonewtons, below which the measured breaking strength of a rope, F_m, is not allowed to fall in a prescribed breaking strength test; see ISO 17893:2004[45]. F_{min} is normally calculated in the manner described in ISO 2408:2004[43], ISO 17893:2004[45] and EN 12385-4:2002[44].

A calculated value is defined in ISO 17893:2004[45] as a value obtained by calculation, based on given or measured values and on conventional factors.

b) Calculated rope breaking load:

The calculated rope breaking load, CRBL, is the calculated strength in force terms of a plain, straight rope after production, including the reduction in strength due to spinning losses during the manufacturing process. When applied to a manufactured sling, CRBL refers to the calculated strength of the body of the sling excluding end terminations and losses associated with application of the sling. The calculated strength of a plain straight rope and of the body of a sling are their respective representative strengths.

c) Calculated grommet breaking load:

A grommet is an endless sling with two legs. The calculated strength of each leg is given by the calculated rope breaking load, CRBL, so that the calculated strength of the complete grommet, CGBL, is two times the CRBL of a grommet's leg. The CGBL, the calculated strength of a complete grommet in force terms, is the representative strength of the body of a grommet, excluding losses associated with application of the grommet.

d) Calculated sling breaking load:

The calculated sling breaking load, CSBL, is the representative strength of a manufactured sling in force terms, including the reduction in strength due to end terminations (expressed by the termination efficiency factor). CSBL is often recorded on a sling certificate with its identification ferrule for a straight sling.

e) Working load limit:

The working load limit, WLL, (3.106) is the maximum load for which a sling, grommet, shackle or lift point is designed in accordance with the WSD method. The WLL is the design strength (also referred to generally as the allowable value) for use in design verification by the WSD method. It is obtained by dividing the representative strength by a safety factor, f_{SF}. The allowable strength value for structural components in the lifted object can be further reduced by the application of a consequence factor (3.15).

The design strength in design verification by the PFD method is obtained analogously by dividing the representative strength by a partial resistance factor, γ_R. Numerical values of the safety factor in WSD and the partial resistance factor in PFD are related by the relationship $f_{SF} = \gamma_f \times \gamma_R$.

For slings and grommets, calculated strengths are given in 18.4.2, representative strengths in 18.4.5 and design strengths in 18.4.6. The strength of shackles is presented in 18.4.7.

NOTE An object being lifted can be specified by its weight, in force units (kilonewtons), or by its mass, in mass units (metric tonnes); these differ by a factor of the acceleration of gravity, g: mass equals weight divided by g. Mass units (metric tonnes) are often used in lifting operations. Working load limits and design strengths in force units (kilonewtons) are converted into masses by dividing by g.

18.4.2 Calculated strengths of the bodies of slings and grommets

18.4.2.1 Steel wire rope slings

Steel wire rope slings, SWRS, are made from a single steel wire rope with various end terminations (3.90). The minimum breaking strength, F_{min}, of a steel wire rope is the value specified by the manufacturer for the particular type of rope, or the value obtained by calculation (see 18.4.1). For steel wire rope with a diameter $d \leqslant 60$ mm, the minimum breaking strength, F_{min}, expressed in kilonewtons, is calculated from Equation (41) that is given in ISO 2408:2004[43], ISO 17893:2004[45] and EN 12385-4:2002[44]:

$$F_{min} = \frac{d^2 \times R_t \times K}{1\,000} \tag{41}$$

where

d is the nominal diameter of the rope, expressed in millimetres;

R_t is the rope grade (tensile strength grade of the wires), expressed in newtons per square millimetre; EN 12385-4:2002[44] specifies that, for diameters up to 60 mm, the rope grade shall be 1 770 N/mm^2, 1 960 N/mm^2 or 2 160 N/mm^2, or an intermediate grade specified by the manufacturer, but not exceeding 2 160 N/mm^2;

K is an empirical factor for the minimum breaking strength for a given rope class and core type; for rope classes of 8×19 and 8×36 construction, both with a steel core, $K = 0{,}346$.

NOTE $K = 0{,}346$ differs from ISO 2408:2004[43] where, for these rope classes, a value of 0,356 is given.

For diameters from 60 mm to 264 mm, EN 12385-4:2002[44] states that the identification of a rope grade is no longer applicable, but that the tensile strength grades of the wires shall be 1 770 N/mm^2, 1 960 N/mm^2 or 2 160 N/mm^2, or a combination thereof. For steel wire rope with $d > 60$ mm, the minimum breaking strength, F_{min}, expressed in kilonewtons, is calculated as given by Equation (42):

$$F_{min} = 8{,}55\, d + 0{,}592\, d^2 - 0{,}000\,615\, d^3 \tag{42}$$

The value of F_{min} that is specified by the manufacturer can be higher than that calculated from Equation (41) or Equation (42). In such cases, the higher value provided by the manufacturer may be used, as long as it can be properly documented.

The calculated strength, CRBL, of the body of a steel wire rope sling, $F_{\text{CS, SWRS}}$, in force terms is equal to F_{min}, as given by Equation (43):

$$F_{\text{CS, SWRS}} = F_{\text{min}} \tag{43}$$

18.4.2.2 Steel cable-laid slings

Steel cable-laid slings (SCLS) (3.87) are normally constructed from six stranded steel wire ropes, helically wound around one straight core steel wire rope, and are provided with spliced eye end terminations.

Cable-laid slings shall be constructed and used in accordance with IMCA M 179. The nominal diameter of the core rope should be at least 12 % but not more than 25 % larger than the nominal diameter of the outer ropes.

The CRBL of the body of a steel cable-laid sling, in force terms, $F_{\text{CS, SCLS}}$, is given by Equation (44):

$$F_{\text{CS,SCLS}} = 0{,}85 \times \sum F_{\text{min}} \tag{44}$$

where

$\sum F_{\text{min}}$ is the sum of the minimum breaking strengths of the outer ropes and the core rope; see 18.4.2.1;

0,85 is an empirical factor accounting for the additional spinning losses in manufacturing a cable-laid sling from the separate wire ropes.

The value of $F_{\text{CS,SCLS}}$ (CRBL) is normally directly taken from the manufacturer's specification.

18.4.2.3 Steel wire rope grommets

Grommets are always of cable-laid construction. Steel wire rope grommets (SWRG) (3.89) shall be constructed and used in accordance with IMCA M 179. The locations of the butt and the tuck positions shall be marked by red paint.

The core rope of a steel wire rope grommet is discontinuous at the butt and tuck positions and, for that reason, the core rope shall be excluded in calculating the grommet's calculated strength. The CRBL of one leg of a steel wire rope grommet, $F_{\text{CS,SWRG,1}}$, in force terms, is given by Equation (45):

$$F_{\text{CS,SWRG,1}} = 0{,}85 \times 6 \times F_{\text{min}} \tag{45}$$

where

$6 \times F_{\text{min}}$ is the accumulated minimum breaking strength of the six outer ropes of one leg of the grommet (see 18.4.2.1), excluding the core rope;

0,85 is an empirical factor accounting for the additional spinning losses in manufacturing the cable-laid grommet from the separate wire ropes.

The calculated strength (CGBL) of the complete steel wire rope grommet, $F_{\text{CS,SWRG,2}}$, in force terms, is given by Equation (46):

$$F_{\text{CS,SWRG,2}} = 2 \times F_{\text{CS,SWRG,1}} \tag{46}$$

The value of $F_{\text{CS,SWRG,2}}$ is normally directly taken from the manufacturer's specification.

18.4.2.4 Fibre rope slings and fibre rope grommets

The CRBL of fibre rope slings (FRS) (3.32) with various types of construction and the CGBL of fibre rope grommets (FRG) (3.31) shall be taken as the breaking strength given on the certificate based on rope tensile destruction tests.

Analogous to 18.4.2.1 to 18.4.2.3, the CRBL of a fibre rope sling is denoted by $F_{\text{CS,FRS}}$. The CRBL of one leg of a fibre rope grommet is similarly denoted by $F_{\text{CS,FRG,1}}$, while the CGBL of the complete fibre rope grommet is denoted by $F_{\text{CS,FRG,2}}$, the value of which is twice $F_{\text{CS,FRG,1}}$. All values are in force terms.

18.4.3 Termination efficiency factor

18.4.3.1 Steel wire rope slings and steel cable-laid slings

The end termination is invariably the weakest point of steel wire rope slings (SWRS) and steel cable-laid slings (SCLS). The reduction in strength of the sling as a whole compared to the body of the sling is accounted for by applying a termination efficiency factor, k_{te}, to the calculated strength (CRBL) from 18.4.2.1 and 18.4.2.2.

The termination efficiency factor, k_{te}, shall be applied as given in the specifications provided by the manufacturer. For certain end terminations of steel wire rope slings and of steel cable-laid slings, the following maximum values may be used as guidance:

k_{te} = 1,00 for resin sockets;

k_{te} = 0,90 for swage fittings on Flemish eyes;

k_{te} = 0,75 for steel ferrules (mechanical termination);

k_{te} = 0,75 for hand splices.

Other methods of termination require special consideration.

18.4.3.2 Fibre rope slings

For fibre rope slings (FRS), the termination efficiency factor shall normally be the value specified by the manufacturer.

18.4.3.3 Steel wire rope grommets and fibre rope grommets

As grommets are endless, loop-shaped slings without end termination, a termination efficiency factor is not applicable.

18.4.4 Bending efficiency factor

18.4.4.1 Steel wire rope slings and steel cable-laid slings

Where a wire rope sling is bent around a shackle, trunnion, padear or crane hook, the strength of the sling is locally reduced by bending. The reduction in strength of the sling is accounted for by applying a bending efficiency factor, k_{be}, to the calculated strength (CRBL) from 18.4.2.1 and 18.4.2.2.

The bending efficiency factor, k_{be}, for steel wire rope slings (SWRS) and steel cable-laid slings (SCLS) can be calculated by Equation (47):

$$k_{\text{be}} = 1{,}0 - 0{,}5\Big/\sqrt{(D/d)} \quad (47)$$

where

d is the nominal diameter of the wire rope sling or the cable-laid sling;

D is the minimum diameter over which the sling is bent.

Values calculated using Equation (47) are summarized in Table 17.

Table 17 — Bending efficiency factors, k_{be}, for steel wire rope slings and steel cable-laid slings

D/d	< 1,0[a]	1,0	1,5	2,0	3,0	4,0	5,0	6,0	7,0
k_{be}	< 0,50	0,50	0,59	0,65	0,71	0,75	0,78	0,80	0,81

[a] Not permitted.

In order to avoid even limited permanent deformation of a sling, a D/d ratio of at least 4,0 should be used. The body of a sling shall not be bent around a diameter less than 2,5d. D/d ratios smaller than 2,5 are applicable only to sling eyes. However, a sling eye shall not be bent around a diameter less than the diameter of the sling to avoid excessive permanent deformation of the eye.

Bending in the way of splices shall be avoided.

