



**International
Standard**

ISO 24132

**Ships and marine technology —
Design and testing of marine
transfer arms for liquefied
hydrogen**

*Navires et technologie maritime — Conception et essais des bras
de transfert marins pour l'hydrogène liquéfié*

**First edition
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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).

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

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

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

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 2, *Marine environment protection*.

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

Introduction

The twenty-first session of the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) was held in Paris, France in December 2015 and finally adopted an agreement for the prevention of global warming, the Paris Agreement. The Agreement requires Parties' efforts to achieve zero net anthropogenic greenhouse gas (GHG) emissions during the second half of the 21st century. The International Maritime Organization (IMO) adopted a strategic plan to reduce GHG emissions from the maritime sector by 50 % in 2050 and finally to zero level within this century. Since the required reduction of GHG emissions is not attainable by a simple improvement in efficiency, the substitution of alternative fuels, including hydrogen, ammonia, and biofuels, for present fossil energies must be considered. Among them, hydrogen is one of the most present energy carriers, not only as fuel, but also as storage and transportation media.

A massive and long-distance transport of hydrogen by ships from production areas to consumption areas would be necessary because production plants are often constructed far from consumption areas, which are typically cities and industrial areas where hydrogen would be used in gas/steam turbine power plants and transportation systems such as railways, automobiles and ships.

In the marine transportation system of liquefied hydrogen, transfer from shore to ship would take place using transfer arms. A number of transfer arms are currently used for the loading and unloading of liquefied natural gas (LNG) at marine terminals. However, the temperature difference between LNG ($-162\text{ }^{\circ}\text{C}$) and liquefied hydrogen ($-253\text{ }^{\circ}\text{C}$) is critical and requires a significant change in the design of the transfer arms. Transfer systems minimize heat loss by applying high performance heat insulation technology. Liquid oxygen ($-183\text{ }^{\circ}\text{C}$) formation on the outer surface of the system should be strictly prevented because some materials can detonate unpredictably from sources of ignition such as flames, sparks or impact from light blows if soaked in liquefied oxygen (LO₂). Leakage should also be prevented because the hydrogen molecule is small in size and hydrogen gas is flammable over a wide range of concentrations.

To ensure the safe and smooth transportation of liquefied hydrogen, well-qualified transfer arms that are compatible with the on-board equipment of hydrogen carriers should be installed at each terminal. This document is, therefore, developed to provide technical guidance and safety requirements for liquefied hydrogen marine transfer arms.

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Ships and marine technology — Design and testing of marine transfer arms for liquefied hydrogen

1 Scope

This document specifies the design, minimum safety requirements, and inspection and testing procedures for liquefied hydrogen (LH2) marine transfer arms intended for use at onshore LH2 terminals handling LH2 carriers. It also covers the minimum requirements for safe LH2 transfer between ship and shore.

Although the requirements for power/control systems are covered, this document does not include all of the details for the design and fabrication of standard parts and fittings associated with transfer arms. This document is mainly focused on hard pipe type transfer systems; hose type transfer systems are not described in detail in the general description of this document. However, hose type transfer systems can also be considered as reasonable vacuum insulated technology for the design of transfer arms for liquefied hydrogen.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For 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, *Steel and steel products — Inspection documents*

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

ISO 16904, *Petroleum and natural gas industries — Design and testing of LNG marine transfer arms for conventional onshore terminals*

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*

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

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 enclosure “p”*

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

IEC 60079-6, *Explosive atmospheres — Part 6: Equipment protection by liquid immersion “o”*

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

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

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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

ASME, *Boiler and Pressure Vessel Code Section IX*

3 Terms and definitions

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

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

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

3.1

apex swivel

articulated, fluid-carrying joint located between the *inboard arm* (3.19) and *outboard arm* (3.32)

Note 1 to entry: See [Figure B.2](#).

Note 2 to entry: It provides *luffing* (3.25) of the outboard arm relative to the inboard arm.

3.2

attitude

various modes of use and/or location of the *transfer arm* (3.58) (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* (3.58)

Note 1 to entry: See [Figure B.2](#).

Note 2 to entry: Sometimes referred to as “standpost”.

3.4

bottom swivel

swivel joint accommodates the *pitching* (3.34) motion of the *LH2 carrier* (3.24) and is located adjacent to *presentation flange* (3.36) in horizontal part of the *TSA* (3.59)

Note 1 to entry: See [Figure B.2](#).

3.5

brinelling

permanent indentation in the *swivel* (3.54) or *structural bearing* (3.49) raceways caused by excessive loading of balls or rollers

3.6

cargo manifold

pipe assembly mounted on board a *LH2 carrier* (3.24) to which the *presentation flange* (3.36) or *QCDC* (3.38) of the *transfer arm* (3.58) is connected

Note 1 to entry: See [Figure B.2](#).

3.7

cavitation

formation and collapse of bubbles in a liquid at or below the liquid saturated vapour pressure

Note 1 to entry: The collapse releases energy and may cause erosion at the cavitation sites, sometimes with an audible sound and vibration.

