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Petroleum and natural gas industries — Design and testing of LNG marine transfer arms for conventional onshore terminals

Industries du pétrole et du gaz naturel — Conception et essais des bras de transfert de GNL sur des terminaux terrestres conventionnels

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

Petroleum and natural gas industries — Design and testing of LNG marine transfer arms for conventional onshore terminals

1 Scope

This International Standard specifies the design, minimum safety requirements and inspection and testing procedures for liquefied natural gas (LNG) marine transfer arms intended for use on conventional onshore LNG terminals, handling LNG carriers engaged in international trade. It can provide guidance for offshore and coastal operations. It also covers the minimum requirements for safe LNG transfer between ship and shore.

Although the requirements for power/control systems are covered, this International Standard does not include all the details for the design and fabrication of standard parts and fittings associated with transfer arms.

This International Standard is supplementary to local or national standards and regulations and is additional to the requirements of ISO 28460.

This International Standard needs not be applied to existing facilities.

2 Normative references

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

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part1: General principles*

ISO 10474:2013, *Steel and steel products — Inspection documents*

ISO 10497, *Testing of valves — Fire type-testing requirements*

ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film*

ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

ISO 28460:2010, *Petroleum and natural gas industries — Installation and equipment for liquefied natural gas — Ship-to-shore interface and port operations*

IEC 60034-5, *Rotating electrical machines — Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) — Classification*

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

IEC 60079-1, *Explosive atmospheres — Part 1: Equipment protection by flameproof enclosures "d"*

IEC 60079-2, *Explosive atmospheres — Part 2: Equipment protection by pressurized enclosures "p"*

IEC 60079-5, *Explosive atmospheres — Part 5: Equipment protection by powder filling "q"*

IEC 60079-6, *Explosive atmospheres — Part 6: Equipment protection by oil immersion "o"*

IEC 60079-7, *Explosive atmospheres — Part 7: Equipment protection by increased safety "e"*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-11, *Explosive atmospheres — Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*

IEC 60079-18, *Explosive atmospheres — Part 18: Equipment protection by encapsulation "m"*

IEC 60079-25, *Explosive atmospheres — Part 25: Intrinsically safe electrical systems*

IEC 60529, *Degrees of protection provided by enclosures (IP Code) and IEC 60529/A1&A2, Amendment 1&2*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 62305-3, *Protection against lightning — Part 3: Physical damage to structures and life hazard*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

ASME*Boiler and Pressure Vessel Code Section IX: Welding and Brazing Qualifications*

3 Terms and definitions

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

3.1
apex swivel
articulated, fluid-carrying joint located between the *inboard arm* (3.20) and *outboard arm* (3.32)

Note 1 to entry: See Figure B.2.

Note 2 to entry: It provides *luffing* (3.26) of the outboard arm relative to the inboard arm.

3.2
attitude
various modes of use and/or location of the *transfer arm* (3.59) (i.e. manoeuvring, stowed, connected, hydrostatic test, and maintenance)

Note 1 to entry: The transfer arm can take several positions for each attitude.

3.3
base riser
riser
vertical assembly which bolts to the loading platform and supports the articulated assembly of the *transfer arm* (3.59)

Note 1 to entry: See Figure B.2.

Note 2 to entry: Sometimes referred to as "standpost".

3.4
bottom swivel
accommodates *pitch*ing (3.35) motion of *LNG carrier* (3.25) and is located adjacent to *presentation flange* (3.37) in horizontal part of *TSA* (3.60)

Note 1 to entry: See Figure B.2.

3.5
brinelling
any permanent indentation in *swivel* (3.55) or *structural bearing* (3.50) raceways caused by excessive loading of balls or rollers

3.6
cargo manifold
pipe assembly mounted onboard *LNG carrier* (3.25) to which the *presentation flange* (3.37) or *QCDC* (3.39) of the *transfer arm* (3.59) is connected

Note 1 to entry: See Figure B.2.

3.7
cavitation
formation and collapse of bubbles in a liquid when the pressure falls to or below the liquid vapour pressure; the collapse releases energy, sometimes with an audible sound and vibration

Note 1 to entry: Such low pressures occur in high velocity zones such as the inner radius of elbows, or at places with variations of diameters.

3.8
clash
any contact during design operational conditions, or as a result of an emergency separation, between any part of a *transfer arm* (3.59) and:

— adjacent transfer arm while both arms are operating or one arm is operating and the other arm is stowed [e.g. the *counterweights* (3.11)];

— adjacent section of the same transfer arm [e.g. *triple swivel assembly* (3.60) and *outboard arm* (3.32)];

— loading platform equipment [e.g. *counterweight* (3.11) and piping or valves]

3.9
contact angle
α
angle between the plane of the *swivel joint* (3.55) or *structural bearing* (3.50) balls or rollers and the centre of contact at the ball or roller raceway interface

3.10
conventional onshore LNG terminal
LNG exporting or receiving terminal that is located on-shore and that has a marine transfer arms for the loading or unloading of *LNG carriers* (3.25) in a harbour or other sheltered coastal location

3.11
counterweight
system of weights used to balance the *inboard arm* (3.20) and *outboard arm* (3.32) assemblies

Note 1 to entry: Some *transfer arms* (3.59) have a single counterweight for this function and others have multiple counterweights.

3.12
design pressure
pressure for which the *transfer arm* (3.59) is designed

Note 1 to entry: See Table A.1.

3.13
design temperature
range of temperatures for which the *transfer arm* (3.59) is designed

Note 1 to entry: See Table A.1.

3.14
drift
longitudinal and/or lateral displacement of the *LNG carrier* (3.25) under the influence of environmental forces

Note 1 to entry: See also *surge fore* (3.52) *or aft* (3.51) and *sway* (3.54).

3.15
emergency release system
ERS
system that provides a positive means of quick release of *transfer arms* (3.59) and safe isolation between the *LNG carrier* (3.25) and shore, following a predefined procedure including an *emergency shutdown* (ESD) (3.16)

Note 1 to entry: See Figure B.2.

3.16
emergency shutdown
ESD
method that safely and effectively stops the transfer of LNG and vapour between the *LNG carrier* (3.25) and shore

3.17
freeboard
vertical distance between the ship's deck and the water level at the manifold location

Note 1 to entry: See Table A.3 and Figure A.1.

3.18
free wheel
ability of a hydraulically operated *transfer arm* (3.59) when connected to a *LNG carrier* (3.25) to follow freely without hydraulic restraint the vertical and horizontal motions of the LNG carrier's manifold (draft changes and *sway* (3.54) and surge motions)

3.19
heave
vertical motion of the *LNG carrier* (3.25) due to wave action

Note 1 to entry: See Table A.4 and Figure A.2.

3.20
inboard arm
product-carrying pipe and any structural members contained between the *apex swivel* (3.1) and the *trunnion swivel* (3.61)

Note 1 to entry: See Figure B.2.

3.21
included angle
angle formed between *inboard arm* (3.20) and *outboard arm* (3.32)

Note 1 to entry: See Figure B.2.

Note 2 to entry: The maximum and minimum included angles are left to the transfer arm manufacturer.

Note 3 to entry: The included angle in the stowed position of the *transfer arms* (3.59) is such, that the arms are parked with the *triple swivel assembly* (3.60) behind the berthing line.

3.22
insulating flange
electrical insulating system, usually dedicated, which is installed in the lower end of the *outboard arm* (3.32) or in the vertical part of the *triple swivel assembly* (3.60)

Note 1 to entry: Its purpose is to prevent stray currents from causing an arc at the *LNG carrier's* (3.25) flange as the *transfer arm* (3.59) is connected or disconnected.

3.23
jack
permanent, adjustable load-carrying mechanism potentially installed in the *triple swivel assembly* (3.60) to transfer a portion of the *arm* (3.59) fluid weight to the deck instead of the *LNG carrier's* (3.25) manifold

Note 1 to entry: See Figure B.2.

3.24
jetty control centre
control centre situated on or adjacent to the jetty primarily to control and/or monitor the *transfer arms* (3.59)

Note 1 to entry: Sometimes referred to as "jetty control room" or "local control room".

3.25
LNG carrier
LNGC
tank ship designed for the carriage of LNG

3.26
luffing
rotary motions of the *inboard arm* (3.20) and *outboard arm* (3.32) in the vertical plane

Note 1 to entry: See Figure B.2.

3.27
main hydraulic unit
MHU
hydraulic unit that generates hydraulic power to ensure the normal operation and emergency release sequence of the arms

3.28
manifold setback
horizontal distance between the board side of *LNG carrier* (3.25) and the face of *cargo manifold* (3.6)

Note 1 to entry: See Table A.3 and Figure A.1.

3.29
manifold spacing
horizontal distance between two adjacent *cargo manifold* (3.6) flange axes

Note 1 to entry: See Table A.3 and Figure A.1.

3.30
middle swivel
accommodates *yawing* (3.63) and surge of *LNG carrier* (3.25) and is located between *top swivel* (3.57) and *bottom swivel* (3.4) in vertical part of *TSA* (3.60)

Note 1 to entry: See Figure B.2.

3.31
operating envelope
volume in which *presentation flange(s)* (3.37) of a (group of) *transfer arm(s)* (3.59) is (are) required to operate

3.32
outboard arm
product-carrying pipe and any structural members contained between the *apex swivel* (3.1) and the *triple swivel assembly* (3.60)

Note 1 to entry: See Figure B.2.

3.33
owner
designated agent
company or group of companies for whose use the *transfer arms* (3.59) are installed, responsible for the safe design and construction of the installation

3.34
pantograph system
system for transmitting balancing loads from the *outboard arm* (3.32) to the *counterweight(s)* (3.11)

Note 1 to entry: The system comprises an assembly of linkages and pinned connections, or a cable and sheaves system (respectively, “rigid link pantograph” and “cables and sheaves pantograph”).

3.35
pitch
rotation of the *LNG carrier* (3.25) around transversal horizontal axis

Note 1 to entry: See Table A.4 and Figure A.2.

3.36
powered emergency release coupling
PERC
powered device to provide a means of quick release of the *transfer arms* (3.59) when such action is required only as an emergency measure

3.37
presentation flange
transfer arm (3.59) flange for connection to either the *cargo manifold* (3.6) or *spool piece* (3.47)

Note 1 to entry: See Figure B.2.

3.38
product
fluid transferred using *transfer arms* (3.59)

Note 1 to entry: Fluids are LNG, NG or LN_2.

3.39
quick connect disconnect coupler
QCDC
coupler
manual or hydraulic mechanical device used to connect the *transfer arm* (3.59) to the *cargo manifold* (3.6) without employing bolts

Note 1 to entry: See Figure B.2.

3.40
remote pendant control
remote control
device to facilitate the fine manoeuvring operation of the *transfer arms* (3.59) from a remote location (e.g. *LNG carrier’s* (3.25) *cargo manifold* (3.6) area)

Note 1 to entry: The system can use a trailing wire or radio-controlled system.

3.41
riser and trunnion swivel assembly
fluid carrying system consists of *riser swivel* (3.43), *trunnion swivel* (3.61) and elbows and mounted on top of the *base riser* (3.3)

Note 1 to entry: See Figure B.2.

3.42
riser flange
transfer arm (3.59) flange for connection to LNG piping

Note 1 to entry: See Figure B.2.

3.43
riser swivel
swing joint in the *riser and trunnion swivel assembly* (3.41) which permits *slewing* (3.46) of the *transfer arm* (3.59)

Note 1 to entry: See Figure B.2.

3.44
roll
rotation of *LNG carrier* (3.25) around longitudinal horizontal axis

Note 1 to entry: See Table A.4 and Figure A.2.

3.45
safety integrity level
SIL
statistical representations of the integrity of the safety instrumented system when a process demand occurs

Note 1 to entry: See Clause 6.

3.46
slew
horizontal, rotary motion of the *transfer arm* (3.59) around the *base riser* (3.3)

Note 1 to entry: See Figure B.2.

3.47
spool piece
short length of pipe for the purpose of matching the *cargo manifold* (3.6) to the *presentation flange* (3.37) or *QCDC* (3.39)

Note 1 to entry: Sometimes referred to as “adaptor” or “short distance piece”.

3.48
spotting line
pre-determined location on the jetty used by the *LNG carrier* (3.25) when berthing to align with the LNG carrier vapour manifold

Note 1 to entry: See Figure A.4.