18.4.4.2 Steel wire rope grommets

Grommets are endless, loop-shaped slings that are used with one end connected to a lift point (typically a trunnion or padear) and one end laid over the crane hook. The bending efficiency factor for a steel wire rope grommet (SWRG) may be calculated from Equation (47) or determined from Table 17 for the lesser D/d ratio, taking d as the nominal diameter of one leg of the grommet and D as the smaller of the diameters over which the sling is bent at the lift point or the crane hook.

For a standard ratio of $D/d = 4{,}0$, a bending efficiency factor $k_{be} = 0{,}75$ may be used (see 18.4.4.1). It should be noted that the bending efficiency factors at the lift point and at the crane hook usually differ as a result of different values of D. If one or both of the bending efficiency factors is/are smaller than 0,75, the smaller value reflecting the more severe reduction in strength shall be used at both ends.

Bending in the way of grommet butt or tuck positions shall be avoided.

18.4.4.3 Fibre rope slings and fibre rope grommets

For fibre rope slings (FRS) and fibre rope grommets (FRG), the bending efficiency factor, k_{be}, normally may be taken as 1,00, provided the bending diameter, D, is not less than the minimum specified by the manufacturer. Alternatively, the bending efficiency factor specified by the manufacturer may be used.

18.4.5 Representative strengths of slings and grommets

18.4.5.1 Steel wire rope slings and steel cable-laid slings

The representative strength of a manufactured sling includes the loss in strength caused by end terminations and/or bending around a shackle, trunnion, padear or crane hook. The representative strength of a steel wire rope sling, SWRS, $F_{RS,SWRS}$, in force terms, is given by Equation (48):

$$F_{RS,SWRS} = \min(k_{te} \times F_{CS,SWRS}, k_{be} \times F_{CS,SWRS}) \quad (48)$$

where $F_{CS,SWRS}$ is determined from Equation (43) or the value specified by the sling manufacturer and $\min(a, b)$ indicates the smaller value of a or b.

Analogously, the representative strength of a steel cable-laid sling, SCLS, $F_{RS,SCLS}$, in force terms, is given by Equation (49):

$$F_{RS,SCLS} = \min(k_{te} \times F_{CS,SCLS}, k_{be} \times F_{CS,SCLS}) \tag{49}$$

where $F_{CS,SCLS}$ is determined from Equation (44) or the value specified by the sling manufacturer.

The values of k_{te} and k_{be} shall be in accordance with 18.4.3.1 and 18.4.4.1.

18.4.5.2 Steel wire rope grommets

The representative strength of a steel wire rope grommet, SWRG, $F_{RS,SWRG}$, in force terms, is given by Equation (50):

$$F_{RS,SWRG} = k_{be} \times F_{CS,SWRG,2} \tag{50}$$

where $F_{CS,SWRG,2}$ is determined from Equation (46) or directly taken from the manufacturer's specification. The value of the bending efficiency factor, k_{be}, shall be taken in accordance with 18.4.4.2.

18.4.5.3 Fibre rope slings and fibre rope grommets

The representative strength of a fibre rope sling, FRS, $F_{RS,FRS}$, in force terms, is given by Equation (51):

$$F_{RS,FRS} = \min(k_{te} \times F_{CS,FRS}, k_{be} \times F_{CS,FRS}) \tag{51}$$

where $F_{CS,FRS}$ is the corresponding breaking strength given on the manufacturer's certificate (see 18.4.2.4). The values of k_{te} and k_{be} shall be taken in accordance with 18.4.3.2 and 18.4.4.3.

Analogously to a steel wire rope grommet [see Equation (50)], the representative strength of a fibre rope grommet, FRG, $F_{RS,FRG}$, in force terms, is given by Equation (52):

$$F_{RS,FRG} = k_{be} \times F_{CS,FRG,2} \tag{52}$$

where $F_{CS,FRG,2}$ is determined in accordance with 18.4.2.4. The bending efficiency factor, k_{be}, shall be taken in accordance with 18.4.4.3.

18.4.6 Working load limits and design strengths of slings and grommets

18.4.6.1 Steel wire rope slings and steel cable-laid slings

The WLL, F_{WLL}, of a steel wire rope sling (SWRS) or a steel cable-laid sling (SCLS) for design verification by the WSD method are given by Equations (53) and (54), respectively:

$$F_{WLL,\,SWRS} = \frac{F_{RS,\,SWRS}}{f_{SF,\,SWRS}} \tag{53}$$

$$F_{WLL,\,SCLS} = \frac{F_{RS,\,SCLS}}{f_{SF,\,SCLS}} \tag{54}$$

where

$F_{WLL,SWRS}$	is the WLL of a steel wire rope sling, in force terms;
$F_{RS,SWRS}$	is the representative strength of a steel wire rope sling from Equation (48);
$f_{SF,SWRS}$	is the safety factor for a steel wire rope sling, which shall be taken as

$f_{SF,\ SWRS} \geqslant 3$ for sling diameters equal to or larger than 50 mm (2 in),

$f_{SF,\ SWRS} \geqslant 5$ for sling diameters smaller than 50 mm (2 in);

$F_{WLL,SCLS}$ is the WLL of a steel cable-laid sling, in force terms;

$F_{RS,SCLS}$ is the representative strength of a steel cable-laid sling from Equation (49);

$f_{SF,SCLS}$ is the safety factor for a steel cable-laid sling, which shall be taken as equal to or greater than 2,25.

The design strength of a steel wire rope sling and of a steel cable-laid sling for design verification by the PFD method are analogously given by Equations (55) and (56), respectively:

$$F_{DS,\ SWRS} = \frac{F_{RS,\ SWRS}}{\gamma_{R,\ SWRS}} \tag{55}$$

$$F_{DS,\ SCLS} = \frac{F_{RS,\ SCLS}}{\gamma_{R,\ SCLS}} \tag{56}$$

where, in addition to the definitions above,

$F_{DS,SWRS}$ is the design strength of a steel wire rope sling, in force terms;

$\gamma_{R,SWRS}$ is the partial resistance factor for a steel wire rope sling;

$F_{DS,SCLS}$ is the design strength of a steel cable-laid sling, in force terms;

$\gamma_{R,SCLS}$ is the partial resistance factor for a steel cable-laid sling.

The partial resistance factors are related to the safety factors by the relationship $f_{SF} = \gamma_{f,s} \times \gamma_R$; see 18.4.1 and 18.3.8. Consequently,

$\gamma_{R,SWRS} \geqslant 3/1{,}3 = 2{,}31$ for steel wire rope slings with diameters $d \geqslant 50$ mm (2 in);

$\gamma_{R,SWRS} \geqslant 5/1{,}3 = 3{,}85$ for steel wire rope slings with diameters $d < 50$ mm (2 in);

$\gamma_{R,SCLS} \geqslant 2{,}25/1{,}3 = 1{,}74$ for steel cable-laid slings.

18.4.6.2 Steel wire rope grommets

The WLL of a steel wire rope grommet (SWRG) (for design verification by the WSD method) and the design strength of a steel wire rope grommet (for design verification by the PFD method) are given by Equations (57) and (58), respectively:

$$F_{WLL,\ SWRG} = \frac{F_{RS,\ SWRG}}{f_{SF,\ SWRG}} \tag{57}$$

$$F_{DS,\ SWRG} = \frac{F_{RS,\ SWRG}}{\gamma_{R,\ SWRG}} \tag{58}$$

where

$F_{WLL,SWRG}$ is the WLL of a steel wire rope grommet, in force terms;

$F_{DS,SWRG}$ is the design strength of a steel wire rope grommet, in force terms;

$F_{RS,SWRG}$ is the representative strength of a steel wire rope grommet from Equation (50);

$f_{SF,SWRG}$ is the safety factor for a steel wire rope grommet, which shall be taken as equal to or greater than 2.25;

$\gamma_{R,SWRG}$ is the partial resistance factor for a steel wire rope grommet, which shall be taken as follows:

$$\gamma_{R,SWRG} \geqslant f_{SF,SWRG} / \gamma_{f,s}$$
$$= 2{,}25/1{,}3$$
$$= 1{,}74.$$

18.4.6.3 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 Equations (59) and (60), respectively:

$$F_{WLL,\,FRS} = \frac{F_{RS,\,FRS}}{f_{SF,\,FRS}} \quad (59)$$

$$F_{DS,\,FRS} = \frac{F_{RS,\,FRS}}{\gamma_{R,\,FRS}} \quad (60)$$

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 Equation (51);

$f_{SF,FRS}$ is the safety factor for a fibre rope sling, which shall be taken as equal to or greater than 4,75;

$\gamma_{R,FRS}$ is the partial resistance factor for a fibre rope sling, which shall be taken as follows:

$$\gamma_{R,FRS} \geqslant f_{SF,FRS} / \gamma_{f,s}$$
$$= 4{,}75/1{,}3$$
$$= 3{,}65.$$

18.4.6.4 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 Equations (61) and (62), respectively:

$$F_{WLL,\,FRG} = \frac{F_{RS,\,FRG}}{f_{SF,\,FRG}} \quad (61)$$

$$F_{DS,\,FRG} = \frac{F_{RS,\,FRG}}{\gamma_{R,\,FRG}} \quad (62)$$

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 Equation (52);

$f_{SF,FRG}$ is the safety factor for a fibre rope grommet, which shall be taken as equal to or greater than 4,75;

$\gamma_{R,FRG}$ is the partial resistance factor for a fibre rope grommet, which shall be taken as follows:

$$\gamma_{R,FRG} \geqslant f_{SF,FRG}/\gamma_{f,s}$$
$$= 4{,}75/1{,}3$$
$$= 3{,}65.$$

18.4.7 Working load limit and design strength of shackles

The minimum breaking strength (MBS) (3.55) of a shackle is a certified strength that may be taken as its representative strength.

The WLL, F_{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 Equations (63) and (64), respectively:

$$F_{WLL,\,sh} = \frac{F_{RS,\,sh}}{f_{SF,\,sh}} \tag{63}$$

$$F_{DS,\,sh} = \frac{F_{RS,\,sh}}{\gamma_{R,\,sh}} \tag{64}$$

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 as equal to or greater than 3,0;

$\gamma_{R,sh}$ is the partial resistance factor for a shackle, which shall be taken as follows:

$$\gamma_{R,sh} \geqslant f_{SF,sh}/\gamma_{f,s}$$
$$= 3{,}0/1{,}3$$
$$= 2{,}31.$$

18.5 Design verifications

18.5.1 Allowable hook load

For a one-hook lift by a single crane, the design hook load, $(F_{dhl})_{PFD}$, from Equation (23) or $(F_{dhl})_{WSD}$ from Equation (32) 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 Equation (24) or $(F_{dhl,i})_{WSD}$ from Equation (33) shall not exceed the allowable crane capacity at the required radius from the crane's load-radius curve for both $i = 1$ and $i = 2$.