Note 2 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

contact during design operational conditions, or as a result of an emergency separation

Note 1 to entry: This contact can occur between any part of a *transfer arm* (3.58) and:

- adjacent transfer arm while both arms are operating, or one arm is operating, and the other arm is stowed (e.g. the counterweights (3.10));
- adjacent section of the same transfer arm (e.g. triple swivel assembly (3.59) and the outboard arm (3.32));
- loading platform equipment (e.g. counterweight (3.10) and piping or valves).

3.9

contact angle

α

angle between the plane of the *swivel joint* (3.54) or *structural bearing* (3.49) balls or rollers and the centre of contact at the ball or roller raceway interface

3.10

counterweight

system of weights used to balance the *inboard arm* (3.19) and *outboard arm* (3.32) assemblies

Note 1 to entry: Some *transfer arms* (3.58) have a single counterweight for this function and others have multiple counterweights.

3.11

design pressure

pressure for which the *transfer arm* (3.58) is designed

3.12

design temperature

range of temperatures for which the *transfer arm* (3.58) is designed

3.13

drift

longitudinal and/or lateral displacement of the *LH2 carrier* (3.24) due to the influence of environmental forces

Note 1 to entry: See also *surge fore* (3.51) or *surge aft* (3.50) and *sway* (3.53).

3.14

emergency release system

ERS

system that provides a positive means of quick release of *transfer arms* (3.58) and safe isolation between the *LH2 carrier* (3.24) and shore, following a predefined procedure including an *emergency shutdown (ESD)* (3.15)

Note 1 to entry: This is also known as an *emergency release coupling* (ERC).

Note 2 to entry: See [Figure B.2](#).

3.15

emergency shutdown

ESD

method that safely and effectively stops the transfer of LH2 and vapour between the *LH2 carrier* ([3.24](#)) and shore

3.16

freeboard

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

3.17

free wheel

ability of a hydraulically operated *transfer arm* ([3.58](#)) when connected to a *LH2 carrier* ([3.24](#)) to follow freely, without hydraulic restraint, the vertical and horizontal motions of the LH2 carrier's manifold (draft changes and *sway* ([3.53](#)) and surge motions)

3.18

heave

vertical motion of the *LH2 carrier* ([3.24](#)) due to wave action

3.19

inboard arm

product-carrying pipe and any structural members contained between the *apex swivel* ([3.1](#)) and the *trunnion swivel* ([3.60](#))

Note 1 to entry: See [Figure B.2](#).

3.20

included angle

angle formed between *inboard arm* ([3.19](#)) 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* ([3.58](#)) is such, that the arms are parked with the *triple swivel assembly* ([3.59](#)) behind the berthing line.

3.21

insulating flange

electrical insulating system, usually dedicated, that is installed in the lower end of the *outboard arm* ([3.32](#)) or in the vertical part of the *triple swivel assembly* ([3.59](#))

Note 1 to entry: Its purpose is to prevent stray currents from causing an arc at the *LH2 carrier's* ([3.24](#)) flange as the *transfer arm* ([3.58](#)) is connected or disconnected.

3.22

jack

permanent, adjustable load-carrying mechanism potentially installed in the *triple swivel assembly* ([3.59](#)) to transfer a portion of the *transfer arm* ([3.58](#)) fluid weight to the deck instead of the *LH2 carrier's* ([3.24](#)) manifold

Note 1 to entry: See [Figure B.2](#).

3.23

jetty control centre

control centre situated on or adjacent to the jetty primarily to control and/or monitor the *transfer arms* ([3.58](#))

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

3.24

LH2 carrier

LH2C

tank ship designed for the carriage of LH2

3.25

luffing

rotary motions of the *inboard arm* (3.19) and *outboard arm* (3.32) in the vertical plane

Note 1 to entry: See [Figure B.2](#).

3.26

main hydraulic unit

MHU

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

3.27

manifold setback

horizontal distance between the board side of the *LH2 carrier* (3.24) and the face of the *cargo manifold* (3.6)

3.28

manifold spacing

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

3.29

middle swivel

swivel joint accommodates *yawing* (3.62) and surge of the *LH2 carrier* (3.24) and is located between the *top swivel* (3.56) and *bottom swivel* (3.4) in the vertical part of the *TSA* (3.59)

Note 1 to entry: See [Figure B.2](#).

3.30

onshore LH2 terminal

LH2 exporting or receiving terminal that is located on shore and that has marine *transfer arms* (3.58) for the loading or unloading of *LH2 carriers* (3.24) in a harbour or other sheltered coastal location

3.31

operating envelope

volume in which *presentation flange(s)* (3.36) of a (group of) *transfer arm(s)* (3.58) 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* (3.59)

Note 1 to entry: See [Figure B.2](#).

3.33

owner

designated agent

company or group of companies for whose use the *transfer arms* (3.58) are installed, responsible for the safe design and construction of the installation

3.34

pitch

rotation of the *LH2 carrier* (3.24) around the transversal horizontal axis

3.35

powered emergency release coupling

PERC

powered device to provide a means of quick release of the *transfer arms* (3.58) when such action is required only as an emergency measure

3.36

presentation flange

transfer arm (3.58) flange for connection to either the *cargo manifold* (3.6) or *spool piece* (3.46)

Note 1 to entry: See [Figure B.2](#).