3.49
stress analysis
detailed calculation of the structural loading in the *transfer arm* (3.59) and *cargo manifold* (3.6) for various positions and attitudes to check the integrity of the transfer arm for the service intended

3.50
structural bearing
bearing in the load carrying components supporting the product line that, in combination, allow the *transfer arm* (3.59) to follow freely the motion of the *LNG carrier* (3.25)

3.51
surge aft
longitudinal *LNG carrier* (3.25) afterward motion

Note 1 to entry: See Table A.4 and Figure A.2.

3.52
surge fore
longitudinal *LNG carrier* (3.25) forward motion

Note 1 to entry: See Table A.4 and Figure A.2.

3.53
surge pressure
rapid change in pressure as a consequence of a change in flow rate in a pipeline and/or piping systems (including *transfer arms* (3.59))

3.54
sway
transverse *LNG carrier* (3.25) motion

Note 1 to entry: See Table A.4 and Figure A.2.

3.55
swivel joint
swivel
swing joint contained in the *transfer arm* (3.59) to permit the arm to follow freely the motion of the *LNG carrier* (3.25)

3.56
terminal
LNG producing/receiving plant with loading/unloading facilities

3.57
top swivel
accommodates *roll*ing (3.44), heave and sway motion of *LNG carrier* (3.25) and is located between *outboard arm* (3.32) and *middle swivel* (3.30) in horizontal part of *TSA* (3.60)

Note 1 to entry: See Figure B.2.

3.58
transfer
loading or unloading operation

3.59
transfer arm
arm
articulated metal transfer system used for transferring *product* (3.38) to or from *LNG carrier* (3.25) with the capability of accommodating differences in tides, *freeboard* (3.17) and LNG carrier’s motions

Note 1 to entry: See Figure B.2.

Note 2 to entry: It can be referred to as a “loading arm” or “unloading arm”.

3.60
triple swivel assembly
TSA
group of three *swivels* (3.55) and elbows located at the end of the *outboard arm* (3.32)

Note 1 to entry: See Figure B.2.

3.61
trunnion swivel
swing joint in the *riser and trunnion swivel assembly* (3.41) which permits the *inboard arm* (3.20) to rotate around the horizontal axis

Note 1 to entry: See Figure B.2.

3.62
uninterrupted power supply
UPS
back-up of the electrical supply system providing power to critical control and safety systems so that the plant can be kept in safe conditions

3.63
yaw
rotation of the *LNG carrier* (3.25) around vertical axis

Note 1 to entry: See Table A.4 and Figure A.2.

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

CPMS constant position monitoring system

ERS emergency release system

ESD emergency shutdown

FL fluid load

LNG liquefied natural gas

LNGC liquefied natural gas carrier

LN_2 liquefied nitrogen gas

MHU main hydraulic unit

NDE non destruction examination

NG natural gas

N_2 nitrogen gas

OBE operating basis earthquake

PERC powered emergency release coupling

PL pressure load

PQR performance quality records

QCDC quick connect disconnect coupler

SIL safety integrity level

SSE safe shutdown earthquake

TL thermal load

TSA triple swivel assembly

UPS uninterrupted power supply

WL wind load

WPS welding procedure specifications

5 Design of the arms

5.1 Definition of the length and the configuration of the arms, arms description

5.1.1 General

The transfer arm general arrangement is given in Figure B.2.

The length and the configuration of the transfer arms shall allow for the connection of the on-shore piping to the ship's cargo manifold. The connection shall allow for free movement within the operating envelope.

The transfer arms are normally composed of the following (see definitions in Clause 3):

— triple swivel assembly (TSA) including emergency release system (ERS) and quick connect disconnect coupler (QCDC), if specified;

— outboard arm;

— apex swivel assembly between the outboard and inboard arm;

— pantograph system;

— inboard arm;

— riser and trunnion swivel assembly between the inboard arm and the base riser;

— base riser.

The product piping subject to low temperature shall be free to expand or contract within the structure. The structure itself shall not be subjected to low temperature.

All piping supports shall be adequately designed so that stresses in the piping and the structure are within allowable limits for all attitudes and positions.

Any parts of transfer arm, e.g. seals, bolts and nuts, shall not come off or unfasten and drop into product piping due to product flow, vibration, negative pressure and cryogenic condition.

5.1.2 Balancing

The complete TSA and outboard arm shall be balanced in the empty condition without ice. It shall be balanced with pantograph system about the apex swivel.

The complete, articulated assembly shall be balanced in empty condition without ice. It shall be balanced about the trunnion swivel.

The design of the transfer arms shall consider, in addition to the normal operation, the emergency release of the arms in both the empty and full condition. There should be no clash of the arms with the ship or the jetty.

5.1.3 Arms dimensions and clearances

5.1.3.1 Arms dimensions

Transfer arm dimensions, based on the design data in Tables A.1 to A.15 and Figures A.1 to A.4 attached, shall be determined by the transfer arm manufacturer to ensure that the transfer arm satisfies all specified requirements.

5.1.3.2 Clearance study

The design shall cater for the following minimum clearances unless otherwise specified in Table A.6:

— 0,15 m minimum clearance between any part of an operating arm and a stowed arm;

— 0,3 m minimum clearance between any part of an operating arm and any adjacent structures, piping, equipment;

— 0,3 m minimum clearance between any part of adjacent operating arms;

— 0,15 m minimum clearance between counterweights of operating arms.

Table B.1 shows the location of main clearance checkpoints.

Transfer arm manufacturer's clearance study shall include all cases including emergency release positions and retracting attitude following emergency release.

The study shall identify all check points, based on a drawing of the jetty layout in elevation and plan. Consideration should be given for any future expansion.

In the stowed position, no part of the transfer arm shall extend beyond the jetty face or berthing line with compressed fenders plus the additional safety margin corresponding to the maximum rolling angle of the LNG carrier (see Tables A.4, A.6, Figures A.2 and A.3).

5.2 Design basis

5.2.1 Product line diameter and product data

The LNG product line should be sized for a maximum liquid product speed of 12 m/s unless otherwise specified by the owner. Higher speeds can be locally acceptable in reduced passages for example in the ERS, provided cavitation and vibration is acceptable.

Pressure loss curve for LNG and vapour return within the transfer arms should be provided by the transfer arm manufacturer and agreed with the owner.

5.2.2 Material and grades

Material and grades shall have chemical, physical and mechanical properties conformable to the specified design conditions, such as pressure, temperature, wind and earthquake loads and environment application.

Material and grades used for critical parts such as pressure containing parts including bolts and nuts and main structural parts are subject to owner's approval.

In the product carrying components, stainless steel (304, 304L, 316 or 316L) should be used for low temperature fracture toughness. Corrosion resistant property of stainless steel in a chloride environment should be considered.

For welding purposes, the carbon content of carbon steels for structural components should not be higher than 0,26 % except in case certified by welding procedure specifications (WPS) and performance quality records (PQR).

Other material and grade may be considered for use if it can be demonstrated that it meets all safety and operational performance criteria.

If the transfer arms are installed in low ambient temperature, the grade used for the structure shall be adequate. The same applies to parts between the product line and the structure which may be subject to low temperature.

5.2.3 Stress analysis

5.2.3.1 General

A complete analysis of stresses and deflections in the transfer arm and LNG carrier's manifolds shall be performed for all appropriate arm conditions.

The calculated stresses shall be lower than or equal to the allowable design stress.

Loading combination, allowable design stress and design loads shall be in accordance with 5.2.3.2 to 5.2.3.9 or complied with the local or national standards and regulations or code agreed with the owner.

5.2.3.2 Loading combination

The transfer arm manufacturer shall prepare a stress report for the loading combinations in Table A.15 at all appropriate transfer arm attitudes within the envelope. The LNG carrier manifold shall be included, if required by 5.2.3.10.

Where combinations other than those in Table A.15 (e.g. exclusion of a load) can be shown to lead to a greater feasible loading effect, then the design shall also allow for that condition.

Where applicable, the stress report shall also include loading effects of using any installation/maintenance lifting lugs.

5.2.3.3 Allowable design stress

The basic allowable design stress (Sd) for pressure containing and non-pressure containing structural components shall be the lower of either

— yield strength /1,5, or

— ultimate tensile strength /3 for austenitic steels, and ultimate tensile strength /2,4 for ferritic steels.

The yield strength and ultimate tensile strength should be the values specified in the applicable material standards.

The allowable design stress is obtained by multiplying the basic allowable design stress with the K factor as provided.

5.2.3.4 Pressure load

The pressure loads (PL) shall be based on design pressure.

5.2.3.5 Fluid load

The fluid loads (FL) shall be based on the highest density of LNG.

5.2.3.6 Ice build-up

Unless otherwise specified in Table A.9, the dead load and wind load (DL + WL) shall include ice build-up (specific gravity = 0,80) as follows:

a) 6 mm on all components in cold climate;

b) 25 mm on product carrying components.

NOTE These criteria are not cumulative.

5.2.3.7 Thermal load

The thermal loads (TL) are the loads caused by material temperature differences. The temperature differences used in the design shall be based on the design temperatures specified and the ambient and solar radiation temperatures. These temperatures shall be applied in the most extreme combination.

A cool-down procedure shall be included in the operating procedures. This procedure shall provide temperature gradients across fluid and structural members and/or recommended maximum cool-down rate and minimum cool-down duration to prevent excessive stresses and strains.

5.2.3.8 Wind load

5.2.3.8.1 The wind loads (WL) shall be calculated for the worst direction(s). The transfer arm manufacturer shall calculate wind loads as follows.

5.2.3.8.2 Velocity pressure

The velocity pressure is calculated as follows:

$$q_z = 0{,}613 \times K_Z \times K_{ZT} \times V^2 \times I \qquad (1)$$

where

q_z velocity pressure at height z above minimum water level (N/m^2);

K_Z velocity pressure co-efficient evaluated at height z;

K_{ZT} topographic factor (use 1,0);

V^2 basic 3 s gust wind speed at 10 m above lowest low water (m/s);

I importance factor (use 1,0).

K_Z is determined as follows:

$$K_Z = 2{,}01 \times (Z / Zg)^{2/\alpha} \text{ for } 4{,}6 \le Z \le Zg \qquad (2)$$

$$K_Z = 2{,}01 \times (4{,}6 / Zg)^{2/\alpha} \text{ for } Z < 4{,}6 \qquad (3)$$

where

Z heights above low tide (m);

Zg gradient height (m), see Table 1;

α power law coefficient, see Table 1.

Table 1 — Exposure

Exposure	α	Zg m
C	9,5	274
D	11,5	213

Exposure C covers open terrain with scattered obstructions having heights generally less than 10 m.

Exposure D covers flat, unobstructed locations which are exposed to wind flowing over open water for a distance of at least 1,6 km. Exposure D extends 4 000 m inland from the shoreline or 10 times the height of the transfer arm, whichever is greater.

NOTE Exposure D is generally used for transfer arms except where Exposure C can be justified.

5.2.3.8.3 Wind forces

The wind force is calculated as follows:

$$F = q_z \times G \times Cf \times Af \tag{4}$$

where

- F design wind force (N);
- G gust effect factor (use 0,85);
- Cf force coefficient;
- Af projected area normal to wind (m^2).

The gust effect factor, G, accounts for the loading effects in the along-wind direction due to the effect of wind turbulence on the transfer arm. It also accounts for along-wind loading due to dynamic amplification for flexible structures. It does not include cross-wind loading effects, vortex shedding, instability or dynamic torsional effects. If a higher value factor is justified due to dynamic sensitivity to wind, it should be determined in accordance with EN 1991-1-4.

The force coefficient, Cf, accounts for along-wind effects due to the shape or drag of the transfer arm. Transfer arms are unique structures and there are no wind tunnel test data available to establish precise force coefficients. However, based on recommendations provided in EN 1991-1-4 for round cylindrical shapes and flat or angular shaped members, the coefficients as listed in Table 2 are recommended.

Table 2 — Force coefficients

Cross-section	Type of surface	Cf
Round $D\sqrt{q_z} > 5{,}3$	Moderately smooth Rough	0,7 1,0
Round $D\sqrt{q_z} > 5{,}3$	All	1,2
Flat or angular	All	1,7
D is diameter (m). q_z is velocity pressure at height z above minimum water level (N/m^2).		

