

BS EN ISO 16904:2016



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

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The UK participation in its preparation was entrusted to Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries.

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English Version

**Petroleum and natural gas industries - Design and testing
of LNG marine transfer arms for conventional onshore
terminals (ISO 16904:2016)**

Industries du pétrole et du gaz naturel - Conception et
essais des bras de transfert de GNL sur des terminaux
terrestres conventionnels (ISO 16904:2016)

Erdöl- und Erdgasindustrie - Auslegung und Prüfung
von Schiffsverladearmen für Flüssigerdgas für
konventionelle landseitige Terminals (ISO
16904:2016)

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European foreword

This document (EN ISO 16904:2016) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” in collaboration with Technical Committee CEN/TC 282 “Installation and equipment for LNG” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2016, and conflicting national standards shall be withdrawn at the latest by September 2016.

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Endorsement notice

The text of ISO 16904:2016 has been approved by CEN as EN ISO 16904:2016 without any modification.

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Foreword

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

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 — Part 1: 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 “s”*

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

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 *pitching* (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 LN₂.

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 *rolling* (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 (S_d) 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:

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

where

q_z velocity pressure at height z above minimum water level (N/m²);

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:

$$K_Z = 2,01 \times (Z / Z_g)^{2/\alpha} \text{ for } 4,6 \leq Z \leq Z_g \quad (2)$$

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

where

Z heights above low tide (m);

Z_g gradient height (m), see [Table 1](#);

α power law coefficient, see [Table 1](#).

Table 1 — Exposure

Exposure	α	Z_g 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:

$$F = q_z \times G \times C_f \times A_f \quad (4)$$

where

F design wind force (N);

G gust effect factor (use 0,85);

C_f force coefficient;

A_f projected area normal to wind (m²).

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, C_f , 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	C_f
Round $D\sqrt{q_z} > 5,3$	Moderately smooth	0,7
	Rough	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/m²).

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 N₂ 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) $\times P_{CA \text{ swivel}} + PL$ against structural failure,
- b) safety factor b (SF_b) $\times P_{CA \text{ swivel}} + PL$ against leakage, with maximum allowable leakage rate as defined in [9.2.2.2.5](#), and
- c) safety factor c (SF_c) $\times P_{CA \text{ swivel}} + PL$ 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 ($P_{CA \text{ swivel}}$) is calculated by Formula (5):

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

where

F_A externally applied axial load (N);

M_T externally applied bending moment (N · m);