3.37

product

fluid transferred using *transfer arms* (3.58)

Note 1 to entry: Fluids are LH2 or GH2.

3.38

quick connect disconnect coupler

QCDC

coupler

manual or hydraulic mechanical device used to connect the *transfer arm* (3.58) to the *cargo manifold* (3.6) or *spool piece* (3.46) without employing bolts

Note 1 to entry: See [Figure B.2](#).

3.39

remote pendant control

remote control

device to facilitate the fine manoeuvring operation of the *transfer arms* (3.58) from a remote location (e.g. *LH2 carrier's* (3.24) *cargo manifold* (3.6) area)

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

3.40

riser and trunnion swivel assembly

fluid carrying system consisting of a *riser swivel* (3.42), *trunnion swivel* (3.60) and elbows, and mounted on top of the *base riser* (3.3)

Note 1 to entry: See [Figure B.2](#).

3.41

riser flange

transfer arm (3.58) flange for connection to LH2 piping

Note 1 to entry: See [Figure B.2](#).

3.42

riser swivel

swing joint in the *riser and trunnion swivel assembly* (3.40) which permits *slewing* (3.45) of the *transfer arm* (3.58)

Note 1 to entry: See [Figure B.2](#).

3.43

roll

rotation of *LH2 carrier* (3.24) around longitudinal horizontal axis

3.44

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](#).

3.45

slew

horizontal, rotary motion of the *transfer arm* ([3.58](#)) around the *base riser* ([3.3](#))

Note 1 to entry: See [Figure B.2](#).

3.46

spool piece

short length of pipe for the purpose of matching the *cargo manifold* ([3.6](#)) to the *presentation flange* ([3.36](#)) or the *QCDC* ([3.38](#))

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

3.47

spotting line

pre-determined location on the jetty used by the *LH2 carrier* ([3.24](#)) when berthing to align with the LH2 carrier vapour manifold

Note 1 to entry: See [Figure A.1](#).

3.48

stress analysis

detailed calculation of the structural loading in the *transfer arm* ([3.58](#)) and *cargo manifold* ([3.6](#)) for various positions and attitudes to check the integrity of the transfer arm for the service intended

3.49

structural bearing

bearing in the load carrying components supporting the product line that, in combination, allow the *transfer arm* ([3.58](#)) to follow freely the motion of the *LH2 carrier* ([3.24](#))

3.50

surge aft

longitudinal *LH2 carrier* ([3.24](#)) after ward motion

3.51

surge fore

longitudinal *LH2 carrier* ([3.24](#)) forward motion

3.52

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* ([3.58](#)))

3.53

sway

transverse *LH2 carrier* ([3.24](#)) motion

3.54

swivel joint

swivel

swing joint contained in the *transfer arm* ([3.58](#)) to permit the arm to follow freely the motion of the *LH2 carrier* ([3.24](#))

3.55

terminal

LH2 producing/receiving plant with loading/unloading facilities

3.56

top swivel

swivel joint accommodates *rolling* (3.43), *heave* (3.18) and *sway* (3.53) motion of the *LH2 carrier* (3.24) and is located between the *outboard arm* (3.32) and *middle swivel* (3.29) in the horizontal part of the *triple swivel assembly* (3.59)

Note 1 to entry: See [Figure B.2](#).

3.57

transfer

loading or unloading operation

3.58

**transfer arm
arm**

articulated metal transfer system used for transferring *product* (3.37) to or from the *LH2 carrier* (3.24) with the capability of accommodating differences in tides, *freeboard* (3.16) and the LH2 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”.

3.59

triple swivel assembly

TSA

group of three *swivels* (3.54) and elbows located at the end of the *outboard arm* (3.32)

Note 1 to entry: See [Figure B.2](#).

3.60

trunnion swivel

swing joint in *riser and trunnion swivel assembly* (3.40) which permits the *inboard arm* (3.19) to rotate around the horizontal axis

Note 1 to entry: See [Figure B.2](#).

3.61

**uninterruptible 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

3.62

yaw

rotation of the *LH2 carrier* (3.24) around vertical axis

4 Abbreviated terms

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

CPMS	constant position monitoring system
DL	dead load
EMC	electro-magnetic compatibility
ERS	emergency release system
ESD	emergency shutdown
FL	fluid load
GH2	gaseous hydrogen
He	helium
H2	hydrogen gas
IP	ingress protection
LHe	liquefied helium
LH2	liquefied hydrogen
LNG	liquefied natural gas
LH2C	liquefied hydrogen carrier
LN2	liquefied nitrogen gas
LO2	liquefied oxygen
MHU	main hydraulic unit
NDE	non-destructive examination
N2	nitrogen gas
OBE	operating basis earthquake
PERC	powered emergency release coupling
PL	pressure load
QCDC	quick connect disconnect coupler
SSE	safe shutdown earthquake
TL	thermal load
WL	wind load

5 Design of the arms

5.1 Definition and description of the arms

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 onshore 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), if specified;
- outboard arm;
- apex swivel assembly between the outboard and inboard arm;
- balancing system;
- inboard arm;
- riser and trunnion swivel assembly between the inboard arm and the base riser;
- base riser.