Alternatively, the transfer arm manufacturer may determine wind loads from wind tunnel tests on a representative model including adjacent arms.

5.2.3.9 Earthquake load

The earthquake load shall be based on operating basis earthquake [(OBE) see Table A.9]. When the owner requires, the earthquake load based on safe shutdown earthquake (SSE) shall also be considered. In this case, transfer arm manufacturer shall define the allowable stress for owner's approval.

The earthquake loads shall be considered to act in the plane parallel and perpendicular to the jetty face. Also it should be considered to act in horizontal and vertical simultaneously.

The seismic design shall be in accordance with local or national standards and regulations, but with arms in stowed conditions. An analysis in connected condition may be required by the owner (see Table A.15).

5.2.3.10 Design stress procedure

The design stress procedure shall be as follows:

a) determine the design loads for the various load cases;

b) calculate the stresses using linear elastic material behaviour and the equivalent (Tresca, von Mises or Principal) stress;

c) determine the allowable design stress;

d) equivalent stress shall not exceed the allowable design stress;

e) stresses due to local discontinuity and/or local thermal stresses shall not exceed two times the yield stress;

f) in absence of reference to the local or national standards and regulations or code, components under predominantly compressive stresses shall be shown to have a safety factor of 2 against instability;

g) maximum deformation of components shall be limited such that the functionality of the equipment and the clearance requirements as specified are guaranteed under all loading conditions;

h) check dynamic behaviour where appropriate;

i) complete wire rope assemblies, including their anchorages, shall have a safety factor of at least 5, related to minimum rated breaking strength;

j) the transfer arm manufacturer should ensure that the loads transmitted to the manifold flange, under all circumstances are limited to the maximum given specified by the owner, but not exceeding those given in the latest edition of "Recommendations for Manifolds for Refrigerated Liquefied Natural Gas Carriers (LNG)" by OCIMF/SIGTTO.

   The manifold loads shall be analysed based on Cases 4 and 5 of Table A.15;

k) stress intensification factors shall be used for elbows flanges and pipe bends etc. Correction factors for flanged ends shall be restricted to arc angles of 90° or less. The effect of swivels shall be considered, if appropriate.

5.3 Swivel joints

5.3.1 General

The product swivel joint is made up of a product sealing arrangement, a bearing system and an external sealing arrangement.

5.3.2 Product sealing arrangement

The arrangement shall comprise of minimum two seals, one primary and one secondary. The secondary seal is to avoid external leakage or leakage into the bearing in case of primary seal failure. The design should not allow for over pressurization between primary and secondary seal that could lead to external leakage beyond the defined leakage rate (see Clause 9).

The detection port shall be provided in the annular space between the primary and secondary seal.

The swivels shall accommodate temporary partial vacuum conditions.

5.3.3 Bearing system

The bearing system shall be kept dry with N_2 to prevent internal ice formation.

5.3.4 External sealing arrangement

The external sealing arrangement shall prevent ingress of water and particulate matter into the bearing.

5.3.5 Design

The swivel joints shall be designed for a minimum (see 9.2.2.2.5)

a) safety factor a (SF_a) × $P_{CA\ swivel}$ + PL against structural failure,

b) safety factor b (SF_b) × $P_{CA\ swivel}$ + PL against leakage, with maximum allowable leakage rate as defined in 9.2.2.2.5, and

c) safety factor c (SF_c) × $P_{CA\ swivel}$ + PL against brinelling, with allowable brinelling as defined in 9.2.2.2.5.

The safety factor as listed in Table 3 is the ratio of the maximum equivalent axial load at which the event occurs and the calculated maximum equivalent axial load.

Table 3 — Safety factor

Case no. (see Table A.15)	SF_a structural failure	SF_b leakage	SF_c brinelling
3, 4, 5 or 9	4,0	2,0	1,5
1, 2, 7, 8 or 10	3,33 (=4,0/1,2)	1,67 (=2,0/1,2)	1,25 (=1,5/1,2)
SSE	2,0 (=4,0/2,0)	1,0 (=2,0/2,0)	0,75 (=1,5/2,0)

NOTE 1 Swivel joints need not be designed in case 6.

NOTE 2 PL or PL_T are added only in case of 5, 8 and 10 as per Table A.15.

When loading combinations are different from Table A.15, appropriate safety factor shall be selected.

The equivalent axial load ($P_{CA\ swivel}$) is calculated by Formula (5):

$$P_{CA\ swivel} = F_A + 5\frac{M_T}{d} + 2{,}3F_R \tan\alpha \quad (5)$$

where

F_A externally applied axial load (N);

M_T externally applied bending moment (N · m);

d raceway diameter (m);

F_R externally applied radial load (N);

A contact angle (the angle between the plane of the balls or rollers and the centre of contact at the ball or roller raceway interface).

5.4 Structural bearings

5.4.1 Design

5.4.1.1 General

The design of structural bearings shall be based on cyclic motions and static loads.

5.4.1.2 Cyclic motions

Unless otherwise specified by the owner, the following annual vessel manifold movements shall be used as input as a minimum:

— heave of LNG carrier = 1×10^6 movements/year (total manifold displacement per year 75 000 m);

— surge of LNG carrier = 1×10^6 movements/year (total manifold displacement per year 100 000 m);

— sway of LNG carrier = 1×10^6 movements/year (total manifold displacement 5 000 m).

Each individual bearing rotating motion shall be calculated separately for each of the above movements and maximum rotating angle shall be selected for the bearing design.

The above numbers shall be multiplied by the design service life and shall be used to calculate bearings cyclic motions.

For the cyclic motions, the structural bearings shall be designed/selected with a safety factor to failure of at least four.

5.4.1.3 Static load

For the static loading profile, the following criteria shall be met:

a) safety factor a (SF_a) × $P_{CA\ bearing}$ there shall not be any structural failure;

b) safety factor c (SF_c) × $P_{CA\ bearing}$ the width of any brinelling shall be a maximum of 8 % of the ball or roller diameter.

The safety factor is the ratio of the maximum equivalent axial load at which the event occurs and the calculated maximum equivalent axial load in Table 3.

The equivalent axial load ($P_{CA\ bearing}$) is calculated by Formula (6):

$$P_{CA\ bearing} = F_A + 5\frac{M_T}{d} + 2{,}3F_R \tan\alpha \qquad (6)$$

where

F_A external axial load (N);

M_T externally applied bending moment (N · m);

d raceway diameter (m);

F_R externally applied radial load (N);

α contact angle (angle between the plane of the balls or rollers and the centre of contact at the ball or roller raceway interface).

In case the above method is not applicable for the type of bearing used, other design rules may be proposed by the transfer arm manufacturer e.g. ISO 76.

5.4.2 Protection of structural bearings

The bearings shall be provided with adequate seals and protection covers suitable for marine environment:

— lubrication points shall be accessible in the stowed attitudes;

— readily visible lubrication relief ports shall be provided and designed to prevent over-pressurization from lubrication;

— grease lines and fittings shall be of austenitic stainless steel, coated copper alloy or other proper material suitable for marine environment;

— each raceway shall be fitted with grease ports. There shall be sufficient ports to ensure even distribution of grease.

The number of greasing points and the method of seal protection shall be subject to approval by the owner.

5.4.3 Grease sampling point

The bearings shall be provided with adequate grease sampling points to enable grease sampling to determine the condition of the bearings.

5.5 Accessories

5.5.1 Adjustable support (jack)

As stated in 5.2.3.10, the transfer arm loads transmitted to the ship's manifold should not exceed those given in the latest edition of "Recommendations for Manifolds for Refrigerated Liquefied Natural Gas Carriers (LNG)" by OCIMF/SIGTTO.

If the transfer arm is equipped with an adjustable support, or jack, it shall take into account that the manifold area on individual LNG carriers may not be designed accordingly.

If installed, the support should be made of two adjustable legs to rest on the deck of the LNG carrier.

The height of the support may be adjustable from 450 mm to 1 400 mm from the centre line of the presentation flange, or otherwise agreed.

The design of the support on the transfer arm shall not interfere with free movement of the arm with the motion of the LNG carrier.

5.5.2 Nitrogen injection line

At the end of the loading/unloading operation, N_2 is used to displace the product. The nitrogen injection line shall be connected to the product line of the transfer arms or jetty piping. For location, refer to Table A.10. This line shall be equipped with a non-return valve and a shut-off valve. The non-return valve should be located as close as possible to the tie-in. Threaded connections shall not be used.

5.5.3 Stowing locking device

All transfer arm functional movements shall be locked by stowing locking device in the stowed position even in the worst load conditions. Stowing locks shall be easily released and operable by one person.

The stowing locks shall be as follows:

- locking of the outboard arm shall be either mechanical or hydraulic. In the case of hydraulic locking, it shall be achieved by a separate locking valve;
- inboard arm (slewing and luffing function) shall be mechanically locked;
- it shall be possible to hydraulically lock the slew motion when in the maintenance attitude;
- locks shall not be capable of being engaged during normal operation;
- hydraulic locks shall be manually operated and independent of the remote control system;
- attempted movement while the locks are engaged shall not result in over-pressurization of the hydraulic system.

5.5.4 Ladders and platforms

Transfer arm shall be provided with a safe means of access and platforms with handrails to provide safe working areas for those parts where frequent inspection and maintenance are required.

5.5.5 Vapour recovery lines

Vapour recovery lines, if required by local or national standards and regulation or the owner, may be installed from leak detection port of product swivels to return gas line in order to recover minor leaking gas through primary seal and avoid pressurizing of a chamber between primary and secondary seals. A check valve shall be installed between vapour recovery line and return gas line.

5.5.6 Liquid nitrogen line

A LN_2 line, if required, may be installed as a piggy-back on an arm. It shall be equipped with an ERS or another safe means of disconnection.

5.5.7 Thermal insulation

If thermal insulation is required by the owner, the additional weight and size shall be considered in the design.

5.5.8 Ice fall protection

Ice fall protection may be considered reflecting the terminal operating philosophy and procedures.

5.6 Pipework and fitting

5.6.1 Process connections

Wherever possible all connections should be welded, including the product connection of the transfer arm to the jetty piping.

5.6.2 Drain connection

Drain connections shall be provided to confirm complete drainage of the arm before disconnection. Drain valves on cargo manifold and on jetty piping may be used for an outboard, inboard and base riser respectively. For location, refer to Table A.10. All connections should be terminated with a valve and provided with a blank flange. The size of the drain connections should be based on the size of the transfer arm, but should not be less than NPS 1 (DN 25) for both the riser and the outboard arm. NPS 1 connections should be reinforced.

5.6.3 Plugged connection

When specified, there should be a plugged connection at the base of the riser and at the triple swivel assembly for a pressure gauge.

5.6.4 Valve

All the soft seated valves installed on the drain connections and the nitrogen injection line shall have the fire safe requirements in accordance with ISO 10497.

5.6.5 Connection flange

The specification of all flange connection for pipes, valves, fittings and accessories shall be in accordance with ASME B16.5, or local or national standards and regulations.

5.6.6 Gasket

All gaskets shall be in accordance with local or national standards and regulations or specified by the owner.

5.7 Welding

Welds on pressure containing parts shall be carried out by a qualified operator using approved welding procedures in accordance with ASME Boiler and Pressure Vessel Code Section IX, or local or national standards and regulations.

5.8 Corrosion protection and embrittlement protection

5.8.1 Corrosion protection

Preservation and corrosion protection shall be taken into account of its environment and be specified by the owner.

Salt-laden or aggressive atmospheres and operating conditions shall be taken into account when selecting coating systems.

In case the product piping is coated, special attention shall be paid to the fact that the product piping undergoes frequent thermal cycling.

Hot dip galvanized coating on ferrous materials, fabricated iron and steel articles should be determined according to ISO 1461 and their test methods should be as described in ISO 1460.

Paint and varnishes corrosion protection of steel structures should be as described in ISO 12944.

Wire ropes shall be constructed of galvanized steel and impregnated with a non-polluting dressing.

Hydraulic cylinder rods shall be in stainless steel, finished to resist corrosion in a marine environment.

5.8.2 Embrittlement protection

Critical equipment, piping and structural elements, which can be affected by LNG leakage, shall be protected from brittle failure. In accordance with the result of appropriate studies and tools, the transfer arm manufacturer may assist the owner to identify particular equipment, piping and structural elements that shall be protected against LNG leakage. Potential sources of leakage should be considered, e.g. flanges, swivels, small bore nipples, small bore valves, etc.