Load-radius curves for cranes are generally given in terms of safe working loads, which term is equivalent to the working load limit defined in 3.106. 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 can be confirmed, the design hook load for checking against the load-radius curves may be determined excluding the dynamic amplification factor. The nominal hook load, F_{hl}, from Equation (11) is then replaced by a nominal hook load, F_{hl}*, given by the sum of the gross weight, W, and the rigging weight, W_{rw}.

The basis of the load-radius curves shall be carefully reviewed to ensure consistency with the intended application, particularly for offshore operations.

18.5.2 Slings and grommets

18.5.2.1 General

The fundamental requirement is that the design forces for slings and grommets shall not exceed their corresponding design strengths.

18.5.2.2 One-part slings

A one-part sling shall satisfy Equation (65) when designed in accordance with the PFD method or Equation (66) when designed in accordance with the WSD method:

$$(F_{\mathrm{dsf}})_{\mathrm{PFD}} \leqslant F_{\mathrm{DS,Y}} \tag{65}$$

$$(F_{\mathrm{dsf}})_{\mathrm{WSD}} \leqslant F_{\mathrm{WLL,Y}} \tag{66}$$

where

F_{dsf} is the design sling force for a one-part sling from Equation (25) or Equation (34);

$F_{\mathrm{DS,Y}}$ is the design strength of a sling of type Y, where Y refers to the sling types SWRS, SCLS or FRS, in force terms;

$F_{\mathrm{WLL,Y}}$ is the working load limit 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 Equations (55), (56) and (60); the corresponding working load limits are given by Equations (53), (54) and (59).

18.5.2.3 Two-part slings

By full analogy, a two-part sling shall satisfy Equation (67) when designed in accordance with the PFD method or Equation (68) when designed in accordance with the WSD method:

$$(F_{\mathrm{dsf,2\ parts}})_{\mathrm{PFD}} \leqslant F_{\mathrm{DS,Y}} \tag{67}$$

$$(F_{\mathrm{dsf,2\ parts}})_{\mathrm{WSD}} \leqslant F_{\mathrm{WLL,Y}} \tag{68}$$

where, in addition to the definitions in 18.5.2.2, $F_{\mathrm{dsf,2\ parts}}$ is the design force for each part of a two-part sling from Equation (26) or Equation (35).

The design strengths and working load limits are given by the same equations as for a one-part sling.

18.5.2.4 Grommets

The design strengths and working load limits of the two legs of a grommet are identical and equal to half the design strength and working load limit of the complete grommet. However, just as for a two-part sling, the two grommet legs can be subjected to different design forces (see 18.3.7). Design verification shall, therefore, be based on the most heavily loaded leg of a grommet.

One leg of a grommet shall satisfy Equation (69) when designed in accordance with the PFD method or Equation (70) when designed in accordance with the WSD method

$$(F_{\text{dgf,1}})_{\text{PFD}} \leqslant 0{,}5 \times F_{\text{DS,Y}} \tag{69}$$

$$(F_{\text{dgf,1}})_{\text{WSD}} \leqslant 0{,}5 \times F_{\text{WLL,Y}} \tag{70}$$

where

$F_{\text{dgf,1}}$ is the design force for one leg of a grommet from Equation (27) or Equation (36);

$F_{\text{DS,Y}}$ is the design strength of a grommet of type Y, in force terms;

$F_{\text{WLL,Y}}$ is the working load limit of a grommet of type Y, in force terms;

Y refers to the grommet types SWRG or FRG.

The corresponding design strengths are given by Equations (58) and (62); the corresponding working load limits are given by Equations (57) and (61).

18.5.3 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 Equation (71) or Equation (72), as appropriate, when designed in accordance with the PFD method, or either Equation (73) or Equation (74), as appropriate, when designed in accordance with the WSD method:

$$(F_{\text{dsf}})_{\text{PFD}} \leqslant F_{\text{DS,sh}} \tag{71}$$

$$(F_{\text{dgf}})_{\text{PFD}} \leqslant F_{\text{DS,sh}} \tag{72}$$

$$(F_{\text{dsf}})_{\text{WSD}} \leqslant F_{\text{WLL,sh}} \tag{73}$$

$$(F_{\text{dgf}})_{\text{WSD}} \leqslant F_{\text{WLL,sh}} \tag{74}$$

where

F_{dsf} is the design sling force for a one-part sling from Equation (25) or Equation (34);

F_{dgf} is the design force for a complete grommet from Equation (28) or Equation (37);

$F_{\text{DS,sh}}$ is the design strength of a shackle, in force terms, from Equation (64);

$F_{\text{WLL,sh}}$ is the working load limit of a shackle, in force terms, from Equation (63).

Where the shackle is at the lower end of the rigging, the weight of the rigging components above the shackle (including DAF and accounting for the sling angle) may be deducted from the rigging weight when determining the appropriate design sling force.

18.5.4 Lift points and their attachment to the structure and supporting members

18.5.4.1 General

The overall structure, the primary members supporting lift points and the lift points themselves shall be analyzed for structural integrity. Structural calculations shall be based on adequate modelling of the entire structure, including appropriate detail of the local structure around lift points. The structural analysis shall further include a number of well-defined load cases sufficient to ensure structural integrity during the envisaged lifting operation. By way of example, for an indeterminate four-point lift, the following load cases should normally be considered:

a) a base case using the lift weight resolved to the lift points, without the skew load factor;

b) a second case using the lift weight with the skew load factor applied to one diagonal;

c) a third case using the lift weight with the skew load factor applied to the other diagonal.

Sling angles and points of application of applied actions shall be modelled as accurately as possible. Any offset or torsional action imposed by the unequal (45 % to 55 %) distribution of forces between the two legs of a two-part sling or grommet shall be duly considered.

When lift points are incorporated in a structural joint, the analysis shall include the forces imposed by members framing into the lift point as well as any eccentric actions caused by the offset of a lift point to the structural joint.

18.5.4.2 Structural analysis by the PFD method

The overall structure shall be analyzed first for all relevant load cases, including those mentioned in 18.5.4.1, using PFD design forces (P_{dvf}, P_{ddf} and P_{dlf}) that are applied to the lift points, as computed from Equations (29), (30) and (31), as appropriate, and the partial action factor, $\gamma_{\mathrm{f,m}}$. Members directly supporting or framing into the lift points shall next be examined for the most severe load case(s) from the overall analysis, using PFD design forces that are applied to the lift points and the partial action factor $\gamma_{\mathrm{f,mf}}$. Finally, the lift points themselves and their attachments to the structure shall further be examined for the most severe load case(s) from the overall analysis, using PFD design forces applied to the lift points and the partial action factor $\gamma_{\mathrm{f,lp}}$.

Because the results of the analysis should be in the elastic range, the design checks for the members directly supporting or framing into the lift points and for the lift points themselves can be easily performed by multiplying the results of the overall analysis by $\gamma_{\mathrm{f,mf}}/\gamma_{\mathrm{f,m}}$ and $\gamma_{\mathrm{f,lp}}/\gamma_{\mathrm{f,m}}$, respectively, provided that the structural model includes adequate detail around the lift points.

For further details of the structural analysis, for any simultaneously applied actions with their associated partial action factors over and above those from the lifted object, and for applicable partial resistance factors, reference is made to ISO 19902[29].

18.5.4.3 Structural analysis by the WSD method

The analysis procedure is the same as for the PFD method, except that in this case the WSD design forces (P_{dvf}, P_{ddf} and P_{dlf}) on the lift points are computed from Equations (38), (39) and (40), as appropriate.

For lifting operations, the allowable stresses that are normally associated with a structural analysis shall be reduced by applying the partial action factors in Table 16 as additional safety factors (consequence factors). The allowable stresses for structural members away from the lift points shall be reduced by dividing them by the factor $\gamma_{\mathrm{f,m}}$. The allowable stresses for members directly supporting or framing into the lift points shall be reduced by dividing them by the factor $\gamma_{\mathrm{f,mf}}$. The allowable stresses in the lift points themselves and their attachments to the structure shall be reduced by dividing them by the factor $\gamma_{\mathrm{f,lp}}$; see 18.3.8.

18.6 Lift point design

18.6.1 Introduction

In addition to the structural requirements in 18.1 to 18.5, it is recommended that, at an early stage of the design of the lift points, the designer consult the marine contractor to ensure the strength and dimensions of the connections of the lift points to the structure are adequate.

18.6.2 Sling ovalization

Adequate clearance shall be maintained between cheek plates or inside trunnion keeper plates to allow for sling ovalization under applied actions. In general, the width available for the sling shall be not less than $1{,}25\,d + 25$ mm, where d is the nominal sling diameter, expressed in millimetres. However, the practical aspects of the rigging and derigging operations can demand a greater clearance than this, in which case the resulting eccentricities shall be considered in design.

For cast padears, the geometry of the padear shall be configured such as to fully support and maintain the sling geometry and shape under the applied actions.

18.6.3 Plate rolling direction and direction of loading

In general, for fabricated lift points, the direction of loading should be in line with the plate rolling direction. Lift point drawings should show the rolling direction.

Through-thickness loading of lift points and of their attachments to the structure should be avoided. If through-thickness loading cannot be avoided, the material used should be documented as being free from laminations, with a recognized through-thickness designation, or local ultrasonic testing should be performed.

18.6.4 Pinholes

Pinholes should be bored and reamed, and should be designed to suit the proposed shackle. Adequate spacer plates should be provided to centralize the shackles.

The following guidance is given for the diameter of the pin hole:

— for shackle pins with a diameter not exceeding 50 mm: $d_h = d_p + 2$ mm;

— for shackle pins with a diameter larger than 50 mm: $d_h \leqslant 1{,}04\, d_p$ but not exceeding $d_p + 4$ mm

where

d_p is the diameter of the shackle pin, expressed in millimetres;

d_h is the diameter of the shackle pinhole, expressed in millimetres.

18.6.5 Cast padears and welded trunnions

Cast padears and welded trunnions shall be designed taking into account the following aspects:

— geometrical considerations given in 18.6.2;

— load paths, trunnion geometry, space and support for slings and grommets, including effects caused by sling eccentricities;

— finite element design process (modelling and action application), where applicable;

— manufacturing process and quality control.

Sling-keeper plates shall be incorporated into the padear/trunnion design to prevent the loss of sling or grommet prior to and during lifting. These devices shall be proportioned to allow easy rigging and derigging whilst being capable of supporting the weight of the sling during transportation.

18.6.6 Cheek plates

Individual cheek plate thickness should preferably not exceed 50 % of the main plate thickness to maintain the primacy of the main plate in load transfer to the structure and to provide robustness to lateral forces. The individual cheek plate thickness shall in no case exceed 100 % of the main plate thickness.

Cheek plate welds shall be proportioned and designed with due regard to possible uneven bearing across the padeye/cheek plate thickness due to the design lateral force caused by combined known and unknown misalignments, as discussed in 18.3.6.3.

Non-loadbearing spacer plates may be used to centralize shackle pins to effectively increase the padeye thickness. Spacer plate internal holes shall be greater than the pinhole diameter; see 18.6.4.