All product carrying components shall be adequately heat insulated against ambient temperature to avoid producing liquefied oxygen and to minimize heat in leak (e.g. vacuum) insulated double wall construction, where the inner piping shall be free to expand or contract with the outer piping.

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.

No parts of the transfer arm, e.g. seals, bolts, and nuts, shall come off or unfasten and drop into product piping due to product flow, vibration, negative pressure and cryogenic conditions.

The characteristics of hydrogen are described in ISO/TR 15916.

The main hazards to be considered in the design of transfer arms for liquefied hydrogen are:

- low ignition energy;
- a wide range of flammability limits;
- cryogenic temperature and liquefaction/solidification of inert gas and constituents of air which can result in an oxygen-enriched atmosphere;
- high permeability;
- low viscosity;
- hydrogen embrittlement including weld metals;
- cryogenic temperatures which can cause injury to people (frostbite) and also damage non-cryogenic materials such as carbon steel, which lose their mechanical properties, become brittle and thus have a greater susceptibility for fracture.

NOTE Local and national rules and regulations can apply.

The complete TSA and outboard arm shall be balanced in the empty condition without ice. It shall be balanced at the apex swivel.

The complete, articulated assembly shall be balanced in the 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 conditions. There shall be no clash of the arms with the ship or the jetty. Risk assessments of such operational scenarios shall also be conducted.

5.1.2 Arms dimensions

Transfer arm dimensions shall be determined by the transfer arm manufacturer to ensure that the transfer arm satisfies all specified requirements.

Clearance study shall be carried out by following the description specified in ISO 16904.

5.2 Design basis

5.2.1 Product line diameter and product data

The LH2 product line shall be sized in consideration of allowable pressure loss and acceptable cavitation and vibration unless otherwise specified by the owner.

Pressure loss curve for LH2 and vapour return within the transfer arms shall 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 the owner's approval.

In the product carrying components, austenitic stainless steel (304, 304L, 316 or 316L) shall be used for fracture toughness at cryogenic temperature and hydrogen embrittlement. The corrosion resistant property of stainless steel in a chloride environment shall be considered.

Other material and grades 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 at a 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 can 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 the force on the LH2 carrier's manifolds incurred by the loading arm shall be performed for all appropriate arm conditions.

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

The loading combination, allowable design stress and design loads shall be in accordance with [5.2.3.2](#) to [5.2.3.9](#). Local or national standards and regulations can be applicable, with agreement of the owner.

5.2.3.2 Loading combination

The transfer arm manufacturer shall prepare a stress report for the loading combinations in [Table A.6](#) at all appropriate transfer arm attitudes within the envelope. The LH2 carrier manifold shall be included, if required.

Where combinations other than those in [Table A.6](#) (e.g. exclusion of a load) can be shown to lead 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 shall 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 exemplified in [Table A.6](#).

5.2.3.4 Pressure load

The pressure loads (PL) shall be based on internal design pressure. Vacuum condition (negative pressure) shall also be considered as pressure load, if required.

5.2.3.5 Fluid load

The fluid loads (FL) shall be based on the density of LH2 at its specific conditions.

5.2.3.6 Ice build-up

Unless otherwise specified on the OCIMF website, [Table A3](#),^[12] the dead load and wind load (DL and WL) shall include appropriate ice build-up (specific gravity = 0,80) for cold parts.

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.

Cool-down and warm-up procedures shall be included in the operating procedures. These procedures should provide temperature gradients across fluid and structural members and/or recommended maximum cool-down/warm-up rates and minimum cool-down/warm-up durations to prevent excessive stresses and strains.

An item such as a bellows or compensators should be equipped, if necessary, to avoid significant thermal stress caused by the temperature difference, which is greater with LH2 than LNG.

The arm and its components shall be designed for the expected amount of thermal cycles over the lifetime of the arm and consequential fatigue induced stresses, if necessary. When adopting the fatigue design, the number of cycles shall be agreed upon with the owner.

5.2.3.8 Wind load

The wind loads (WL) shall be calculated for the worst direction(s) by following the method presented in appropriate local rules or specifications, or ISO 16904.

5.2.3.9 Earthquake load

The earthquake load shall be based on operating basis earthquake (OBE) (see OCIMF website, Table A3 [12]). When the owner requires, the earthquake load based on safe shutdown earthquake (SSE) shall also be considered. In this case, the transfer arm manufacturer shall define the allowable stress for the owner's approval.

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

The seismic design should be conducted with arms in stowed conditions. Local and national standards and regulations can apply. An analysis in the connected condition can be required by the owner (see Table A.6).