Such a protection shall be achieved by an appropriate material selection (concrete, stainless steel, etc.) or by an insulating with material, or water curtain, or other appropriate measures that will protect the equipment and specific bulk material from the cold shock.

Cabinets and panels may be located out of reach of LNG splashes that cause brittle failure.

5.9 Maintenance

The replacement of major components should be possible with the minimum of operational downtime.

Transfer arms should be designed to permit easy *in situ* inspection and maintenance of vital components of the swivel and structural bearing, and the replacement of the component of the swivel, without having to dismantle major sections of the transfer arm and without using mobile cranes.

The transfer arm manufacturer should ensure maximum standardization and interchangeability of components.

6 Safety systems

6.1 General

The function of the emergency shutdown (ESD) system (generally referred to as an “ESD I”) is to safely stop and isolate the transfer of liquid and vapour between ship and shore. Typically this system may be activated by the following:

— fire or gas detection;

— tank high level or abnormal pressure;

— ship’s drift;

— electric power failure on shore or a manual signal.

It shall result in the tripping of transfer pumps both ship or shore as applicable, and the timed closure of ESD valves on the ship and shore to reduce hydraulic surge in the transfer lines to acceptable limits.

The function of the emergency release system (ERS) (generally referred to as an “ESD II”) is to protect the transfer arms and to minimize the spillage of LNG by quick disconnection, in case the ship drift out of its operating envelope. The ERS consists of a powered emergency release coupling (PERC), interlocked isolating valves to minimize loss of product when the PERC parts, and sensors to monitor transfer arm angle. The ERS is activated automatically or manually. Initiation of the ERS shall result in the simultaneous closing of interlocking ERS isolating valves, followed by the PERC separation and the transfer arms withdrawing clear of the ship’s structure and adjacent arms, preventing the arms from being damaged. Unless otherwise specified by the owner, all the disconnected arm(s) of a bank shall automatically raise and retract behind the berthing line with compressed fenders in a controlled manner and shall lock hydraulically.

The ship and shore monitoring and activation systems should be linked to ensure the coordinated operation of both ESD and ERS functions on ship and shore.

ESD and ERS systems shall be in compliance with ISO 28460, in particular the required safety integrity level (SIL) of the systems should be determined by the owner as described in IEC 61511 (all parts). The transfer arm manufacturer shall demonstrate that the SIL is achieved for ESD and ERS system of transfer arms. Electrical and electronic components which are part of the safety system shall comply with IEC 61508. Electro Magnetic Compatibility (EMC) for electrical and electronic components which are part of safety system should be taken into consideration.

6.2 Two stage alarm and shutdown system

6.2.1 First stage

The first stage alarm shall shutdown the transfer operations. Typically it initiates the following:

a) berth emergency shutdown (ESD) system;

b) LNG pumps shutdown.

If the owner requires the ERS isolating valves to close at first stage, a risk assessment shall be undertaken, using validated data, to ensure that this is beneficial to the overall safety and integrity of the system. This should consider, as a minimum, any increasing complexity of the control system, possible drift speeds of the LNG carrier, the possibility of LNG being "locked in" between the isolating valve and the effect of surge pressures generated in the transfer system including that part between LNG carrier's ESD valve(s) and the ERS valves.

6.2.2 Second stage

At any initiation of a second stage alarm, the ERS isolating valves shall close and the PERC operation shall be initiated. Unless otherwise specified by the owner, all connected arms shall disconnect simultaneously.

Unless otherwise specified by the owner, the disconnected arm(s) shall retract behind the berthing line with compressed fenders in a controlled manner and shall lock hydraulically.

The transfer arm manufacturer shall verify that no clashing of the arm(s) during disconnection, raise and retraction will occur particularly in the case where not all arms are retracted simultaneously.

6.3 Monitoring and alarm systems

6.3.1 Alarm envelopes

The determination of the transfer arm alarm envelopes shall be the result of studies to assess the behaviour of the LNG carrier at the berth, as detailed in ISO 28460.

6.3.2 Arm positioning alarms system

A system of alarm thresholds shall be installed on each arm for luffing and slewing in all three dimensions in order to detect the excessive drift of the LNG carrier and to initiate the first stage and second stage alarm.

In principle solid state, inductive proximity switches are used with separate switches for each alarm condition (see Figure B.1). Alternative systems may be considered if they comply with SIL required by the owner.

A pre-alarm may be provided in addition to the first and second stage alarms, which will not initiate any function, other than human intervention.

The detection of an alarm limit initiates visual and audible alarms and is included into the emergency release sequence. As a minimum, the alarms shall be in the jetty control centre, additional alarms should be agreed with the owner.

Any system components failure should be detected and appropriate action shall be taken upon.

6.3.3 Arm constant position monitoring system (CPMS)

In addition to 6.3.2, a system of constant monitoring of the position of arms may be used to provide real time information to the operator and ship. The CPMS shall have SIL as required by the owner, if it is used for ESD/ERS initiations.

6.3.4 Pressure and hydraulic level alarm

The following visual and audible alarms, as a minimum, shall all be displayed at the local control panel and may be repeated in the jetty control room:

— abnormal pressure in PERC actuators chambers, which can be excluded in case intrinsically safe hydraulic circuit is adopted (see 6.4.3);

— low pressure in hydraulic accumulators, if accumulators are installed;

— low N_2 pressure in accumulators, if accumulators are installed;

— low oil level in hydraulic reservoir tank.

6.4 ERS

6.4.1 General

The transfer arm shall be equipped with double valves and a powered emergency release coupling (PERC) to achieve a quick release of the arm from the ship. Valves are fitted on each side of the PERC and the whole system shall be installed in the vertical upstand of the TSA of the arm with the PERC flange faces in the horizontal plane.

In order to ensure ERS disconnection under the specified LNGC drift velocity, the ERS valves closure time should be set between 5 s to 10 s and PERC opening time shall be within 2 s. The alarm distances shall be defined accordingly. This ERS valves closure time shall be taken into account in the hydraulic surge pressure analysis of jetty piping.

The spillage from the trapped volume of product between both valves shall be minimal. The spillage volume and pressure drop shall be agreed between the transfer arm manufacturer and owner.

The PERC shall permit a clean and safe separation of the transfer arm from the ship manifold. The lower part of the TSA shall remain connected to the ship's manifold and a device shall stop this lower part rotating around the bottom swivel joint and falling down on the ship's deck or manifold service platform. The design should consider ease of reconnection after the release of the ERS. A device or indication shall be provided on the PERC to ensure a correct orientation during reassembly after disconnection.

The ERS shall be equipped with a device to prevent overpressure due to thermal expansion of trapped product between the two valves.

6.4.2 Design of ERS

The strength of the ERS shall be based on the combination of the internal design pressure and the maximum design equivalent load, L_{CA}, which is based on the combination of the most stringent arm attitude and external axial, bending moment and shear loads at the PERC at every case.

The minimum safety factors as listed in Table 4 shall be used to design for the maximum design equivalent loads:

a) safety factor a (SF_a) × L_{CA} + PL against structural failure and separation;

b) safety factor b (SF_b) × L_{CA} + PL against leakage and permanent deformation.

Table 4 — Safety factor

Case no. (see Table A.15)	SF_a structural failure and separation	SF_b leakage and permanent deformation
3,4,5 or 9	4,0	2,0
1, 2, 7, 8 or 10	3,33 (=4,0/1,2)	1,67 (=2,0/1,2)
SSE	2,0 (=4,0/2,0)	1,0 (=2,0/2,0)

NOTE 1 ERS or QCDC need not be designed in case 6.

NOTE 2 PL or PL_T are added only in case of 5, 8 and 10 as per Table A.15.

When loading combinations are different from Table A.15, appropriate safety factor shall be selected.

6.4.3 Safety devices on ERS

The system shall be designed so that the ERS is active only during LNG transfer and testing. A manually operated hydraulic valve shall be installed on the hydraulic supply line to secure it when the arm is not connected to the ship's manifold.

The two following systems are acceptable.

a) The two ERS valves shall be mechanically interlocked and be operated simultaneously by a single actuator fitted to the top valve. This shall also enable activation of the PERC.

b) The two ERS valves shall be operated independently of the PERC, by two interlocked actuators. Unintended activation of the PERC due to hydraulic malfunction, such as internal leakage of PERC solenoid valve or back pressure of drain line, shall not be possible.

It shall not be possible for the PERC to open unless the ERS valves are closed. When separated, the valves shall remain safely closed even in case of hydraulic or electric power failure. An electric, hydraulic or mechanical system shall be provided to prevent reopening of the valves(s) before reassembly of the PERC after disconnection.

Transfer arm manufacturer shall provide operation and maintenance procedures of this equipment as described in ISO 28460:2010, 15.4.

6.5 Safety devices

6.5.1 Fire safety requirements

The following fire safety requirements shall apply:

— ERS valves and drain valves on the transfer arm shall be fire safe in accordance with ISO 10497;

— hydraulic system shall be positioned as such that potential fire water is positively drained away from the main hydraulic unit (MHU);

— critical tubing/hoses for supply of hydraulic oil to the emergency release systems, as well as items of electrical equipment which ensure closing of the ERS valve(s) and opening of the powered emergency release coupling (PERC) should be protected against fire as far as considered practical. For example, a fire of 1 100 °C during 1,5 min and/or 350 °C during 10 min. As a general guideline, tubing/hoses may be critical on the lower part of the outboard arm only.

The owner may specify other requirements pertaining to equipment, outdoor cabinets and panels, piping and structural elements which shall be protected where required from fire effects in accordance with ISO 28460 or local or national standards and regulations.

Passive fire protection shall be designed to maximize protection, complemented by active fire protection systems (e.g. sprinklers, waterspray, monitors).

6.5.2 Electrical safety requirements

6.5.2.1 General

The electrical power supply specifications shall be determined by the owner in Table A.7.

The main power supply cable shall have overload protection. The isolating switch, provided by the transfer arm manufacturer, shall be rated accordingly.

6.5.2.2 Hazardous area classification

The installation shall be subjected to a hazardous area analysis. Such analysis shall be performed in accordance with IEC 60079-10-1 and ISO 28460 or local or national standards and regulations, particularly for the hazardous zones generated when the LNG ship is alongside.

6.5.2.3 Electrical components

All electrical equipment, instrumentation and installations located in each hazardous area shall be in accordance with IEC 60079-0, IEC 60079-1, IEC 60079-2, IEC 60079-5, IEC 60079-6, IEC 60079-7, IEC 60079-11, IEC 60079-14, IEC 60079-18 and IEC 60079-25 or local or national standards and regulations.

6.5.2.4 Lightning and earthing

Lightning protection and earthing is part of the terminal design and should follow IEC 62305-1 and IEC 60364-5-54 or local or national standards and regulations.

The jetty earthing details shall be provided by the owner.

Physical damage to structures and life hazard due to lightning shall be assessed according to IEC 62305-3 or local or national standards and regulations.

6.5.3 Failure of electrical power supply

6.5.3.1 General

Hydraulic or electric power failure shall not cause activation of the ERS system.

6.5.3.2 Hydraulic power backup system

The hydraulic power backup system such as hydraulic accumulators, multiple power source or emergency generator shall be installed to provide hydraulic power.

The capacity of hydraulic power shall be sufficient to enable the emergency disconnection, raise and retraction of all the arm(s) of a bank to a position behind the berthing line with compressed fenders in a controlled manner even if not all the arms disconnect simultaneously.

In case of power failure during normal operation, hydraulic QCDC is opened by manual devices of QCDC and the arm is retracted using hydraulic power backup system.

6.5.3.3 Electric power backup system

Electric power backup system for logic and control systems shall be provided by the terminal, e.g. UPS, multiple power source or backup generator, in accordance with local or national standards and regulations.

6.5.4 Stray current protectors

An insulating flange shall be inserted near the triple swivel assembly of the arm to electrically isolate the ship from the transfer arm. The insulating flange shall be located in a position where it cannot touch the ship structure.

Insulating non-metallic flexible hose or insulating flanges shall be used in any hydraulic, lubricating, purge or drain systems that bridge the insulating flange.