18.7 Clearances

18.7.1 Introduction

The required clearances depend on the nature of the lift, the proposed limiting weather conditions, the arrangement of bumpers and guides, and the size and motion characteristics of the crane vessel and the transport barge.

Subject to the above, for offshore lifts, the clearances in 18.7.2 to 18.7.4 should normally be maintained at each stage of the operation. Smaller clearances can be acceptable for inshore or onshore lifts. Clearances are based on a level lift (no tilt) of the lifted object. Additional clearances can be required for objects with a prescribed tilt, or tilt due to misalignment of the hook and CoG.

The values for clearances given in 18.7.2 to 18.7.4 are derived from Reference [42]. Smaller values may be used if they can be shown to give the same level of confidence. These smaller values can result in weather-restricted lifting operations.

18.7.2 Clearances around lifted objects

The following guidance is given for clearances around lifted objects from the edges of the envelope of the motions of the lifted object:

- 3 m between any part of the lifted object (including spreaders and lift points) and the crane boom;
- 3 m vertical clearance between the underside of the lifted object and any other previously installed structure, except in the immediate vicinity of the intended landing area or of an installation aid, subject to installation aid clearances, if appropriate;
- 5 m between the lifted object and other structures on the same transport barge, unless specific bumpers and guides are used for lift-off;
- 3 m horizontal clearance between the lifted object and any other previously installed structure;
- 3 m remaining travel between travelling block and fixed block at maximum hoist elevation.

If purpose-built guides or bumpers are fitted for certain configurations, the clearances around the lifted object may be reduced.

18.7.3 Clearances around crane vessel

The following guidance is given for clearances around the crane vessel from the edges of the envelope of the crane vessel motions and mooring line motions to the obstruction (subsea or other asset).

Where the crane vessel is moored adjacent to an existing fixed structure, the following clearances apply:

- 3 m between any part of the crane vessel or crane and the fixed structure on which the lifted object will be placed;
- 5 m between any part of the crane vessel hull extremity or submerged lift and the fixed structure;
- 10 m between any anchor line of the crane vessel and the fixed structure.

Where the crane vessel is dynamically positioned, a clearance of 5 m between any part of the crane vessel and the fixed structure applies.

Clearances around the crane vessel, either moored or dynamically positioned, and any floating structure, drilling rig or submersible, shall be determined as special cases based on the stationkeeping analysis of the floating structure, drilling rig or submersible and the crane vessel.

A clearance of 3 m shall be maintained between the crane vessel keel (including thrusters if applicable) and the sea floor, after taking account of tidal conditions, vessel motions, increased draught and changed heel or trim during the lift.

Positioning equipment shall be designed and positioning procedures shall be defined to maintain minimum clearances for specific operations and minimum durations.

The values of clearances given above have been derived from Reference [42]. Reduced values may be used if special precautions are taken and if they can be shown to give the same levels of confidence. These reduced values can result in weather-restricted marine operations.

18.7.4 Clearances around mooring lines and anchors of crane vessels

The clearances stated below are given as guidance. The specific requirements and clearances should be defined for each project and operation, taking into account particular circumstances such as

- water depth;
- proximity of subsea assets;
- survey accuracy;
- stationkeeping ability of the anchor handling vessel;
- sea floor conditions;
- estimated anchor drag during embedment;
- single mooring line failure in the vessel stand-off position;
- probable weather conditions during anchor installation.

Owners and contractors can have their own requirements, which can differ from those stated below and which should govern if they are more conservative.

Clearances should take into account the possible working and stand-off positions of the crane vessel.

Moorings should never be laid in such a way that they can make contact with any subsea asset (i.e. pipeline, cable, umbilical, riser or subsea structure). This requirement may be relaxed when the subsea asset is a trenched pipeline, provided that it can be demonstrated that the mooring does not cause frictional damage or abrasion and that appropriate approvals can be obtained.

Moorings shall not be laid over the top of a subsea completion or wellhead.

Whenever an anchor is towed out from the crane vessel to its dropping position beyond a pipeline, flowline or umbilical, the anchor shall be securely stowed on the deck of the anchor handling vessel to minimize the chance of accidentally dropping the anchor. In circumstances where either gravity anchors or closed stern tugs are used and anchors cannot be stowed on deck, the anchors shall be double secured through the additional use of a safety strap or similar device.

The vertical clearance between any mooring line and any subsea asset should not be less than 20 m in water depth exceeding 40 m, and 50 % of the water depth in depths of less than 40 m.

Clearance between any mooring line and any structure other than a subsea asset should not be less than 10 m.

When an anchor of a crane vessel is placed between the vessel and an existing subsea asset, it should be at least 200 m away from the asset.

Relaxation of the clearance requirements can be considered for subsea installations in locations with abandoned assets.

When the subsea asset is located between an anchor and the crane vessel, a mooring layout with safe clearances should be deployed. Relaxation may be given depending on the water depth and the accuracy of the anchor handling management system.

During lifting operations, crossed mooring situations should be avoided. Where crossed moorings cannot be avoided, the separation between active catenaries should not be less than 30 m in water depth exceeding 100 m, and 30 % of the water depth in water depths of less than 100 m. These separations for crossed moorings also apply to the catenaries of steel catenary risers and umbilicals.

If any of the clearances specified above are impractical because of the mooring configuration or sea floor layout, a risk assessment of the reduced clearances shall be carried out to demonstrate that an adequate level of reliability is achieved involving special precautions, as necessary.

18.8 Bumpers and guides

18.8.1 Introduction

The arrangement and design philosophy for bumpers and guides assisting object installation shall be prepared by the marine contractor, where applicable. In general, bumpers and guides should be designed in accordance with 18.8.2 to 18.8.5.

18.8.2 Object movements

The maximum object movements during installation should be defined; they depend on the crane vessel and the local weather conditions. Typical values for maximum object motion amplitudes are:

a) vertical movements ± 1,00 m;

b) horizontal movements ± 1,50 m;

c) longitudinal tilt ± 2°;

d) transverse tilt ± 2°;

e) plan rotation ± 3°.

The plan rotation limit is applicable only when the object is close to its final position or adjacent to another structure on a cargo barge.

18.8.3 Position of bumpers and guides

The position of bumpers and guides shall be determined taking account of acceptable support points on the object(s).

Dimensional control reports of the as-built bumper and guide system shall be reviewed to ensure fit-up offshore.

Nominal clearances between bumpers/guides and pins/buckets shall be 25 mm to account for fabrication and installation tolerances. These may be reduced based on trial fits and/or a more stringent dimensional control regime.

18.8.4 Bumper and guide loads

An assessment of impact loads on bumpers and guides should be based on considerations of impact conditions and deformation energy, which should, in turn, be based on realistic assumptions of velocities, impact positions and deformation patterns.

In the absence of more detailed calculations, typical loadings for the design of bumpers and guides during offshore lifts are given in Table 18, as a percentage of W_{st}, where W_{st} is the static hook load, equal to the sum of the gross weight, W, and the rigging weight, W_{rw}.

The configurations of bumpers and guides given in Table 18 are explained in A.6.

Table 18 — Bumper and guide loading[a]

Vertical sliding bumpers	
Horizontally directed force in plane of bumper, F_h	0,10 W_{st}
Horizontally directed (friction) force out-of-plane of bumper, F_l	0,05 W_{st}
Vertically directed (friction) force, F_v	0,01 W_{st}
Pin/bucket guides	
Horizontally directed force on cone/end of pin, F_h	0,05 W_{st}
Vertically directed (or stabbing) force on inclined cone/end of pin, F_v	0,10 W_{st}
Horizontal “cow-horn” type bumpers with vertical guide	
Horizontally directed force in any direction, F_h or/and F_l	0,10 W_{st}
Vertically directed (friction) force, F_v	0,01 W_{st}
Vertical “cow-horn” type guide with horizontal bumper	
Horizontally directed force in any other direction, F_h or/and F_l	0,05 W_{st}
Vertically directed (stabbing) force on inclined face of guide	0,10 W_{st}

[a] See figures in Clause A.6.

For each of the configurations in Table 18, the loads in all relevant directions shall be combined to establish the most onerous loading condition.

For inshore lifts under controlled conditions, bumpers and guides may be designed to 70 % of the forces shown in Table 18.

18.8.5 Design considerations

The connections of bumpers and guides, and the members supporting bumper or guide locations, shall be at least as strong as the bumper or guide.

The stiffness of bumper and guide members should be as low as possible, in order that they can deflect appreciably without yielding.

Design of bumpers and guides shall cater for an easy sliding motion of the bumper when in contact with the guide. Sloping members should be at a well designed angle to the vertical. Ledges and sharp corners should be avoided on areas of possible contact, and weld beads shall be ground flush.

For bumpers and guides that are deemed to be “sacrificial”, the allowable stresses for member design in the WSD method may be increased. In the PFD method, the partial action factor may be reduced. No increase in allowable stresses or reduction of the partial action factor should be used in the design of the connections of the bumper and guide to the supporting structure.

18.9 Heave compensated lifts

Lifts performed using heave compensation should be reviewed with great care to ensure that equipment limitations and appropriate procedures have been correctly identified. In determining limiting sea states, any single point failure of the heave compensation system should be treated as an accidental event.

18.10 Lifts using DP

Lifts using DP shall be considered on a case-by-case basis, in accordance with industry best practice. Field-specific guidance shall be developed and operational limitations identified prior to the start of operations and shall be included in the field-specific operational guidelines document.

18.11 Practical considerations

18.11.1 Adequate and safe access shall be provided to cargo barges (either ladders or securely attached surfer landings to permit safe personnel access from a rigid inflatable boat) and to working platforms on the object being lifted for the connection of slings, particularly where connection or disconnection is required offshore or underwater.

18.11.2 Sea fastening on the transport barge that carries the lifted object should be designed to

— provide easy access;

— minimize offshore cutting;

— provide restraint after cutting;

— allow lift-off without fouling.

Cut lines should be clearly marked. Where a two-stage lift is planned involving two sets of cut lines (e.g. barge to SSCV followed by SSCV to final position), the cut lines should be in different colours.

18.11.3 Adequate equipment shall be available on the transport barge, including

— burning sets;

— tugger winches and lifting gear;

— means of securing loose sea fastening material;

— lighting for night operations;

— safety equipment for personnel.

Loose equipment, machinery, pipework and scaffolding shall be secured against movement during the lift, and their weights and positions shall be included in the gross weight.

Lifts shall not begin unless a suitable weather forecast has been received from an experienced weather forecaster for a duration that is adequate to complete the operation, including contingencies, and taking account of any subsequent critical marine operations.

18.11.4 The slings and their deployment shall satisfy the following requirements.

— The slinging arrangement is in accordance with accepted practice.

— The slings are matched as accurately as possible using matched pairs of slings unless the rigging arrangement is deliberately non-symmetrical to take account of the position of the CoG. Where minor mismatch in sling length exists, the slings should be arranged to minimize skew loads.

— The slings are adequately secured against barge motions prior to the start of the lift.