5.2.3.10 Design stress procedure

The design stress procedure shall be as follows:

- a) the design loads for various load cases shall be determined;
- b) the stresses using linear elastic material behaviour and the equivalent (Tresca, von Mises or Principal) stress shall be calculated;
- c) the allowable design stress shall be determined;
- d) equivalent stress shall not exceed the allowable design stress;
- e) stresses due to local discontinuity and/or thermal stresses shall not exceed two times the yield stress;
- f) components under predominantly compressive stresses shall be shown to have a safety factor of 2 against instability. Local and national standards and regulations can apply;
- 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) dynamic behaviour where appropriate shall be checked;
- i) complete wire rope assemblies, if applicable, including their anchorages, shall have a safety factor of at least 5, related to minimum rated breaking strength;
- j) the transfer arm manufacturer shall ensure that the loads transmitted to the manifold flange, under all circumstances are limited to the maximum given specified by the owner. The manifold loads shall be analysed based on the connected condition with pressure load and wind speed during operation.
- 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.

5.2.4 Thermal analysis

A complete thermal analysis for estimating the heat inleak of the transfer arm shall be performed, if required. The result of thermal analysis shall be provided by the transfer arm manufacturer and agreed with the owner, if specified.

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 be comprised of a minimum of two seals, one primary and one secondary. The secondary seal is to avoid external leakage or leakage into the bearing in the case of primary seal failure. The design shall not allow for over pressurization between the 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, i.e. spaces between the product secondary seal and the external seal, shall be kept dry with helium to prevent any internal ice formation.

The pressure of helium shall be higher than the atmospheric pressure and controlled appropriately.

If the design temperature of the bearing system allows lubricant, the requirements specified in [5.4.2](#) and [5.4.3](#) shall be followed.

5.3.4 External sealing arrangement

The external sealing arrangement shall prevent ingress of air, 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](#)):

- safety factor a ($F_{S,a}$) $\times P_{CA,swivel}$ + pressure load (p) against structural failure;
- safety factor b ($F_{S,b}$) $\times P_{CA,swivel}$ + pressure load (p) against leakage, with maximum allowable leakage rate as defined in [9.2.2.2.5](#);
- safety factor c ($F_{S,c}$) $\times P_{CA,swivel}$ + pressure load (p) against brinelling, with allowable brinelling as defined in [9.2.2.2.5](#).

The safety factor as listed in [Table 1](#) is the ratio of the maximum equivalent axial load at which the event occurs and the calculated maximum equivalent axial load.

Table 1 — Safety factor

Case no. (see Table A.6)	$F_{S,a}$ structural failure	$F_{S,b}$ leakage	$F_{S,c}$ 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 It is not possible to design swivel joints in case 6.			
NOTE 2 p or p_T are added only in the case of 5, 8 and 10 as per Table A.6 .			

When loading combinations are different from [Table A.6](#), the appropriate safety factor shall be selected.

The equivalent axial load ($P_{CA,swivel}$) is calculated by [Formula \(1\)](#):

$$P_{CA,swivel} = F_A + 5 \frac{M_T}{D} + 2,3 F_R \tan \alpha \quad (1)$$

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);
- α 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

A structural bearing, when applied, is a non-pressure containing bearing taking only structural loads. The vessel manifold movements and frequency of use specified by the owner shall be considered as cyclic motions.

5.4.1.2 Static load

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

- a) safety factor a ($F_{S,a}$) $\times P_{CA,bearing}$ there shall not be any structural failure;
- b) safety factor c ($F_{S,c}$) $\times P_{CA,bearing}$ 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 1](#).

The equivalent axial load ($P_{CA,bearing}$) is calculated by [Formula \(2\)](#):

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

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 (the 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, such as ISO 76.

5.4.2 Protection of structural bearings

The bearings shall be provided with adequate seals and protection covers suitable for the 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 material suitable for the marine environment;
- each raceway shall be fitted with grease ports. There shall be sufficient ports to ensure even distribution of grease;
- avoid the impact of pipeline low temperature on structural bearings.

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 by the owner.

If the transfer arm is equipped with an adjustable support, or jack, it shall take into account that the manifold area on individual LH2 carriers is possibly not designed accordingly.

If installed, the support should be made of two adjustable legs to rest on the deck of the LH2 carrier.

The height of the support may be adjustable 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 LH2 carrier.

5.5.2 Product purge gases injection line

Before the loading/unloading, air shall be first displaced with N₂, after that N₂ shall be displaced with H₂. An example of the method is given in [Annex D](#). A gas detector shall be used for confirming the completion of the displacement.

At the end of the loading/unloading operation, first H₂ or He shall be used to displace the product, and then the purge gases shall be displaced by nitrogen. The purge gases and/or nitrogen injection line shall be connected to the product line of the ship's manifold piping or jetty piping.

5.5.3 Stowing locking device

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

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;

- the 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

The 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 may be installed from the leak detection port of product swivels to the return gas line in order to recover minor leaking gas through the primary seal and to avoid pressurizing of a chamber between the primary and secondary seals. A check valve shall be installed between the vapour recovery line and return gas line. Local and national standards and regulations can apply.

5.5.6 Liquid nitrogen line

A LN2 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 Ice fall protection

Ice fall protection may be needed after reviewing the terminal's operating philosophy and procedures.