The resistance of the insulating flange and flexible hose shall be no less than the following values:

— as manufactured after installation in the arm -10 000 Ω;

— after hydrostatic testing and during its life cycle -1 000 Ω.

Measurement shall be performed initially using a 500 V or more insulation tester, thereafter routine testing should be undertaken with an insulation tester specifically designed to have a typical driving voltage of 20 V or more, when applied to a resistance of 1 000 Ω or greater with the arm in empty condition at ambient temperature.

6.5.5 Bonding

All flanged connections, including swivel joints, but with the exception of the insulating flange, shall be bonded by electric bonding cables, with a maximum value of 2 Ω.

NOTE It is considered that the ERS and the QCDC have electrical continuity and do not require separate bonding as this can prevent safe operation.

7 Connection with the ship

7.1 General

Specific requirements are given in Table A.10.

The connection of the arm to the ship can be achieved by the following means:

— bolted flange according to a standard specified by the owner;

— manual coupler (manual QCDC);

— hydraulic coupler (hydraulic QCDC).

Aligning and centering devices shall be furnished for each diameter of flanges to which a QCDC shall connect.

Seals and flange surface finishing shall be compatible with the LNG carrier manifold.

Gaskets, depending on their type, shall be in accordance with local or national standards and regulations, or specified by the owner.

7.2 Design of QCDC

The strength of the QCDC shall be based on the combination of the internal design pressure and the maximum design equivalent load, L_{CA}, which is based on the combination of the most stringent arm attitude and external axial, bending moment and shear loads on the manifold flange.

The following minimum safety factors in Table 4 shall be used to design for the maximum design equivalent loads:

a) load factor (safety factor) a (SF_a) × L_{CA} + PL (see NOTE 2 in 6.4.2) against structural failure and separation;

b) load factor (safety factor) b (SF_b) × L_{CA} + PL (see NOTE 2 in 6.4.2) against leakage and permanent deformation.

When loading combinations are different from Table A.15, appropriate safety factor shall be selected.

The safety factors shall be calculated allowing for the orientation in which the minimum number of connecting clamps will be in tension due to the bending moment only.

Coupler shall remain leak tight when at least one of the connecting clamps fails at the maximum design equivalent load plus at least operating pressure.

7.3 QCDC system

Flange rating and diameter shall be as specified in Table A.10.

QCDC clamping mechanism shall be designed to compensate for up to 5 mm of uneveness of thickness of the nominal manifold flange.

QCDC shall be provided with a mechanical or hydraulic locking device to prevent inadvertent release due to human error, pressure or vibration. Activation of this device should be clearly visible by a method approved by the owner.

Connection and disconnection operations of hydraulically operated QCDC shall be possible both from the transfer arm control panel at the jetty platform and also at the local control station, which is typically a portable or pendant control panel.

For hydraulically operated QCDC, an interlock shall be provided to prevent opening during product transfer or when there is pressure in the arm or ERS ready of the arm.

Hydraulically operated QCDC clamps shall operate simultaneously with equal forces and shall not overstress the mating tanker manifold flanges.

In the event of loss of hydraulic pressure, the hydraulically operated QCDC and any associated hydraulically operated product valve shall remain “as is”. A manual release shall be provided.

For hydraulically operated QCDC, the operating time range should be 10 s to 15 s (see Table A.10). For clamp safety reasons, the operating time shall not be less than the specified minimum.

QCDC shall be capable of disconnection under the maximum manifold loads, including specified ice build-up.

Manual couplers shall not require extension bars on the clamp/release lever, which are not part of the original design.

Lubrication of all moving parts shall be possible without dismantling the coupler.

7.4 Flange cover

QCDC or bolted flange shall be provided with a flange cover to prevent ingress of any foreign matter, water or moisture. The cover may not need to be designed to withstand the transfer arm operating pressure.

The cover shall have tapped hole and be fitted with a plug to enable to fit a bleed valve or pressure relief port for depressurization before removal.

Handles should be provided on the flange cover to facilitate installation and removal by hands.

8 Hydraulic and electric control systems

8.1 General

The operating and control system shall be designed as an electro-hydraulic system to ensure the normal operation of the arm, the emergency release sequence and retracting the arm empty or full of product after emergency release.

The system shall have a two speed manoeuvring mode.

The system shall be designed for intermittent (stop/start) operations.

The power to operate the arm and the accessories shall be hydraulic oil, supplied by a dedicated main hydraulic unit. The control logic shall be installed in the jetty control room or in an instrument room. The control display and actuating devices should be on the jetty side and comprise of the following:

a) control panel, (see Table A.12), as close as possible to the berthing line and in sight of the LNG carrier manifold. Control switches, buttons and lights shall be available in this control panel;

b) remote control device, (see Table A.13), allowing to operate the arm from the LNG carrier side near the LNG carrier manifold for normal connection and disconnection of the arms;

c) the arm control panel and the remote control shall not be operational simultaneously. Simultaneous movement of more than one arm should not be possible during normal operation.

Alternative remote control locations may be proposed for approval (see Table A.14).

Electro Magnetic Compatibility (EMC) for electrical and electronic components which are part of safety system should be taken into consideration.

NOTE Other control system, e.g. using only electrical or other power generation may be acceptable if it has been developed, tested and qualified for related standards and if it ensures all the functions described in Clause 8 for the hydraulic and electrical control system.

8.2 Arms operations

Arms operations include the following.

a) Single arm manoeuvring, enabling:

— luffing and slewing for normal operation, which includes the capability of manoeuvring over the LNG carrier's rail and manoeuvring at the manifold end in the connection area;

— manoeuvring into the maintenance position.

b) Hydraulic fluid flow at acceptable pressure for the following conditions:

— free wheel mode, normal LNG carrier movements;

— free wheel mode at drift speed;

— control mode during connection, normal LNG carrier movements;

— control mode after connection: the design should be such as to prevent damage to the arm, if not be placed in free wheel mode after connection to the ship.

c) Connection and disconnection of the hydraulically operated QCDC, if applicable.

d) Operation of the ERS including automatic raise and retraction.

e) Manoeuvring, following ERS operation of the following:

— full outboard arm to just above horizontal position to facilitate draining;

— full and empty transfer arm to the stowed attitude;

— full and empty transfer arm to the connected attitude to reconnect the PERC.

f) An individual manual valve per arm for emergency release in case of complete electric power failure shall be provided. The location of these individual valves may be on each arm or alternatively outside the hydraulic unit. Provision shall be made to ensure unintentional or accidental operation of these valves.

8.3 Hydraulic components

Design of the hydraulic system, as it is being used to manoeuvre the transfer arm into position shall be based on the following:

a) wind load on the arm in operation;

b) friction of swivel joints and other moving parts;

c) 10 % reserve on a) and b);

d) arm movement speed of 0,15 m/s at the end of the extended arm and the resulting forces of inertia;

e) arm maximum unbalanced moment in emergency release condition;

f) unbalance moment due to weight of ice.

The arm movement and the valve closing speeds shall be controlled by flow regulators and not needle valves.

Pressure build-up in the free wheel circuit shall be limited at as low a value as possible.

Pressure relief valves shall be fitted to each different supply line. Pressure gauges with their surge dampeners shall be provided on circuits of different pressures. Spool type valves shall be designed such that no incorrect assembly can be made. All the solenoid valves shall be equipped also with a manual override to allow manual operation without electric power and only possible under controlled conditions.

The hydraulic circuit that operates PERC shall be designed to avoid unintentionally PERC activation by over pressure caused by hydraulic leakage, temperature rise, misoperation, or any other reasons.

A filter shall be fitted on the discharge line and return line to the tank.

Filters with replaceable cartridges shall be installed.

For safety reasons, the installation shall be equipped with two hydraulic "power" sources, one in standby in case of failure of the other.

Hydraulic system shall be designed to ensure emergency disconnection and first 2 m of rising up of the maximum number of arms connected simultaneously at the emergency release sequence timing and rising up speed, this is generally achieved by a dedicated hydraulic accumulator per arm. Then the retraction of all disconnected arms shall continue until they will reach a position behind the berthing line with compressed fenders, where they shall be hydraulically locked. In normal operation, with all electrical power source working, this shall be achieved automatically (see 6.1), and in case of electrical power failure, some additional manual action can be made to achieve the safe position behind the berthing line with compressed fenders (see 6.5.3.2).

Hydraulic accumulators, if applied, shall be equipped with a system for controlling N_2 pressure in the bladder or cylinder.

Unless otherwise specified by the owner, the hydraulic reservoir shall be constructed of stainless steel for corrosion protection. Other material such as coated carbon steel may be acceptable if it has been validated that no coating or material particle can go in hydraulic oil and pollute the system.

The hydraulic reservoir shall be fitted with a moisture absorbent filter on the vent orifice.

Stainless steel (304, 304L, 316, 316L) should be used for the materials of piping, tubing and fittings. Pipe runs shall be securely supported and be positioned to avoid mechanical damage. The number of fittings shall be minimised. All fittings shall be of welding type or a single standard and double ferrule type. Where attached to carbon steel supports, insulated fittings or coating shall be used to avoid corrosion.

Hose end fittings should be stainless steel and tubing clamps should be UV resistant.

Sealing of threaded connections shall be made with jointing compounds. Sealing tapes should only be used when there is no reasonable alternative. If these products are used, then great care should be taken to ensure that they do not enter the hydraulic system.

Independent flushing of each of the hydraulic circuits shall be possible.

Biodegradable hydraulic oil should be used to avoid expansion of seawater pollution.

8.4 Electric components

Cables installed on the transfer arms shall be for intrinsically safe circuits only and comply with the certification requirements with regards to limiting cable parameters.

Electrical components shall be designed for intermittent operation.

A study shall be undertaken to define the required IP degrees of protection for electrical components such as enclosures, switches, button, etc. in accordance with IEC 60529 and IEC 60034-5. For outdoor electrical components, a minimum class IP 56 shall be selected.

Field assembly of electrical equipment shall be kept to a minimum.

The remote control both wired and wireless shall also be of an intrinsically safe type.

Motor “stop” push-buttons shall be self-reset type.

Flexible cables shall be installed on the articulated sections of the transfer arms. The outer sheath of flexible cables shall be impervious to hydrocarbon and salt water, resistant to UV light and shall maintain flexibility within the temperature range specified in the service conditions and shall be corrosion resistant.

8.5 Testing of control systems

Provisions shall be provided for routine testing of control system, e.g. interlocks, alarms, lamps.

8.6 Remote control

The remote control shall, at minimum, be equipped as described in Table 5.

Table 5 — Remote pendant control commands

Type	Commands	Visualization
Arm selection	Selector switch with a neutral position	—
Motion speed selection	Selector switch (high/low)	—
Arm movements	Actuating device (to move outboard/inboard up and down and slewing)	—
QCDC operation (if applicable)	Actuating device	—

8.7 Transfer arms jetty control console

Transfer arms control console shall be positioned on the jetty.

The console shall be equipped at minimum with the instrumentation defined in Table 6.

Table 6 — Jetty control console

Type	Commands	Alarms
ESD I	Manual activation for ESD I	Dedicated audible and visible signals
ESD II	Manual activation for ESD II (see note below)	Dedicated audible and visible signals
NOTE Switch for manual activation is installed by the owner.		

9 Inspection and tests

9.1 General

Test protocols and acceptance criteria shall be submitted to the owner for written approval before testing commences. The owner or his representative shall approve inspection results. This approval shall contain results of tests completed.

9.2 Prototype test

9.2.1 General

If prototype test certificates for each equipment of the same type and size specified and having been subjected to at least the same test loads are not available or unacceptable, the equipment shall be prototype tested except swivel joint life time qualification dynamic test.

9.2.2 Swivel joint

9.2.2.1 Life time qualification dynamic test

9.2.2.1.1 General

Transfer arm manufacturer shall prove by swivel joint life time qualification dynamic testing that the swivels are designed to accept vessel manifold movements; adjusted for an operational life of 5 years; representing approximately 24 000 h of connection time.

NOTE 24 000 h = 24 h × 200 operations per year × 5 years.

When transfer arm manufacturer provides operational data of existing operations, at least 5 years of continuous and successful operations with same type and size swivels in LNG service without breakdowns, the transfer arm manufacturer shall be relieved of the swivel life time qualification dynamic test.