— The slings do not foul obstructions, such as walkways and handrails, when lifted, and any unavoidable obstructions are properly protected.

— The slings do not kink when lifted.

— After the lift operation, the slings (and spreaders if used) can be safely laid down without damage.

— Slings are marked with a white line along their length to aid installation and determine if the sling is twisted.

Slings with hand-spliced terminations should be prevented from rotation.

No bending should be allowed at or close to the termination of a sling; see also 18.4.4.1. For example, a shackle connecting two slings should not be located close to a padear or trunnion.

Slings may be shackled together end-to-end to increase the length. However, slings of opposite lay shall not be connected end-to-end.

The length of a sling may be increased by inserting extra shackles. Any shackle-to-shackle connection should be bow-to-bow, not pin-to-pin or pin-to-bow so that shackles remain centred under load and also during the load take-up.

Crane vessel motions should be monitored prior to the lift, to confirm that the dynamic behaviour is acceptable, taking into account the weight and size of the lifted object, the clearances for lifting off the transport barge, the hoisting speed, the clearances for installation and the installation tolerances.

Transport barge motions should be similarly monitored prior to the start of the lift. The change in attitude of the transport barge when the weight is removed should be taken into account.

18.12 Lifting operation manual

A lifting operation manual and supporting document should be prepared for the operation and issued for information and approval, as appropriate. Items that shall be included in the lifting operation manual and its supporting documents, as appropriate, are listed in 6.5.2 and 17.18.

19 Decommissioning and removal

19.1 Introduction

Clause 19 addresses provisions for the marine operations associated with decommissioning, removal and disposal of

— GBSs;

— piled steel structures, whether surface-piercing or subsea;

— floating structures, including their anchors and mooring systems, or tendons and foundations, as applicable;

— topsides;

— parts of the above structures.

The provisions of Clause 19 are not intended to limit the use of alternative methods of removal. For every removal operation, appropriate safety levels shall be discussed and agreed with the owners and the regulators, based on risk assessments as specified in Clause 5. In most cases, the consequences of damage and loss are not deemed to be as severe as if these occur during the installation of a new structure.

Removal options should be defined during the design of the structure. Any removal aids that are integrated into the structure should be installed at the time of construction, with a design service life exceeding the maximum foreseen operational life of the structure itself.

Selection of a removal option depends on several environmental, technical and economical parameters, including

— effect of removal and/or disposal on marine life, navigation and fishing activities;

— technical feasibility and risks;

— risk to personnel.

19.2 Removal planning

19.2.1 Surveys

In order to establish the condition of the structure, to confirm the feasibility of the approach to the removal and to define the necessary preparation measures, appropriate surveys shall be performed including, but not limited to the following:

— field survey of the topsides for compliance with as-built documentation, to assess changes in weight and centre of gravity of the topsides; the required accuracy of this assessment depends on the proposed lifting method(s) and on the tolerance of the lifting system to inaccuracy in CoG location and weight estimate;

— topsides equipment and piping survey, to identify potential requirements for decontamination and cleaning requirements and avoid pollution risk; generally, decontamination of topsides equipment and topsides is done onshore, and the purpose of this evaluation is to best determine how to split the process piping to avoid disturbing the process vessels. If vessels are removed separately, consideration can be given to the option of decontaminating them offshore;

— field survey of the topsides and support structure for actual structural condition;

— field survey of the condition of the structure in preparation for dismantling, identifying cutting locations and assessing the status of mooring, foundation and/or piles and pile-to-structure connections;

— assessment of the condition of ballasting systems and the possible need for reinstatement;

— field survey of wells, well protectors, drill cuttings and pipeline connections to risers; accumulations of cuttings on mudmats can significantly affect the lift weight of the structure; studies should be conducted to ascertain whether the environmental risk of disturbing the drill cuttings is more serious than the risk of simply leaving them undisturbed;

— field survey of debris around the platform;

— field survey of the offshore towing route to ensure that no obstructions are encountered for circumstances where a portion of the support structure can be towed, suspended beneath a barge or handling vessel.

19.2.2 Operational procedures

Prior to removal operations, step-by-step procedures should be developed, covering the marine aspects at all stages of the operations, such as

— preparation works before removal;

— specification of the removal spread and mooring arrangement, if necessary;

— topsides removal, sea fastening and transportation to disposal site;

— support structures removal, sea fastening and transportation to disposal site;

— marine operations at disposal site;

— marine operations for the completion works at the removal site and at the disposal site.

19.2.3 Deballasting

19.2.3.1 Solid ballast

If solid ballast is being removed from a support structure before removal and/or refloat, the method, equipment and procedures for this operation should be addressed in detail. The effect on stability shall also be analysed; see 19.2.4 and 19.2.6.

Two types of solid ballast are generally used: sand and iron ore. Both are installed in a slurry state. Clean sand is more practical to remove by jetting (if it has not been stabilized by cement). Removing it from a closed tank is not necessarily straightforward. Iron ore is normally dumped in open compartments, and, after a few years, removal can be very problematic due to caking.

19.2.3.2 Water ballast

The guidelines in Clause 10 apply for any water deballasting system and its operation. However, a simpler system with respect to capacity, flexibility and instrumentation can be acceptable, with reference to 19.1 and to the outcome of the risk assessment recommended in 5.6.

Retaining the deballasted water can be necessary for treatment and later disposal at an appropriate location.

A thorough commissioning of the deballast system shall be performed, especially if parts of the original ballast system used during the installation of the structure are being reused during removal.

It is not necessary to pump any sea water ballast discharged from a compartment that had no process piping in it, nor any exposure to contaminants, to the surface for treatment and discharging elsewhere. For such situations, samples should be tested, if practical, to determine discharge requirements.

19.2.4 Weight control

The weight of the parts of the structure being removed shall be established, based on information from the owner (see Clause 8). This information shall include the total weight and the CoG. The confidence level for the weight data shall be taken into account, in particular with respect to lifting.

A major concern is any increase in the weight of the structure during its life. The weight increases that affect the CoG can be due to various factors, such as marine growth, grout and/or soil adherence to foundation elements, accidental flooding of steel structure members and/or floating system compartments, or successive modifications and upgrading of topsides.

TLPs should be subject to an inclining test after disconnection of tendons, in order to check the changes in CoG before ballasting or draught changes are made afloat.

19.2.5 Structural checking

The structure’s resistance to actions induced by removal, transportation and disposal operations shall be checked, with due consideration to structural deterioration.

In addition, the structural verification should address reinforcements, new bracing, lifting points and lifting appliances and tugger line connections.

19.2.6 Stability checking

In case of removal of structures by floatation, the ballast configuration and any supplementary floatation arrangements shall be determined, with corresponding structural reinforcements.

Stability during floating phases of the removal shall be verified. As far as practical, non-reversible operations should be avoided.

19.2.7 Removal of fixed concrete structures

The structural strength as well as the stability during lift-off, deballasting phases and floating phases of the removal should be verified; see Clause 9.

The underbase suction can create special hydrodynamic effects at lift-off, which should be assessed and accounted for in the removal operational planning. The possibility of ascertaining the hydrostatic stability of the structure by means of an inclining test during removal should be investigated. Stability information should be available from historical data. The sensitivity of the trim and stability to the CoG data during the critical phases of the removal operation should be checked. The consequences on stability and control of a sudden, partial or full loss of any underbase grout during the operation should be assessed.

If water injection underneath the platform is necessary, the consequences on stability and structural strength should be checked.

19.2.8 Mooring and towing aids

For the design of the temporary offshore mooring of a structure, the requirements and guidance in Clause 13 are applicable. Requirements and guidance for towing arrangements and tugs are given in Clause 12.

19.2.9 Transportation to and offloading at an offshore disposal site

The following aspects shall be investigated:

— stability, structural strength and sea fastening during transportation on a cargo barge or a removal barge;

— offloading by skidding, trailers or lifting, as applicable;

— floating condition, stability and structural strength of the structure in case of towing.

19.2.10 Offloading at an onshore dismantling site

The following options for offloading at an onshore dismantling site should be considered:

— offloading from barge to quay by skidding or by trailers; see Clause 11;

— offloading by lifting; see Clauses 17 and 18.

The above does not preclude other options, such as a salvage company dismantling the structure on the barge at the quayside.

19.3 Preparation for removal

19.3.1 Decontamination and cleaning

Decontamination of topsides equipment, tanks and piping as further described in 19.3.2 to 19.3.5, should normally be done onshore. For special cases, e.g. where the topsides is toppled *in-situ*, decontamination operations can be conducted offshore.

This decontamination operation includes but is not limited to

— the purging and flushing of vessels and piping used in the storage, gathering, processing and transport of hydrocarbons, chemicals and contaminated water;

— the identification, removal and disposal of naturally occurring radioactive material (NORM) or low specific activity (LSA) material, asbestos, polychlorinated biphenyl (PCB), scale, or other contaminants.

19.3.2 Pipeline disconnection

After their decommissioning, pipelines, risers, flowlines, etc., shall be disconnected from the structure and removed as necessary.

19.3.3 Structural preparation

The following structural preparations shall be considered:

— reinforcement of the structure when necessary;

— preparation of lift points and lifting appliance connection(s) and any other handling aids such as air tugger or winch connections on the parts being removed by lifting;

— temporary guides, if necessary, for removal part by part;

— structural piping disconnections between parts being removed;

— conductor severing below mudline;

— mooring disconnection and removal of mooring lines;

— anchor retrieval or suction pile removal;

— pile severing;

— rigging of structures to avoid unexpected movement as cutting proceeds as a result of, for example, dynamic overload or loss of static stability.

19.3.4 Preparation of removal equipment

The equipment being used for removal shall be mobilized, commissioned and tested. The equipment includes, but is not limited to,

— power supply, temporary accommodation and services;

— deballast system;

— additional buoyancy tanks, when required for floatation;

— equipment to overcome in a controlled manner any suction effects between the seabed and the structure or its appurtenances during a refloat operation;

— operational control and monitoring equipment;

— tow equipment;

— marine equipment, including crane vessels, barges and tugs.

19.3.5 Onshore disposal site

With respect to marine operations, the reception facilities at the onshore disposal site should, as a minimum, include

— adequate water depth;

— mooring and craneage facilities;

— quayside for offloading.

19.4 Removal

19.4.1 Introduction

Key aspects of a removal operation include

— lifting and handling of heavy and/or awkward structures;

— minimizing and checking the feasibility of subsea cutting activities (large steel thickness and deepwater cutting);

— barge or removal vessel workability in the local environmental conditions (motion amplitude, critical period, heave compensation device, stationkeeping);

— load transfer and duration of critical phases of dismantling;

— deballasting system preparation and operation for floatation;

— hydrodynamic and hydrostatic stability of the structure if free floating;

— overcoming any suction effects under a GBS before float-up;

— soil or grout adhesion underneath the base of a GBS structure or within its skirt compartments; this can affect its submerged weight and buoyancy, or change the buoyancy should it come off during the lifting operation.