5.5.8 Process connections

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

5.5.9 Drain connection

Drain connections may be provided by the owners' requirement to rapidly evacuate the remaining LH2 in the piping.

5.5.10 Vacuum insulation

If a vacuum insulated double wall structure is adopted, the following functions shall be installed to maintain adequate vacuum pressure of loading arm:

- at the vacuum area which has weak points such as bellows, vacuum pressure shall be monitored at all times to confirm that suitable heat insulation performance is satisfied;
- the vacuum monitoring device, such as a vacuum gauge, shall be installed to make maintenance easy;

NOTE This monitoring can be substituted by measurement of the outer surface temperature, which is dependent on the vacuum pressure in the vacuum insulated space.

- the connection ports for vacuuming shall be installed at each vacuum area;
- the surface of each connection port for vacuuming shall be covered with consideration of the movement of the loading arm;

- to avoid damage at the outer pipe because of the pressure increase at vacuum area, parts that enable the release of pressure shall be installed;
- the direction of the connection ports for easy vacuum operation shall be approved by the owner.

5.6 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. Local or national standards and regulations can apply.

5.7 Corrosion protection and embrittlement protection

5.7.1 Corrosion protection

Preservation and corrosion protection shall take into account the environment and be specified by the owner.

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

Hot dip galvanized coatings on ferrous materials, fabricated iron and steel articles should be determined in accordance with ISO 1461 and their test methods should be in accordance with ISO 1460.

Paint and varnish corrosion protection of steel structures should be as specified in ISO 12944.

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

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

5.7.2 Embrittlement protection

Critical equipment, piping and structural elements, which can be affected by LH2 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 in identifying particular equipment, piping and structural elements that shall be protected against LH2 leakage. Potential sources of leakage shall be considered, such as flanges, swivels, small bore nipples and small bore valves.

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

Cabinets and panels shall be located out of reach of LH2 splashes that can cause brittle failure.

5.8 Maintenance

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

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

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

6 Safety systems

6.1 General

The function of the emergency shutdown (ESD) system is to safely stop and isolate the transfer of liquid and vapour between the 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;
- a manual signal.

It shall result in the tripping of transfer pumps on 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) is to protect the transfer arms and to minimize the spillage of LH2 by quick disconnection in the case of the ship drifting out of its operating envelope. The ERS consists of a powered emergency release coupling (PERC), 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 ERS isolating valves, PERC separation, and the transfer arms withdrawing clear of the ship's structure and adjacent arms, preventing the arms from being damaged.

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

Electromagnetic compatibility (EMC) for electrical and electronic components that are part of the safety system shall 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) LH2 pumps shutdown.

In the case when the ERS installed with isolating valves is closed at the 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 shall consider, at a minimum, any increasing complexity of the control system, possible drift speeds of the LH2 carrier, the possibility of LH2 being "locked in" between the isolating valve and the effect of surge pressures generated in the transfer system, including the part between LH2 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.

A provision shall be made to avoid a liquefied oxygen drop from the arm side ERS valve.

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 transfer arm manufacturer shall verify that no clashing of the arm(s) during disconnection, raising 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 LH2 carrier at the berth.

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 LH2 carrier and to initiate the first stage and second stage alarms.

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 the 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. At a minimum, the alarms shall be in the jetty control centre, the placement of additional alarms shall be agreed to by the owner.

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

6.3.3 Arm constant position monitoring system (CPMS)

In addition to [6.3.2](#), a system of constant monitoring of the position of the arms may be used to provide real time information to the operator and ship. The CPMS shall be SIL rated as determined by a SIL assessment required by the owner in the case of being used for ESD/ERS initiations.

6.3.4 Pressure and hydraulic level alarm

The following visual and audible alarms, as a minimum, shall 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 when an intrinsically safe hydraulic circuit is adopted (see [6.4.3](#));
- low pressure in hydraulic accumulators if accumulators are installed;
- low N2 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 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.

To ensure ERS disconnection under the specified LH2C drift velocity, the ERS activation time shall be set appropriately with the PERC opening time within 2 s. The alarm distances shall be defined accordingly. The ERS valves closure time shall be taken into account in the hydraulic surge pressure analysis of upstream piping including transfer arms and ERS themselves.

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 and shall be verified by risk assessment.

The PERC shall permit a clean and safe separation of the transfer arm from the ship's manifold. The lower part of the TSA shall remain connected to the ship's manifold and a device shall stop the lower part from rotating around the bottom swivel joint and falling down on the ship's deck or manifold service platform. The design shall 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.

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

6.4.2 Design of the 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 2](#) shall be used to design for the maximum design equivalent loads:

- a) safety factor a ($F_{S,a}$) $\times L_{CA}$ + pressure load (p) against structural failure and separation;
- b) safety factor b ($F_{S,b}$) $\times L_{CA}$ + pressure load (p) against leakage and permanent deformation.