9.2.2.1.2 Test protocol

The life time qualification dynamic test shall be performed on one unit of full size production swivel and shall be subjected to the following conditions:

— rotation as a result of the above movements (at least 400 000 movements, varying angle of oscillation preventing that the impact of movement stops, movement varying randomly between 6° to 25° with an average rotation angle of 8° to 10°, period of the movements 10 s on average);

— temperature lower than -160 °C (swivel internally to be filled with e.g. LN_2 to ensure the sealing arrangements is submerged in LN_2 at all times during the test, measure liquid nitrogen level, control by small slipstream of e.g. LN_2);

— internal pressure in the swivel varying between 0,25 MPa and 0,35 MPa.

— when subjected to a PCA swivel load of approximately 600 kN (axial load of 41 000 N, a radial load of 21 000 N and a bending moment of 46 000 Nm) for a 16 inches swivel. For other swivel diameters, comparative values established by the transfer arm manufacturer and shall be submitted to owner approval;

— swivel drying system as per normal operation to be applied during the test (see 5.3.3);

— after around each 40 000 movements the temperature of the swivel shall be raised to ambient;

— dismantling of the test swivel shall take place after completion of 30 %, 60 % and 100 % of the number of movements.

9.2.2.1.3 Test acceptance criteria

During the test, the following items shall be continuously measured:

— the swivel joint shall still be functional with the defined leakage rate (10 cm^3/minutes/cm primary seal diameters at detection port between primary and secondary seals);

— rotation friction shall not significantly increase.

After dismantling of 30 %, 60 % and 100 % of the number of movements shall be inspected as below:

— brinelling shall not exceed 8 % of ball or roller diameter;

— external seal shall still be functional, i.e. no collection of water, formation of ice internally nor damage to the seal;

— significant wear of the sealing (primary and secondary product seals and an external seal) and bearing (raceways and balls or rollers) surfaces shall not be allowed (wear = loss of metal by fretting).

9.2.2.2 Prototype test

9.2.2.2.1 Hydrostatic pressure test

Hydrostatic pressure test of the swivel shall be carried out at ambient temperature and not less than 1,5 times the design pressure and maintained for at least 30 min. Permanent deformation shall not be allowed.

9.2.2.2.2 Partial vacuum and leakage tests

The partial vacuum and leakage tests shall be conducted after pressure test above continuously.

— Stage 1: After hydrostatic testing, swivel shall be partial vacuum tested at 50 kPa (abs).

— Stage 2: The design pressure shall then be hydrostatically applied to demonstrate that the seals reseat correctly. Any leakage shall not be allowed.

— Stage 3: After drainage, at least 0,3 MPa internal pressure shall then be applied using air and/or N_2 to check no leakage from secondary seal. Some bubbles but not continuous are acceptable, they may be caused by temperature change.

The duration of each test shall be 30 min.

9.2.2.2.3 Rotation test

Swivel shall be hydrostatically leak tested while being rotated at least ±5° at period of the movements 10 s at a pressure of 1 MPa or the specified operating pressure whichever higher at ambient temperature.

Any leakage shall not be allowed.

The duration of the test shall be 30 min.

9.2.2.2.4 Moisture protection test

With the swivel drying system in operation, expose the swivel to cryogenic temperature, e.g. filled with LN_2, and stabilize the swivel temperature profile lower than -160 °C. Neither external loads nor internal pressure need be applied. Spray the swivel with water until 10 mm layer of ice forms and holds for one hour. Allow the swivel to return to ambient temperature.

The swivel shall be rotated and oscillated during test as specified in 9.2.2.2.3.

Drying N_2 pressure should be monitored throughout the test and maintained at the pressure level/rate specified for the field application.

Disassemble the swivel and inspect the swivel internal that neither collection of water, formation of ice, nor damage to seals.

9.2.2.2.5 Load capacity test

The load capacity test shall be conducted at the design pressure *PL* as a minimum; loaded such that the test load combination P_{CT} is equal to the worst calculated load combination, i.e.:

$$P_{CT} = SF \times P_{CA\ swivel} + PL$$

where P_{CT} is test load, being the maximum load resulting from the calculation *SF* (see Table 3) × $P_{CA\ swivel}$ (see 5.3.5) for each loading combination in Table A.15 where *PL* (see 5.2.3.4) is also present.

The test shall be carried out at ambient temperature and at a temperature lower than -160 °C at stage 1 and stage 2. Stage 3 shall be carried out at only ambient temperature.

SF at each stage is defined in Table 7.

Table 7 — SF at each stage

Stage	1	2	3
SF	SF_c	SF_b	SF_a

The holding time of each stage shall be at least 10 min.

Apply internal design pressure using air and/or N_2 or suitable liquid at ambient temperature and using LN_2 at cryogenic temperature, but only stage 1 and stage 2, and then apply external loads.

After stage 1, the swivel shall be disassembled and inspected for brinelling. The allowable maximum brinelling is when the width of the indentation is equal or less than 8 % of the ball or roller diameter. Measurement of ball or roller indentation shall be performed using suitable metrology equipment.

At stage 2, the swivel joint shall be inspected for leakage from primary seal.

Acceptance criteria are as follows:

— at ambient temperature, any leakage shall not be allowed. Depending on the measuring method, some bubbles but not continuous are acceptable, they may be caused by temperature change;

— at cryogenic temperature, leakage rate shall not exceed 10 cm^3/minutes/cm primary seal diameters at detection port between primary and secondary seals.

At stage 3, neither structural failure of the swivel body or components nor separation shall occur.

NOTE 1 At stage 1 and stage 2, internal pressure (design pressure) are applied even if *PL* is not required in loading combination in Table A.15. In this case, other external load, equivalent to *PL* can be reduced from $SF \times P_{CA\ swivel}$.

NOTE 2 At stage 3, SF being over the leakage design criteria, internal pressure is not applied even if *PL* is required in loading combination in Table A.15. In this case, other external load, equivalent to *PL* is added to $SF \times P_{CA\ swivel}$.

9.2.3 ERS

9.2.3.1 Hydrostatic pressure test

Hydrostatic pressure test of ERS assembly shall be carried out at ambient temperature and not less than 1,5 times the design pressure with valves open or not assembled condition and maintained for at least 30 min. Permanent deformation shall not be allowed.

9.2.3.2 Pneumatic pressure test

0,6 MPa internal pressure shall be applied using air and/or N_2 to check no leakage with valves open or not assembled condition. The duration of the test shall be 30 min.

9.2.3.3 Strength test

The strength test shall be conducted at the design pressure *PL* as a minimum; loaded such that the test load combination L_{CT} is equal to the worst calculated load combination, i.e.:

$$L_{CT} = SF_b \times L_{CA} + PL$$

where L_{CT} is test Load, being the maximum load resulting from the calculation SF_b (see Table 4) × L_{CA} (see 6.4.2) for each loading combination in Table A.15 where *PL* (see 5.2.3.4) is also present.

The test shall be carried out at ambient temperature and at a temperature lower than -160 °C with SF_b.

In addition, it shall be proven by calculation that the ERS shall not allow structural failure with SF_a (see Table 4).

The holding time shall be at least 10 min.

Apply internal pressure using suitable liquid or, when the owner specifies, air and/or N_2 at ambient temperature and using LN_2 at cryogenic temperature, and then apply external loads.

Acceptance criteria shall be neither leakage nor permanent deformation.

NOTE Internal pressure (design pressure) is applied even if *PL* is not required in loading combination in Table A.15. In this case, other external load, equivalent to *PL* can be reduced from $SF_b \times L_{CA}$.

9.2.3.4 Valve operating test

ERS shall be tested for valve operating under the following simultaneous conditions:

a) at a temperature lower than -160 °C;

b) L_{CA};

c) design pressure.

Following initial cooldown and once the temperature and pressure have stabilized the valves shall be closed and opened 10 times under design pressure and opened 10 times with a relief pressure of a valve sealing mechanism, which is not more than 0,5 MPa, as a differential pressure between lower valve side and higher PERC side.

The valve operating torques or the actuator hydraulic pressure shall be recorded and check the value is below minimum available operating torques or hydraulic pressure specified to operate.

9.2.3.5 Release performance test

ERS shall be tested for performance under the following simultaneous conditions:

a) at a temperature lower than -160 °C;

b) L_{CA};

c) ice build-up of 25 mm (or thicker if specified by the owner).

For safety reasons, the ERS shall not be pressurized, however, other external load, equivalent to *PL* shall be added to L_{CA}.

The specified ice build-up shall be achieved by applying a fine water mist spray.

The hydraulic pressure shall be set to the minimum available.

The release test shall be performed three times. In all tests, the valves shall close and then the PERC shall release. The 1st and 2nd tests, confirm PERC releasing but actual separation of two valves is not required to avoid icing of valve sealing surface using appropriate device such as reassembling bolting system. The last of these tests shall be confirmed completely disconnection.

In all tests, the valve shall close and then the PERC shall release within 2 s of activation.

9.2.3.6 Cryogenic seat leak test

The test shall be conducted on an ERS upper valve complete with actuator.

The valve shall be supported in its normal operating attitude, i.e. valve axis vertical with PERC flange at the horizontal lowest point.

The valve shall be filled with LN_2 and conditions allowed to stabilize at a temperature lower than -160 °C.

The pressure retaining valve seat shall remain immersed in LN_2 throughout the test, if the liquid falls below the seat then that particular step has to be repeated.

Seat and gland seal leakage rates shall be measured and recorded over a period of 1 min × 2 times with the unit pressurized to 0,3 MPa, 1 MPa and design pressure.

The allowable leakage rates shall be:

a) valve stem: zero;

b) valve seat: 1 cm^3/min of collected N_2 per mm of valve nominal diameter.

9.2.4 QCDC

9.2.4.1 Hydrostatic pressure test

Hydrostatic pressure test of the QCDC assembly shall be carried out at ambient temperature and not less than 1,5 times the design pressure with the blanking plate for appropriate pressure rating and maintained for at least 30 min. Permanent deformation shall not be allowed.

9.2.4.2 Pneumatic pressure test

0,6 MPa internal pressure shall be pneumatically applied using air and/or N_2 to check no leakage. The duration of the test shall be 30 min.

9.2.4.3 Strength test

The strength test shall be conducted at the design pressure *PL* as a minimum; loaded such that the test load combination L_{CT} is equal to the worst calculated load combination, i.e.:

$$L_{CT} = SF_b \times L_{CA} + PL$$

where L_{CT} is test load, being the maximum load resulting from the calculation SF_b (see Table 4) × L_{CA} (see 7.2) for each loading combination in Table A.15 where *PL* (see 5.2.3.4) is also present.

The test shall be carried out at ambient temperature and at a temperature lower than -160 °C with SF_b.

In addition, it shall be proven by calculation that the QCDC shall not allow structural failure with SF_a (see Table 4).

The holding time of each stage shall be at least 10 min.

Apply internal pressure using suitable liquid or, when the owner specifies, air and/or N_2 at ambient temperature and using LN_2 at cryogenic temperature and then apply external loads.

For safety reasons, no hydraulic pressure in the actuator system shall be applied during the strength test.

Acceptance criteria shall be neither leakage nor permanent deformation.

NOTE Internal pressure (design pressure) is applied even if *PL* is not required in loading combination in Table A.15. In this case, other external load, equivalent to *PL* can be reduced from SF_b × L_{CA}.

9.2.4.4 Emergency leakage test

QCDC shall be tested for emergency leakage under the following simultaneous conditions:

a) make at least one of clamps failed;

b) at least operating pressure;

c) L_{CA};

d) the test shall be carried out at ambient temperature using suitable liquid or, when the owner specifies, air and/or N_2 at a temperature lower than -160 °C using LN_2.

Any leakage shall not be allowed.

9.2.4.5 Release performances test (hydraulic QCDC)

The test shall be performed three times for consistency. In all tests, the QCDC clamps operating time shall all be 10 s to 15 s maximum upon activation. In all tests, the QCDC shall release from the test flange without hook up.

The test shall be applied at ambient and at low temperature (lower than -160 °C) under the following conditions (three times per each temperature condition).

For safety reasons, the QCDC shall not be pressurized.

At ambient temperature, the maximum manifold loads, considering friction of articulated transfer arm, reaction force of each driven system and wind load, etc. but F_L need not be considered.

At low temperature:

a) ice build-up of 25 mm (or thicker if specified by the owner);

b) the maximum manifold loads, considering friction of articulated transfer arm, reaction force of each driven system, wind load and ice weight etc. but F_L need not be considered.