19.4.2 Cutting activities

The cutting of conductors, caissons, piles, skirt piles, bracings, etc., before dismantling can be performed by explosives, abrasive water jetting, diamond wire, mechanical or other methods.

The selection of the cutting method depends on the item being cut, its location, the practicality of doing it remotely with ROVs and environmental concerns, and shall take into account

— safety of personnel by minimizing the human intervention during critical phases;

— cutting sequence and the static stability of structures;

— reliability of explosive charges in case of postponed operation;

— access to interior of piles below mudline;

— detection of unsuccessful cuts;

— ability to confirm cuts;

— duration of the cutting activities.

NOTE Attention is also drawn to regulatory requirements.

19.4.3 Removal by lifting

Conceptually, topsides removal is a procedure similar to the reverse of the original installation procedure. In some cases, it can be identical. However, the number, size and order of lifts can well be different based on the equipment available at the time of abandonment.

The guidelines of Clause 18 apply to the topsides removal operations.

Small support structures can be removed in one piece by lifting. When dismantling by small pieces or parts, the structural integrity and stability of the structure at each step should be maintained. However, for abandonment, structural integrity should mean only that the structure has the reserve and residual strength to be lifted safely. Local damage and redistribution of forces is acceptable as removing the structure in an undamaged state is not necessary.

19.4.4 Removal by floatation

19.4.4.1 Steel structures

Structures that were originally self-floating can be lifted off the sea floor and brought back to a stable floating condition using appropriate deballasting systems combined with additional buoyancy elements. After floatation, the structure is towed to the disposal site.

Structures that were not originally self-floating can also be removed by floatation methods by attaching auxiliary buoyancy. After floatation, the structure is towed to the disposal site.

19.4.4.2 GBSs

Tests should be performed to check that the system for refloating, including controls and monitoring, is able to properly perform the operation.

The structure is raised off the sea floor and set into a floating configuration by deballasting, in a reverse sequence compared to the installation.

19.4.4.3 Floating structures

The structure should be ballasted, if required, to disconnect the permanent mooring and/or tendon system. An inclining test should then be performed to find or confirm the vertical position of the CoG before further adjustments are made, as appropriate, to ensure stability during its tow to the disposal site; see 19.2.4.

19.4.5 Toppling

Toppling consists of severing selected members, usually by a sequential explosion of charges, such that the structure collapses to the sea floor.

The risks involved in cutting activities and appropriate contingency procedures should be duly considered.

19.5 Transportation and disposal

Transportation operations shall comply with Clause 12, paying particular attention to specific aspects of structure transportation after dismantling, such as

— stability and sea fastening of parts of structures on cargo barges, and integrity during transportation;

— stability and floating configuration during towing of the (immersed) structure.

The structures should be disposed, either at sea or onshore, by lifting, launching or another method. In any case, the method and geographic location for the disposed structure are normally subject to governmental consideration and approval.

19.6 Site clearance

After removal, the site should be cleared of debris. The degree of debris removal depends on the water depth, the practicality and safety of debris removal, as well as on regulatory requirements.

Annex A
(informative)

Additional information and guidance

A.1 General

This annex provides additional information and guidance on selected subclauses in the body of this part of ISO 19901.

NOTE 1 In this part of ISO 19901, the verbal forms “shall” and “shall not” are used to indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

NOTE 2 In this part of ISO 19901, the verbal forms “should” and “should not” are used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

NOTE 3 In this part of ISO 19901, the verbal form “may” is used to indicate a course of action permissible within the limits of the document.

NOTE 4 In this part of ISO 19901, the verbal forms “can” and “cannot” are used for statements of possibility and capability, whether material, physical or causal.

A.2 Guidance for 6.6.2: Required or recommended documentation

The guidance on the required or recommended documentation is presented in Table A.1 and describes the principal types of documentation for various types of vessels and floating structures. The description is keyed to the line number in Table 1, which also summarizes the applicability of the documentation.

Table A.1 — Description of the principal types of documentation for various types of vessels and floating structures

Line in Table 1	Document	Guidance
1	Certificate of registry	The certificate of registry contains the details from the flag state register in which the vessel has been registered, including principal dimensions, tonnage and ownership. The certificate of registry is issued by the flag state register. Certain vessels, particularly in domestic service, do not have a certificate of registry.
2	Certificates of class (hull and machinery)	Vessels and their machinery that are built and maintained in accordance with the RCS are assigned a class in the RCS's register book and issued with the relevant certificates that indicate the character assigned to the vessel and machinery. Certificates of class are issued by the RCS.
4	Tonnage certificate	The tonnage certificate shows the tonnage measured by the flag state, which is a measure of volume rather than weight.
5	Cargo ship safety construction certificate	This certificate covers the hull, machinery and equipment of a cargo ship. It shows that the ship complies with the construction and safety regulations applicable to the ship and the voyages on which it is engaged. It is issued by the flag state or by an RCS.
6	Cargo ship safety equipment certificate	The cargo ship safety equipment certificate is a record of the safety equipment carried on the vessel, in compliance with SOLAS, including life-saving appliances, fire-fighting equipment, lights and shapes, pilot ladders, magnetic compass. It is issued by the flag state or an RCS.
7	Certificates for navigation lights and shapes	This certificate is normally covered under the cargo ship safety equipment certificate. Where temporary lights are placed on a structure not in possession of a cargo ship safety equipment certificate, it is expected that they be individually certified or in possession of a manufacturer's guarantee of compliance.
8	Load line certificate	The load line certificate is issued after a vessel has been assigned and marked with load line marks. The certificate gives details of the dimensions related to the freeboard and various special marks, e.g. TF (tropical fresh), WNA (winter North Atlantic). The vessel should be periodically inspected to confirm that no changes have occurred to the hull or topsides that render invalid the data on which the assignment of freeboard was made. The load line certificate is issued by the flag state or an RCS.
9	Load line exemption	Where a vessel or structure is exempt from some or all of the provisions, it can be issued with a load line exemption certificate, which includes any qualifying provisions. The load line exemption certificate is issued by the flag state or an RCS.
10	MARPOL and IOPP certificate	The MARPOL certificates ensure that the vessel complies with international oil pollution regulations. The MARPOL certificates are comprised of — the international oil pollution prevention certificate (IOPP) and its supplements, including the ship oil pollution emergency plan (SOPEP); — the international sewage prevention certificate; — the international air pollution prevention certificate. The MARPOL certificates are issued by the flag state or an RCS.

Table A.1 (*continued*)

Line in Table 1	Document	Guidance
11	Safety management certificate (SMC)	This document, which is issued to a ship, signifies that the company and its shipboard management operate in accordance with the approved safety management system. The safety management system is a structured and documented system enabling company personnel to implement the ship owner's safety environmental protection policy.
12	Customs clearance	Customs clearance is issued by customs confirming that, so far as they are concerned, the vessel is free to sail. The clearance is issued after light dues have been paid and on production of various other mandatory documentation.
13	De-rat certificate, or exemption	A de-rat certificate is issued after a vessel has been fumigated or dealt with by other means to rid the vessel of rats. A de-rat exemption is issued when inspection has shown no evidence of rats on board and is issued by a port medical officer.
14	Safety radio certificate	The safety radio certificate is issued by the flag state after a survey of the vessel's radio installation and is a declaration that it is satisfactory for the intended service.
15	Stability booklet	This is a booklet that sets out the vessel's stability particulars and allows a determination of the draught, trim and stability characteristics of the vessel for any cargo arrangement. The stability booklet is generally prepared by the vessel designers and approved by an RCS.
16	ISPS certificate	The international ship and port facility security (ISPS) code is meant to ensure the security of ships and port facilities through the establishment of security management plans for both the ships and the port facilities, and by monitoring and controlling access and activities of people and cargo. Each ship should carry an international ship security certificate indicating that they comply with the requirements of SOLAS and the ISPS code.
20	Certificates for life saving appliances	This certificate is normally covered under the cargo ship safety equipment certificate. Where temporary equipment, e.g. life rafts or fire-fighting equipment, are placed on a structure not in possession of a cargo ship safety equipment certificate, it is expected that they be individually certified, with an in-date inspection.
21	Minimum safe manning document	The minimum safe manning certificate indicates the required crew level for the safe operation of the vessel and is issued by the flag state.
22	Muster list	The muster list provides the name of each individual on board the vessel and assigns the individual's emergency duties and survival craft.

A.3 Guidance for 11.16: Loadout manual

The loadout manual and supporting documents should include the following items:

— method statement;

— detailed listing of operational procedures, including engineering drawings that are necessary to explain the operations;

— detailed checklists, including both operational and safety requirements for appropriate phases of the loadout operations;

— description and drawings of the structure that is undergoing loadout;

— weights and centres of gravity;

- weighing methods and results;
- summary of the results of structural analyses for structure and barge;
- details of site and vessel preparations that are required prior to the initiation of the loadout operations;
- site plan including dimensions, levels and arrangement of mooring bollards;
- summary of the strength of quay approach, quay wall and mooring bollard strength;
- bathymetric and height clearance information;
- barge specification, layout, hydrostatics and tank plans, mooring and towing connections;
- barge documentation;
- design and operational weather conditions, including possible PNR considerations;
- barge mooring arrangements with supporting calculations;
- arrangement of skidways, skidshoes and link beams, with structural justification;
- tidal curves for predicted and contingency loadout dates along with the arrangements for taking tidal readings during loadout;
- ballasting plan and calculations;
- pump specification and layout, including contingency pumps;
- trailer or SPMT specification and arrangement, with justifying calculations;
- winching or jacking system specification and arrangement;
- grillage arrangement;
- barge level survey method, including equipment and tolerances;
- envelopes of safe operation for major pieces of equipment;
- engineering information on the loadout equipment (including slings), preferably current certification or inspection certificates;
- positioning and set-down method, sea fastening schedule;
- barge movements;
- tug specifications;
- management structure, showing reporting, liaison and communications;
- weather forecast services and schedule;
- required notifications to authorities/regulatory agencies;
- contingency and emergency actions;
- contact numbers and addresses, including emergency services;

— operation-specific HSE manual, which is an addendum to the project HSE plan;

— loadout risk assessment results, action and status of actions;

— required personal protective equipment;

— security arrangements and any restricted zones;

— details of any non-destructive testing or positional surveys required;

— checklists for key operations.

A.4 Guidance for 12.8: Transport manual

12.8.1 The transport manual and supporting documents should include the following items:

— detailed engineering data for marine equipment and other reference material and information;

— identification and dimensions of the transport vessel;

— name, horsepower and certified static bollard pull for the tug(s);

— results of calculations to show that the tug bollard pull and transport vessel stability requirements have been satisfied for the applicable metocean criteria;

— drawings showing ballast arrangements required to achieve the desired towing draught and trim;

— specification of assist tugs and description of manoeuvring plans required for transit through waterways;

— proposed tow route with contingency and recovery plans for use in the event of equipment problems or severe weather; identification of accessible safe harbours along the tow route;

— communication equipment and procedures being utilized;

— weather forecasting services available to the tow master;

— special instructions;

— drawings showing tow rigging and transport aids being provided on the transport vessel and associated equipment;

— notification/approval requirements for external agencies and authorities;

— weight, buoyancy, stability and strength characteristics of the vessel, required for performing loadout planning and engineering, including loadout of anchor piles.