Table 2 — Safety factor

Case no. ^a	$F_{S,a}$ structural failure and separation	$F_{S,b}$ 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 It is not possible to design ERS or QCDC in case 6.		
NOTE 2 p or p_T are added only in case of 5, 8 and 10 as per Table A.6 .		
^a See Table A.6 .		

When loading combinations are different from [Table A.6](#), an appropriate safety factor shall be selected.

6.4.3 Safety devices on the ERS

The system shall be designed so that the ERS is active only during LH2 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 following three 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 the PERC solenoid valve or back pressure of the drain line, shall not be possible.

Regarding the above two systems, 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 the 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.

- c) When ERS valves are fail-safe-to-close check valves, they shall immediately close after PERC release and the resulting spillage of product shall be verified as acceptable by a proper risk analysis approved by the owner and/or any other competent authority involved.

6.5 Safety devices

6.5.1 Fire safety requirements

The following fire safety requirements shall apply:

- ERS valves shall be fire safe in accordance with ISO 10497;
- hydraulic systems shall be positioned such that potential firefighting water is positively drained away from the main hydraulic unit (MHU);
- critical tubing/hoses for the supply of hydraulic oil to the emergency release systems as well as items of electrical equipment that ensure proper activation of the ERS shall be protected against fire as far as considered practical. For example, a fire of 1 100 °C for 1,5 min and/or 350 °C for 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 local or national standards and regulations.

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

6.5.2 Electrical safety requirements

6.5.2.1 General

The electrical power supply specifications in OCIMF website, Table A7^[12] shall be determined by the owner.

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, particularly for the hazardous zones generated when the LH2 carrier is alongside. Local or national standards and regulations can also apply.

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. Local or national standards and regulations can also apply.

6.5.2.4 Lightning protection and earthing

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

The jetty earthing details shall be provided by the owner.

Physical damage to structures and hazards to life due to lightning should be assessed according to IEC 62305-3. Local or national standards and regulations can also apply.

6.5.3 Failure of power supply

6.5.3.1 General

A 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 sources or an 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.

6.5.3.3 Electric power backup system

An electric power backup system for logic and control systems shall be provided by the terminal, e.g. UPS, multiple power source or backup generator. Local or national standards and regulations can apply.

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 shall 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 has electrical continuity and does not require separate bonding as this can prevent safe operation.

6.5.6 Safety for liquid oxygen

A provision shall be made to avoid a liquefied oxygen drop from the arm side ERS valve and reaction with the material of the ship side ERS valve.

7 Connection with the ship

7.1 General

The connection of the arm to the ship shall be adequately heat insulated against ambient temperature to avoid producing liquefied oxygen and to minimize heat in leak (e.g. bayonet connection).

The interface between the transfer arm and ship's manifold flange shall be met.

An example of a form of specific requirements by the owner is given in [Table A.1](#).

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 centring 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 LH2 carrier manifold.

Gaskets, depending on their type, shall be in accordance with the specification by the owner. Local or national standards and regulations can also apply.

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 2](#) shall be used to design for maximum design equivalent loads:

- a) load factor (safety factor) a ($F_{S,a}$) $\times L_{CA}$ + pressure load (p) (see NOTE 2 in [Table 2](#)) against structural failure and separation;
- b) load factor (safety factor) b ($F_{S,b}$) $\times L_{CA}$ + pressure load (p) (see NOTE 2 in [Table 2](#)) against leakage and permanent deformation.

When loading combinations are different from [Table A.6](#), an 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.

The 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.1](#).

The 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 a 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.

A lock sequence completion indicator to confirm locked condition shall be provided.

For a 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 ship manifold flanges.

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

For a hydraulically operated QCDC, the operating time range should be 10 s to 15 s (see [Table A.1](#)). For clamp safety reasons, the operating time shall not be less than the specified minimum.

The 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

The connection flange shall be provided with a flange cover to prevent the 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 a tapped hole. A plug, a bleed valve or pressure relief port should be installed by the owner's requirement for depressurization before removal.

Handles shall be provided on the flange cover to facilitate installation and removal by hand. A davit may be needed depending on the mass of the cover.

8 Hydraulic and electric control systems

8.1 General

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

The system shall have a two-speed manoeuvring mode. When starting the operation of the arm or connecting it to the LH2 carrier manifold, the lower speed should be selected for easier and more precise operation.

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

The power to operate the arm and the accessories shall be hydraulic, 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 displays and actuating devices shall be on the jetty side and be comprised of the following:

- control panel (see [Table A.3](#)) as close as possible to the berthing line and in sight of the LH2 carrier manifold. Control switches, buttons and lights shall be available in this control panel;
- remote control device (see [Table A.4](#)) allowing operation of the arm from the LH2 carrier side near the LH2 carrier manifold for normal connection and disconnection of the arms;
- the arm control panel and the remote control shall not be operational simultaneously. Simultaneous movement of more than one arm shall not be possible during normal operation.

Alternative remote-control locations may be proposed for approval (see [Table A.5](#)).

The electromagnetic compatibility (EMC) for electrical and electronic components which are part of the safety system shall be taken into consideration.