The ice build-up shall be achieved by applying a fine water mist spray.

The hydraulic pressure shall be set to the minimum available.

Under the same conditions, the transfer arm manufacturer shall demonstrate by testing that this design has an acceptable method of preventing the spurious or accidental opening of the QCDC clamps.

9.3 Manufacturing inspection and tests

9.3.1 General

Unless otherwise specified, these tests shall be carried out on all transfer arms per project.

9.3.2 Materials

The materials of pressure containment parts and main structural parts shall be certified in accordance with ISO 10474:2013, inspection certificate or local and national standards and regulations.

9.3.3 Welding

All welding procedures and welding operators of pressure containment parts shall be certified in accordance with ASME Boiler and Pressure Vessel Code Section IX, or local or national standards and regulations. All welding procedures and welding operators of main structural parts shall be in accordance with appropriate standards and regulations.

9.3.4 Non-destructive test

9.3.4.1 Radiographic examination of welds

All butt welds of the product line shall be subjected to 100 % radiography examination in accordance with ISO 17636-1, ISO 17636-2 or local and national standards and regulations with the exception of fillet welds and branch connections.

9.3.4.2 Penetrant inspection and magnetic particle inspection of welds

Welds of the product line, which cannot be subjected to radiography and all fillet welds, and branch connections of pressure containment parts shall be 100 % dye-penetrant inspected in accordance with ISO 3452-1 or local and national standards and regulations.

10 % of welds of main structural parts shall be dye-penetrant inspected or magnetic particle inspected in accordance with ISO 3452-1 or ISO 9934-1 respectively or local and national standards and regulations.

9.3.5 Dimensional inspection

Base riser, inboard arm, outboard arm, ERS and QCDC shall be carried out dimensional inspection to confirm the specifications.

9.3.6 Pressure test

Hydrostatic test shall be carried out for each component or sub-assembly of the transfer arm.

The pressure containment parts of the transfer arms shall be tested at 1,5 times of the design pressure.

The test pressure shall be maintained for a minimum period of 30 min in accordance with the protocol of the appropriate pressure rating.

The test medium for hydrostatic test shall be selected to prevent any contamination of material of construction and any risk of test medium retention in critical parts, which could result in damage from the formation of ice when the transfer arm is in low temperature service.

The pressure test shall be performed with all welds of the transfer arm's component in the unpainted condition to confirm there is neither leakage nor permanent deformation.

Water quality of hydrostatic test should be adequate, especially with regard to chloride content when testing stainless steel.

During testing, the arm should be restrained if so required for personnel safety.

Following pressure test, components shall be thoroughly dried. The direct application of heat is prohibited.

9.3.7 ERS

9.3.7.1 Hydrostatic pressure test

Hydrostatic pressure test of ERS assembly shall be carried out at ambient temperature and not less than 1,5 times the design pressure with valves open or not assembled condition during more than 30 min in accordance with the protocol of the appropriate pressure rating.

Acceptance criteria shall be neither leakage nor permanent deformation.

9.3.7.2 Release performance test

Release performance test shall be carried out three times at ambient temperature to verify the interlock(s) and to demonstrate that the activation times of valve closure are in the specified time with ±10 % tolerance and the PERC activation times are within 2 s and to confirm to operate below minimum available hydraulic pressure.

9.3.7.3 Valve leakage test

Seat and gland seal leakage rates shall be measured and recorded at ambient temperature using air and/or N_2 at ambient temperature.

Any leakage is not allowed and at least 0,3 MPa during more than 5 min.

Depending on the measuring method, some bubbles but not continuous are acceptable they may be caused by temperature change.

A cryogenic test shall be carried out for at least one ERS unit (upper valve only) of each size being supplied at lower than -160 °C.

The single cryogenic test shall be undertaken at 3 steps in pressure, whereby the valve axis is vertical and the valve seat is fully immersed in liquid in order to replicate true operating conditions; i.e. 0,3 MPa, 1 MPa and design pressure (minimum 1 min × 2 times). The allowable leakage rate shall be less than 1 cm^3/mm of nominal diameter/minute of N_2 at standard temperature and pressure conditions.

9.3.8 QCDC

9.3.8.1 Hydrostatic pressure test

Hydrostatic pressure test of QCDC assembly shall be carried out at ambient temperature and not less than 1,5 times the design pressure during more than 30 min in accordance with the protocol of the appropriate pressure rating.

Acceptance criteria shall be neither leakage nor permanent deformation.

9.3.8.2 Release performance test

Release performance test shall be carried out three times without external loads at ambient temperature to verify the connection and release functions and to measure that the operating times are between 10 s and 15 s and to confirm to operate below minimum available hydraulic pressure.

The QCDC shall be tested for the full range of flange sizes specified.

9.3.9 Insulating flange (stray current protector)

The resistance of the insulating flange shall be measured after installation in the transfer arm, while all the required hoses, lines, wires etc. parallel to the current protector flange assembly are fitted.

Testing should be undertaken using an instrument designed to have a driving voltage of 20 V or more.

Resistance shall be not less than 1 000 Ω after hydrostatic test.

If the insulation flange test before hydrostatic test is required, resistance shall be not less than 10 000 Ω.

9.3.10 Hydraulic circuit test

All the hydraulic circuit components assembled in workshop shall be tested by transfer arm manufacturer or sub suppliers with an appropriate fluid, at not less than 1,5 times the design pressure to confirm there is no leakage and permanent deformation.

9.4 Factory acceptance tests

One arm of each size per project, complete with its hydraulic power unit and control panel, shall be erected and function tested at empty condition at ambient temperature prior to transport site of installation.

The factory tests shall demonstrate and/or confirm the following:

- complete hydraulic power system;
- control and alarm systems;
- function of ERS valves and PERC;
- function of QCDC;
- operation of the various interlocks;
- operating envelope;
- specification compliance;
- smooth manoeuvrability of arm at all specified speeds;
- suitability of platform and ladders;
- balance of triple swivel unit;
- clearance between moving parts, between steel sharp edges, hoses and cables;
- adequacy of the routing and supports of hydraulic tubing, wires and hoses;
- assessing maintainability, accessibility of instruments, valves and greasing manifold;
- presence of the name plate, item number service etc.

As a minimum, the following tests shall be carried out and tests a), c), d) and f) recorded with suitable marking of dates and times of events to enable accurate assessment of the performance.

a) Balance and behaviour test.

b) Presentation flange of the empty transfer arm shall be manoeuvred to all the extreme corners (total typical number: 8) of the operation envelope, as well as over the highest ship's rail elevation and to its maintenance position. Movable range of the transfer arm shall be checked against operating envelope study. This can also be done by measuring inboard, outboard and horizontal movable range. In cases where the bottom of the operation envelope is below the yard level, the spare stroke of the relevant cylinders shall be measured and calculations carried out to demonstrate whether the spare stroke is adequate to position the presentation flange in the extreme positions below the yard level.

c) All alarm settings shall be checked.

d) Emergency disconnections shall be carried out (location in the envelope to be agreed) as follows:

 — one test with the transfer arm empty connected on a moving dummy manifold;

 — one test with the transfer arm full or simulated full, i.e. product and ice weight condition connected on a moving dummy manifold;

 — one test with the transfer arm empty using the push button from the control panel in static position;

 — one test with the transfer arm empty using the accumulators if supplied to simulate a complete power failure in static position.

e) Following automatic raise and retraction, the full transfer arm shall be manoeuvred to the stowed attitude and the outboard arm raised over the horizontal to facilitate drainage.

f) Reconnection operation shall be carried out with the empty transfer arm.

g) ERS shall be tested to demonstrate that accidental release with the ERS valves open cannot occur due to failure of electric or hydraulic power or components.

h) QCDC, if specified shall be tested for release performance under normal operating conditions.

If an existing qualification for similar arms is not available or not acceptable to the owner, he may request functional tests at temperature lower than -160 °C.

All the ERS factory acceptance tests should be recorded on video so that they can be viewed in slow motion.

It is recommended that two fixed cameras are provided: one showing the full PERC and PERC actuators, and the other one showing the whole arm 90° from the arm retracting plan.

9.5 Site acceptance tests

9.5.1 General

After installation at site, the transfer arm manufacturer shall demonstrate by means of the site acceptance tests the functionality of all transfer arms at ambient temperature. All transfer arms shall be completely assembled, and electric and hydraulic equipment should be completely checked.

The quality of fluid in the hydraulic circuit system shall be checked. Cleanliness shall be the more stringent of code -/18/15 in accordance with ISO 4406 (or equivalent) or the standard set for the valve assemblies by their manufacturer. The water content shall not exceed 0,1 %.

NOTE In order to assist the above, it is suggested that the transfer arm manufacturer be responsible for the provision and installation of the complete hydraulic system (main hydraulic unit and hydraulic tubing).

9.5.2 Transfer arm assembly

9.5.2.1 General

The tests described in 9.5.2.2 to 9.5.2.7 shall be carried out for transfer arm assemblies.

9.5.2.2 Leakage test

Connected joints furnished at site including swivel joints shall be leak checked at 0,6 MPa pressure using air and/or N_2. The duration of the test shall be at least 30 min. Acceptance criteria shall be no leakage.

9.5.2.3 Balance test

The balance between inboard arm and outboard arm, and triple swivel assembly shall be checked at empty condition, and adjusted if necessary. Acceptance criteria shall be in accordance with specification.

9.5.2.4 Clearances check

Presentation flange of the empty transfer arm shall be manoeuvred to critical positions based on the clearance study. Clearances between the arms, the piping and the surrounding structure shall be checked (see Figure B.2).

Acceptance criteria shall be no clash.

9.5.2.5 Operating test

The following tests shall be carried out as the operating test. During all these tests, the interfaces (input/output) with the other parts of the installations shall be checked.

Acceptance criteria shall be in accordance with the following specifications.

— Presentation flange of the empty transfer arm shall be manoeuvred to all the extreme corners (total typical number: 8) of the operating envelope, as well as over the highest ship's rail elevation and to its maintenance position. Movable range of the transfer arm shall be checked against operating envelope study by measuring inboard and outboard and horizontal movable range.

— Clearances between moving parts, sharp edge, hoses and cables shall be checked.

— All alarm settings and interlocks shall be checked.

— CPMS, if provided shall be checked.

— Swivel nitrogen drying system shall be checked.

— QCDC, if provided shall be checked.

Accessibility for maintenance shall be checked.

NOTE This covers clearance around the arms (and dummy manifold flange if provided) for maintenance on arms.

9.5.2.6 ERS release performance test

ERS release performance test shall be tested with empty condition from a static position (location in the envelope to be agreed) using the push button on the control panel and the accumulators, if provided, to simulate a power failure.

This test is done to confirm PERC releasing. Actual disconnection of the valves is not required.

Following the PERC releasing, the transfer arm shall be retracted to the specified position automatically. After that, the outboard arm shall be manoeuvred to above horizontal position and the arm shall be to the stowed attitude finally.

Reconnection operation shall be carried out.

NOTE The owner can consider actual disconnection test of ERS at ambient temperature on one of the first LNGC that calls at LNG terminal.

9.5.2.7 Electrical resistance test

Electrical resistance of insulation flange shall be checked, with all the required hoses, lines, wires etc. installed.

Testing should be undertaken using an instrument designed to have a driving voltage of 20 V or more.

Acceptance criteria shall be not less than 1 000 Ω.

9.5.3 Hydraulic circuit

9.5.3.1 General

The tests described in 9.5.3.2 and 9.5.3.3 shall be carried out for hydraulic circuit.

9.5.3.2 Hydrostatic pressure test

Hydraulic tubing furnished at site, shall be hydrostatically pressure tested at 1,5 times the design pressure. Acceptance criteria shall be neither permanent deformation nor leakage.

9.5.3.3 Leakage test

Connected joints between equipment and tubing that had already been hydrostatically tested shall be hydrostatically pressure tested at design pressure. Acceptance criteria shall be no leakage.

10 Quality assurance and control

10.1 Quality system

The transfer arm manufacturer shall demonstrate that it has implemented and maintains a quality system to the requirements of ISO 9000 and ISO 9001.