12.8.2 Daily reporting should include

— location of the tow at the time the report is issued;

— tow progress during the previous 24 h;

— effective tow velocity at the time of the report;

— weather and sea conditions for the previous 24 h and the forecast for the next 48 h;

- estimated time of arrival at tow destination;
- fuel status and plans for refuelling, if appropriate;
- report of any mechanical problems or significant incidents;
- report of any deviations from the planned tow route.

A.5 Guidance for 17.18: Installation manual

The installation manual and supporting documents should include the following items:

- operational organization with the information identified in 6.2.2;
- elements of the marine operational documents as identified in 6.5.2;
- outline execution plan when and how it is intended to use the installation vessels;
- job descriptions for key personnel; names and contact information along with a list of key personnel required for a particular installation activity, indicating number and job designation of personnel involved;
- safety plan with reference to safety manuals, plans for hazardous operations, pollution prevention plans and the emergency evacuation plan;
- preparations, surveys, and outline check lists with a definition of route corridors, target areas, positioning tolerances and platform orientation, including any detailed sea trials programme for each main installation and survey vessel after mobilization;
- specific step-by-step instructions for each phase of the operation, including sequence, timing, resources and drawings that fully depict and explain the installation operations; also includes details of tolerances, limitations and restrictions for the following activities: loading operations, transportation and deployment operations, ballasting operations; surveying operations, mooring operations, ROV operations, positioning operations, any lifting or lowering operations; debris removal, retrieval and recovery operations; anchor or pile installation; calibration procedures for underwater and vessel mounted survey and positioning equipment; methods employed to prevent twisting of chain and wire rope during pre-lay and hook-up activities;
- contingency plans detailing the actions it is necessary to take in the event of planned abandonment of equipment on the sea floor, unplanned abandonment of equipment on the sea floor, recovery after abandonment of equipment on the sea floor, equipment failure, abnormal weather (including ocean currents) and other credible planned and unplanned eventualities;
- results of related calculations, including pertinent engineering calculations, analyses and data supporting the plans and procedures, engineering data on any purpose-built installation equipment, certificates for marine equipment, performance specifications for any vessels or barges, etc.;
- appendices listing more detailed information with equipment specifications, names and details of installation vessels and equipment, including performance specifications;
- preparation and/or modifications that should be made to any components, installation vessel(s) or other marine equipment;
- list of survey equipment, positioning equipment, ROV and installation equipment, including levels of contingency equipment;
- list of rigging material, appurtenances and special equipment for use, with valid certificates;

— list of equipment for securing, handling, overboarding and lowering anchor piles; storing, spooling, hanging-off and deploying spiral strand wire rope and connectors; storing, handling, hanging-off and deploying platform chain, ground chain and work chain, special chain and spare chain;

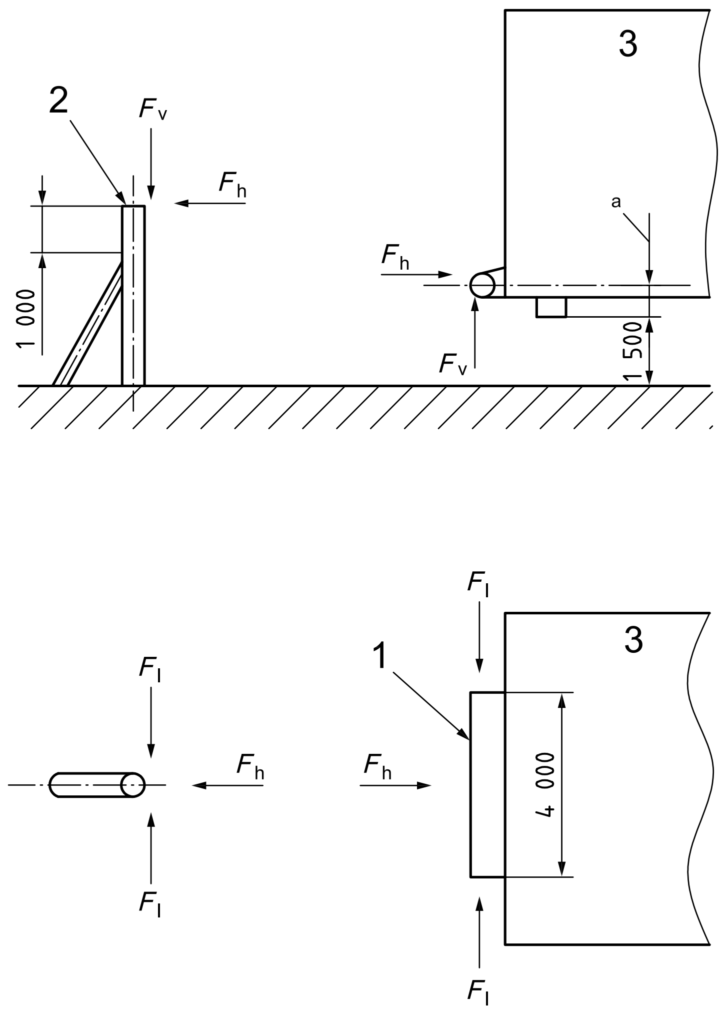
— site information, including location, bathymetry, mooring system component coordinates, installation or drilling vessel mooring pattern(s);

— logistical data describing the offshore support systems, e.g. quartering, transportation of personnel and supplies, weather forecasting services, communications, description of base port.

A.6 Guidance for 18.8.4: Bumper and guide loads

Figures A.1 to A.4 show the bumper and guide configurations to which reference is made in Table 18.

Dimensions in millimetres



Key

1 horizontal primary bumper (flush with module if necessary)

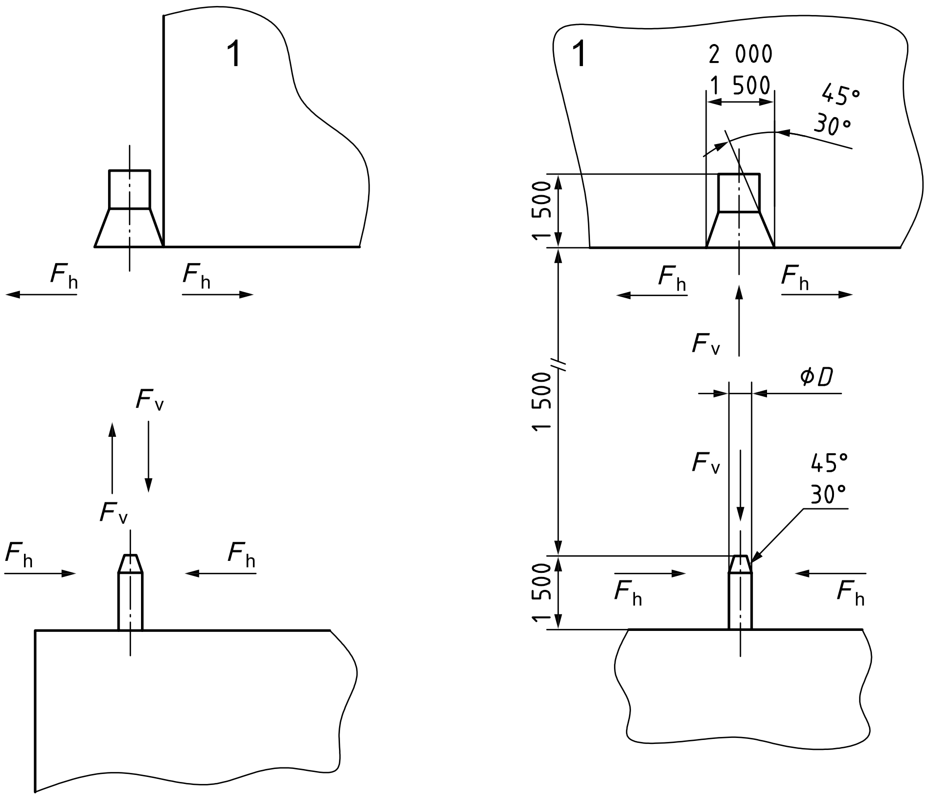
2 primary guide post

3 incoming module

[a] Dimension varies.

Figure A.1 — Vertical sliding bumper

Dimensions in millimetres unless otherwise indicated

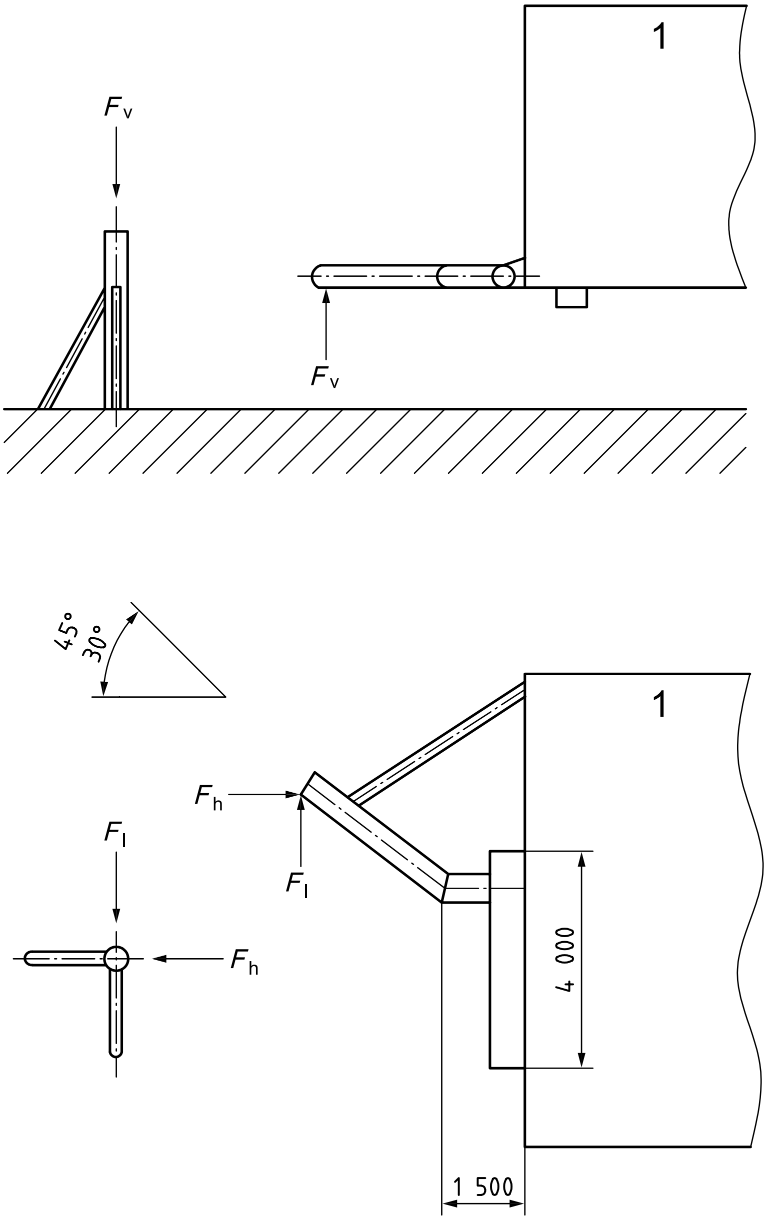


Key

1 incoming module

Figure A.2 — Pin/bucket guide

Dimensions in millimetres unless otherwise indicated

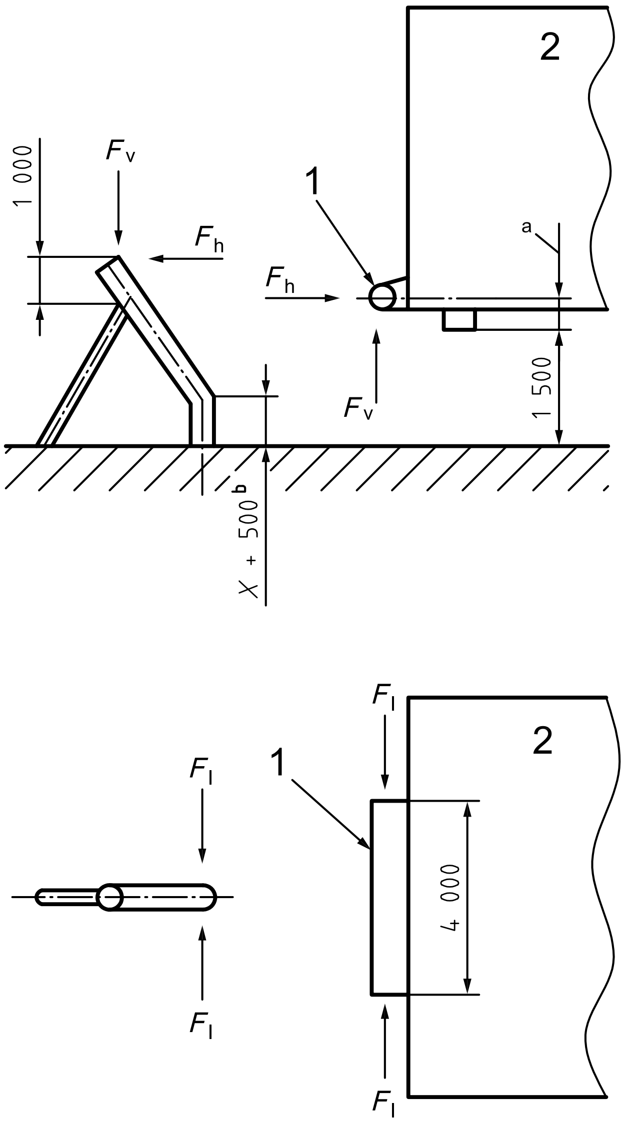


Key

1 incoming module

Figure A.3 — Horizontal cow-horn type bumper with vertical guide

Dimensions in millimetres



Key

1 horizontal primary bumper (flush with module if necessary)

2 incoming module

a Dimension varies.

b Dimension X varies.

Figure A.4 — Vertical cow-horn type guide with horizontal bumper

Annex B
(informative)

Regional information

B.1 Introduction

This annex contains clauses applicable to geographical regions sharing similar environments, and additional requirements for marine operations. The information in this annex is normative for marine operations conducted in the defined areas, and it is informative for other regions. The contents have been developed by experts from the region concerned to supplement the provisions of this part of ISO 19901. This annex contains regional and national data, including regional environmental conditions and local practices. The regulatory framework is explained, but neither regulatory requirements nor reference to specific legislation is included in this part of ISO 19901.

B.2 Canada

B.2.1 General

Material in B.2 is based on CAN/CSA-S475-03 [46], which is copyrighted by the Canadian Standards Association2) and used with their permission. While use of this material has been authorized, CSA accepts no responsibility for the manner in which the information is presented, nor for any interpretations thereof.

B.2.2 Description of region

The geographical basis for Clause B.2 is the region bounded by the continental shelf margins and territorial waters of Canada. The region encompasses shallow water and deep water areas of offshore Canada that can be subjected seasonally to the presence of sea ice and icebergs. Sea ice can be present in the Arctic Archipelago, Beaufort Sea, Davis Strait, offshore Newfoundland and Labrador, and in the Gulf of St. Lawrence, as well as offshore Nova Scotia, although the occurrence of sea ice in the latter area is rare. Icebergs are typically encountered in the waters of Davis Strait and offshore the north and east coasts of Newfoundland and Labrador.

B.2.3 Regulatory framework for Canada

Refer to ISO 19902:2007[29], H.3.2, for the regulatory framework for Canada.

B.2.4 Technical information for Canada

B.2.4.1 General

Provisions in B.2.4.2 to B.2.4.10 shall be used for the special case of marine operations in arctic areas and/or sub-arctic areas where glacial or sea ice is present or can be present. Provisions in B.2.4.2 to B.2.4.10 shall be considered in conjunction with the applicable clauses of this part of ISO 19901. Ice-covered offshore areas pose unique problems for marine operations, some of which are addressed in B.2.4.2 to B.2.4.10.

2) Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada, L4W 5N6; website: www.ShopCSA.ca; telephone: 1-800-463-6727.

B.2.4.2 Ice conditions

When planning a marine operation in the areas described in B.2.2, the ice conditions being considered shall be in accordance with the duration of the operation as indicated in Table B.1.

Table B.1 — General guidance for ice conditions

Duration of the operation	Ice conditions
Fewer than 3 days	Based on specific weather window
3 days to 1 week	1 year environmental condition (seasonal)
1 week to 1 month	10 year environmental condition (seasonal)
1 month to 1 year	Extreme level environmental action (seasonal)
Greater than 1 year	Extreme level environmental action

B.2.4.3 Ice management plan

Where sea ice or icebergs are present or forecast, an ice management plan shall be developed, describing the actions it is necessary to take in response to such ice conditions. This plan shall specify when it is necessary to suspend operations and the method or order of suspension. This plan should also make provision for unexpected or unusually severe ice conditions.

B.2.4.4 Ice forecast lead

Operations that it is necessary to suspend or structures that it is necessary to move in the event of sea ice or icebergs should have forecast durations adequate to safely suspend operations or disconnect and move from location.

B.2.4.5 Contingency plans

Contingency plans should address ice conditions that exceed forecasts and operational limits. Operations under limited visibility should be given due consideration. Capabilities to detect icebergs and sea ice by survey vessels and advance scouting in case of reduced visibility should be provided where appropriate. Communications equipment should be compatible with that of the ice patrol or reconnaissance aircraft. Due account should be taken of replacement supplies for all types of essential equipment.

NOTE Fog is often associated with sea ice, especially near the ice edge and in bergy water.

B.2.4.6 Site and route surveys and preparation

Appropriate route surveys and environmental measurement programmes should be performed. Where navigational charts are of questionable accuracy or are for areas subject to changes in seabed topography, a survey should be carried out as close to the expected date of operations as possible.

Anticipated tow routes (corridors) and alternate routes should be sufficiently wide to accommodate deviations of the tow that can be necessary to avoid encounters with large ice floes or heavy ice features.

NOTE Many arctic and sub-arctic areas have not been charted in sufficient detail for marine operations associated with offshore structures. Likewise, environmental information can be sparse.

B.2.4.7 Strength

Icebelt strengthening should be considered for operations that can involve contact with floating ice during transportation and installation.

B.2.4.8 Damage stability

For tows in ice cover greater than 10 % of the surface area, the structure should have two-compartment damage stability. The requirement for two-compartment damage stability may be waived if adequate safety levels can be demonstrated.

B.2.4.9 Tow

B.2.4.9.1 General

The information in B.2.4.9 should be considered in conjunction with Clause 12, as appropriate. The provisions in B.2.4.9.2 to B.2.4.9.9 should be addressed in planning tows where it is likely to encounter ice.

B.2.4.9.2 Ice management

Where appropriate, capabilities should be provided to manage ice that can interfere with, or that can present a hazard to, towing operations. While towing in sea ice, sufficient icebreaker support should be available.

B.2.4.9.3 Towmaster

A towmaster experienced in towing operations in ice should be employed.

B.2.4.9.4 Towline length

Tug masters should be cognizant of towline catenary at all times, but particularly in shallow water to avoid towline abrasion or snagging on the sea floor. While operating in shallow water, a daily inspection of towlines should be made.

B.2.4.9.5 Tugboats

Tugs used for towing operations in ice should be appropriately strengthened and powered for the anticipated ice conditions.

B.2.4.9.6 Escort vessel

An escort vessel should be equipped with forward scanning bottom profiling equipment, in addition to normal depth sounding equipment where there is a risk of encountering sea floor obstructions such as pingos.

NOTE A pingo is an ice mound covered by a layer of soil on the sea floor.

B.2.4.9.7 Collision prevention

Appropriate measures should be taken to prevent the towed structure from colliding with the forward towing vessels should the vessels' forward motion be slowed or stopped.

B.2.4.9.8 Equipment strength

The arrangement and strength of towing equipment should take into account increased actions that can arise from ice interaction and/or the use of special towing techniques in ice. Low temperatures also affect material properties. This can be important where impact action is possible in lifting or towing.

B.2.4.9.9 Ice contact with cargo

The arrangement of cargo on a towed vessel should prevent ice contact with, or encroachment on, cargo components not designed for ice actions under the expected environmental conditions.

The following remarks concern towing in ice-affected waters.

— It is generally accepted that towing is practical in various concentrations of ice coverage, provided icebreaker assistance is utilized in areas of high ice concentrations.

— Towing in sea ice often necessitates special techniques such as towing on a short towline to enhance manoeuvrability and reduce ice build-up ahead of the towed structure. Broken ice can form a rubble pile along the bow of a vessel and jam around the hull and under the keel.

— Single tows are considered most acceptable in ice regions. Towing in convoy is recommended when more than one tow is involved.

B.2.4.10 Towing connections

B.2.4.10.1 For towing large structures, a sufficient number of connections for tugs should be provided around the structure to ensure manoeuvrability and stopping capability and to provide redundancy in the event of breakage. Typically, quick-release clench plates, chain bridles and wire pendants are provided. Pendant lines should allow tugs to connect without approaching the hull too closely.

B.2.4.10.2 Generally, towing connections and embedments should be designed to ensure that the weak link in the system is the pendant between the chain bridle and the towline. The towing connections should be placed so as not to interfere with ice movement around the hull.

NOTE B.2.4.10.1 complements B.2.4.9.7. B.2.4.10.2 addresses problems of resupply and recovery of towlines in arctic areas. In the event of breakage, the bridle can be retrieved and the broken pendant replaced.

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