10.2 Quality plan

Prior to commencing the works (incl. design activities), the transfer arm manufacturer should submit to the owner a project quality assurance plan which should detail e.g. all activities, the resources, responsibilities, key personnel, working procedures and practices to carry out all the activities for the supply of the transfer arms and associated equipment in an efficient and effective manner.

The quality assurance plan should incorporate the detailed quality control plans for design, manufacturing and testing etc.

The detailed quality control plan should cover as a minimum the following:

— compliance with statutory and specified requirements;

— materials of all components;

— welding procedures and qualifications;

— heat treatment procedures;
— non-destructive testing;
— proposed repair procedures;
— tests within scope of supply;
— dimensional checks;
— cleanliness of hydraulic system;
— painting and corrosion prevention;
— certification and testing of all lifting gear components;
— proof assembly of structural steelwork;
— certification and testing of electrical and instrumentation equipment;
— electrical resistance of insulating flanges;
— packing and preservation.

11 Required documentation

The users of the forms given in Tables C.1 and C.2 are allowed to copy these forms with the tender and after contact award respectively in order to define the owner's documentation requirement.

Annex A
(informative)

Design data sheets

Tables A.1 to A.15 and Figures A.1 to A.4 show the data for transfer arm design.

NOTE 1 The users of the forms (owner and transfer arm manufacturer) given in Tables A.1 to A.15 are allowed to copy these forms.

NOTE 2 Tables A.1 to A.15 are primarily to be filled by owner.

Table A.1 — Transfer arm design details

Berth No	Arm No	Arm diameter mm	Design pressure kPaG	Design flow rate m^3/h	Design temperature min/max °C	Arm operation							
						Single	Connection combinations						

Table A.2 — Product and operational data

Berth No	Product	Arm No	Temperature °C		Density kg/m³		Viscosity kPa s		Vapour pressure kPaG		Flow rate m³/h	Pressure kPaG	
			min.	max.	min.	max.	min.	max.	min.	max.		min.	max.

Table A.3 — LNG carrier details (see Figure A.1)

	Ship type (no. of tanks, containment system)					
	LNG carrier size	(m^3)				
	Freeboard					
a	Laden	(m)				
	Ballast	(m)				
b	Rail height	(m)				
	Manifold height above water level					
c	Minimum	(m)				
	Maximum	(m)				
	Manifold setback					
d	Minimum	(m)				
	Maximum	(m)				
	Manifold spacing					
e	Minimum	(m)				
	Maximum	(m)				

Table A.4 — LNG carrier motions (see Figure A.2)

	Ship type						
	LNG carrier size		(m^3)				
	Motions (at manifold)						
	Surge fore[a]		(m)				
	Surge aft[a]		(m)				
	Sway[a]		(m)				
	Heave, maximum	+	(m)				
		–	(m)				
	Roll, maximum	+	(deg)				
		–	(deg)				
	Pitch, maximum	+	(deg)				
		–	(deg)				
	Yaw, maximum	+	(deg)				
		–	(deg)				

[a] Surge and sway occur simultaneously.

Table A.5 — Manifold details

Ship name			
Product			
Dia mm/ASME rating	/	/	/
Wall thickness/material	/	/	/
Product			
Dia mm/ASME rating	/	/	/
Wall thickness/material	/	/	/
Product			
Dia mm/ASME rating	/	/	/
Wall thickness/material	/	/	/
Product			
Dia mm/ASME rating	/	/	/
Wall thickness/material	/	/	/

Table A.6 — Berth details, general (see Figure A.3)

Dimensions in meters

a	Underside (U/S) base plate above chart datum	
b	Jetty face to berthing line, minimum/maximum	
c	Jetty face to riser centre	
d	Riser spacing	
e	Available jetty length	
f	Available jetty width	
g	Height above U/S base plate of obstructions within area ef	
h	Riser flange above U/S base plate Type 1	
i	Riser flange below U/S base plate Type 2	
J	Riser flange below U/S base plate Type 3	
k	Riser centre to riser flange face	
	Minimum clearance between any part of an operating arm and a stowed arm (see 5.1.3)	
	Minimum clearance between any part of an operating arm and any adjacent structures, piping, equipment (see 5.1.3)	
	Minimum clearance between any part of adjacent operating arms (note: the minimum manifold centers on some ships give less clearance than 0,3m between adjacent ERS and adjacent QCDC) (see 5.1.3)	
	Minimum clearance between counterweights of operating arms (see 5.1.3)	

Table A.7 — Berth details, electrical rating and supply

Electrical supply	Volts	Hz	AC	DC	No phases / no wires	By owner
Electric motors						Yes/no
Logic/trip system						Yes/no
Electrical instruments						Yes/no
Electro-hydraulic components						Yes/no

Table A.8 — Berth details, safety

Hazardous area classification	

Table A.9 — Environmental data

Design wind velocities[a] (see 5.2.3.8) — stowed — manoeuvring/connected — hydrostatic test/maintenance	 (m/s) (m/s) (m/s)	
Earthquake factor(OBE) — vertical direction — horizontal direction	 (G) (G)	
Ambient temperature – minimum Ambient temperature – maximum	(°C) (°C)	
Solar radiation temperature	(°C)	
Thickness of ice build-up to be considered for ice load and effect on windload (WL) (5.2.3.6 and 5.2.3.8) — on all components in cold climate — on product carrying components	 (mm) (mm)	
Water elevation, from chart datum — maximum water level[b] — minimum water level[c]	 (m) (m)	

[a] Basic 3 s gust wind speed at 10 m above lowest water or specified wind velocities complied with the local or national standards and regulations or code agreed with the owner.

[b] Includes tide and positive heave.

[c] Includes tide and negative heave. State + or - for above or below chart datum.

Table A.10 — Specific requirements

Berth no./arm no.		
ERS manufacturer and type		
ERS product valve closing timing		First stage (ESD I)/second stage (ESD II)
ERS product valve closure time	(s)	
PERC opening time	(s)	Within 2
ERS product valves — type — diameter — bore	 (mm) 	 Full/reduced
Mechanical interlock		Yes/no
Hydraulic interlock		Yes/no
Quick Connect/Disconnect Coupler QCDC		Yes/no
QCDC operation		Hydraulic/manual
Clamp operating time minimum/maximum (hydraulic only)	(s)	10–15
Piggy back liquid nitrogen line		Yes/no
Presentation flange rating/diameter (nominal bore)	(mm)	Class
Riser flange rating/diameter (nominal bore)	(mm)	Class
Control system Jetty control console (see Table A.12) Remote control (see Table A.13)		 Yes/no Yes/no
Drain connection, rating/diameter (nominal bore) — base of the riser — bottom of TSA — jetty piping and cargo manifold (in case no drain on transfer arm) — above the upper ERS valve	(mm)	 Yes/no, class Yes/no, class Yes/no Yes/no, class
Nitrogen injection line[a], rating/diameter (nominal bore) — riser — apex — jetty piping or cargo manifold (in case no drain on transfer arm)	(mm)	 Yes/no, class Yes/no, class Yes/no
Outboard arm locking device		Mechanical/hydraulic
Foundation bolts — specified by transfer arm manufacturer — supplied by transfer arm manufacturer		 Yes/no Yes/no
Baseplate template supplied by transfer arm manufacturer		Yes/no
Standby electro-hydraulic pump		Yes/no
Manual hydraulic pump		Yes/no
Swivel drying system		Yes/no
Swivel vapour recovery line		Yes/no

[a] Location of nitrogen injection shall be defined following terminal operating process for arms draining after transfer. When draining process is by gravity, the appropriate location of nitrogen injection is at apex.

Table A.10 *(continued)*

Berth no./arm no.		
Consideration for thermal insulation — inboard arm — outboard arm — riser		 Yes/no Yes/no Yes/no
Jack		Yes/no
Lubrication — grease specification — cartridge — local — central — other		 Yes/no Yes/no Yes/no Yes/no
Maintenance dummy manifold		Yes/no
Hydraulic accumulators		Yes/no
Ice fall protection		Yes/no
Design life	(years)	
[a] Location of nitrogen injection shall be defined following terminal operating process for arms draining after transfer. When draining process is by gravity, the appropriate location of nitrogen injection is at apex.		

Table A.11 — Envelope details (transfer arms with ERS)
(see Figures A.4)

Arm no.			
	Pre-alarm required		Yes/no
a	Pre-alarm luffing	(m)	
b	1st stage alarm (luffing)	(m)	
c	2nd stage alarm (luffing)	(m)	
d	Maximum reach (luffing)	(m)	
e	Bottom limit operating envelope to chart datum	(m)	
f	Top limit operating envelope to chart datum	(m)	
g	Maximum slew right (surge) (see Table A.4)		
h	Maximum slew left (surge) (see Table A.4)		
i	2nd stage alarm slew right	(m)	
J	2nd stage alarm slew left	(m)	
k	1st stage alarm slew right	(m)	
I	1st stage alarm slew left	(m)	
m	Pre-alarm slew right	(m)	
n	Pre-alarm slew left	(m)	
-	Maximum drift velocity (surge direction) when reaching 1st step alarm[a]	(m/s)	
-	Maximum drift velocity (sway direction) when reaching 1st step alarm[a]	(m/s)	
-	Maximum drift velocity (surge direction) when reaching 2nd step alarm[a]	(m/s)	
-	Maximum drift velocity (sway direction) when reaching 2nd step alarm[a]	(m/s)	
-	Maximum drift velocity (surge direction) when reaching arm mechanical limit[a]	(m/s)	
-	Maximum drift velocity (surge direction) when reaching arm mechanical limit[a]	(m/s)	

[a] If available, it is preferable to attach as well the curves drifting distances and drifting speed after ship break-out versus time elapsed after break-out.

Table A.12 — Jetty control console requirements (see Clause 8)

a	Power on/off (key locked)	Yes/no
b	Hydraulic pump(s) on/off	Yes/no
c	Arm selector switch	Yes/no
d	Manoeuvring controls	Yes/no
e	Jetty control console/remote control switch	Yes/no
f	Two speed manoeuvring selector switch	Yes
g	1st stage alarm push button, fitted under a red flap-over cover	Yes[a]
h	2nd stage alarm push button, fitted under a red flap-over cover	Yes[a]
i	Shutdown reset button	Yes/no
j	Alarm lamps	Yes/no
k	ERS valve closure switches	Yes/no
[a]	See 8.7.	

Table A.13 — Remote control requirement (see Clause 8)

a	Transfer arm manoeuvring controls	Yes/no
b	Two speed manoeuvring selection	Yes
c	ERS valve closure switches	Yes/no

Table A.14 — Location of remote control

a	Jetty (one/bank of arms)	Yes/no
b	Triple swivel assembly (one/arm)	Yes/no
c	Radio control	Yes/no

Table A.15 — Design load cases

Case no.	Mode	Loading combination	Allowable stress (s) K[c] × Sd
1	Stowed	DL[b] + WL_S	1,2 Sd
2	Stowed	DL[b] + EL	1,2 Sd
3[a]	Manoeuvring	DL + WL_O	0,9 Sd
4[a]	Connected	DL + WL_O	0,8 Sd
5[a]	Connected	DL + FL + PL + WL_O	0,8 Sd
6	Connected	DL + FL + PL + WL_O + TL	1,5 Sd
7	Emergency release	DL + WL_O	1,1 Sd
8	Emergency release	DL + FL + PL + WL_O	1,1 Sd
9	Maintenance	DL[b] + WL_M	0,9 Sd
10	Hydrostatic test	DL[b] + FL + PL_T + WL_M	1,3 Sd

DL = Dead Load

EL = Earthquake Load

FL = Fluid Load

PL = Design Pressure Load

PL_T = Test Pressure Load

TL = Thermal Load

WL_S = Wind Load in Stowed Mode

WL_O = Wind Load in Operating Mode

WL_M = Wind Load in Maintenance Mode

[a] Usually earthquakes are considered for the arms in stowed position. Should the owner wishes to include earthquake calculation cases for the arms manoeuvring or connected, then the load combinations for these items should be reviewed.

[b] In case 1, 2, 9 and 10, ice build-up is excluded from DL.

[c] Allowable stress for each case no. have been established considering the particularity of transfer arms, which are subjected to pressure piping codes when in operation, connected to jetty piping and to LNG carrier manifold piping, emergency release mode or hydrostatic test mode, and subjected to structural codes when not in service, in stowed mode, manoeuvring mode or maintenance mode.