NOTE Another control system, such as using only electrical or other power generation, can 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 LH2 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 LH2 carrier movements;
 - free wheel mode at drift speed;
 - control mode during connection, normal LH2 carrier movements;
 - control mode after connection: the design shall be such as to prevent damage to the arm, if not be placed in free wheel mode after connection to the ship.
- c) Operation of the ERS including automatic raise and retraction.
- d) 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.
- e) 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 for quick operation. Provision shall be made to ensure no 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 the emergency release condition;
- f) unbalance moment due to the mass 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 to 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 so 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 the PERC shall be designed to avoid unintentional PERC activation by over pressure caused by hydraulic leakage, temperature rise, mis-operation, 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.

The hydraulic system shall be designed to ensure emergency disconnection and that the first 2 m of retraction of all possible arm connection scenarios comply with the emergency release sequence timing and required arm retraction speed. This is generally achieved by a dedicated hydraulic accumulator per arm. Then the retraction of all disconnected arms shall continue until they reach a position behind the berthing line with compressed fenders, where they shall be hydraulically locked. In normal operation, with all electrical power sources working, this shall be achieved automatically (see [6.1](#)), and in case of an electrical power failure, some additional manual actions 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 N2 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 particles can get in the hydraulic oil and contaminate the system.

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

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

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

Sealing of threaded connections shall be made with jointing compounds. Sealing tapes shall only be used when there is no reasonable alternative. If these products are used, then great care shall 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 shall be used to avoid 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 regarding 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, buttons, 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 intrinsically safe. Motor “stop” pushbuttons shall be the 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 hydrocarbons 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 the control system, e.g. interlocks, alarms, lamps.

8.6 Remote control

The remote control shall, at a minimum, be equipped as described in [Table 3](#).

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Table 3 — 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

The transfer arms control console shall be positioned on the jetty.

The console shall be equipped at a minimum with the instrumentation defined in [Tables 3](#) and [4](#).

Table 4 — Jetty control console

Time	Commands	Alarms
ESD	Manual activation for emergency shutdown	Dedicated audible and visible signals
ERS	Manual activation for emergency release (see NOTE below)	Dedicated audible and visible signals
NOTE The switch for manual activation is installed by the owner.		

9 Inspections 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 representative shall approve the inspection reports. 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 subject to at least the same test loads are not available or unacceptable, the equipment shall be prototype tested with the exception of the swivel joint lifetime qualification dynamic test.

9.2.2 Swivel joint

9.2.2.1 Lifetime qualification dynamic test

9.2.2.1.1 Test protocol

The transfer arm manufacturer shall prove by swivel joint lifetime qualification dynamic testing that the swivels are designed to accept vessel manifold movements. When the transfer arm manufacturer provides operational data of existing successful operations with same type swivels in LH2 service, the swivel lifetime qualification dynamic test shall be considered complete.

The lifetime qualification dynamic test shall be performed on one full-size production swivel unit and shall be subject to the following conditions:

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

- temperature lower than or equal to LH2 temperature (swivel internally to be filled with, for example, LH2 to ensure the sealing arrangements are submerged in LH2 at all times during the test, measure liquid hydrogen level, control by temperature sensors);

The swivel including all detecting ports shall be dried and internal air shall be replaced with He or H2 before being filled with LH2.

- internal pressure in the swivel varying between 0,25 MPa and 0,35 MPa;
- the load $P_{CA,swivel}$ and its supporting loads (i.e. an axial load, a radial load and a bending moment) established by the transfer arm manufacturer (and submitted to the owner for approval) (see 5.3.5);
- the swivel drying system as per normal operation shall be applied during the test (see 5.3.3);
- after each approximate 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.

Agreement with the owner is required if another method or the use of LHe as the test liquid is adopted to assess the lifetime of the swivel joint.

9.2.2.1.2 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 cm³/min/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;
- the 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, which means loss of metal by fretting).

If the manufacturer can prove that the measured leakage rate does not have an effect on safety around the site, or does not cause a drop in temperature on the surface of the swivel joint, that can lead to the production of liquefied oxygen, or does not lead to an unacceptable thermal stress by the calculation validated with experimental data at LH2 temperature, then its criteria can be changed after agreement with the owner.

9.2.2.2 Prototype test

9.2.2.2.1 Hydrostatic pressure test

The hydrostatic pressure test of the swivel shall be carried out at ambient temperature and at no less than 1,5 times the design pressure, and maintained for at least 30 min. Permanent deformation, which should preferably be checked after depressurisation, shall not be allowed.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.2.2.2.2 Partial vacuum and leakage tests

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

- Stage 1: After hydrostatic testing, the swivel shall be partially vacuum tested at 50 kPa (abs).
- Stage 2: The design pressure shall then be hydrostatically applied to demonstrate that the seals reseal correctly. No leakage shall be allowed.
- Stage 3: After drainage, at least 0,3 MPa internal pressure shall be applied using air, N₂, and/or mixture of N₂ and He or H₂ to verify that there is no leakage from the secondary seal. Some non-continuous bubbles which can arise because of the temperature change, are acceptable.

The duration of each test shall be 30 min.

9.2.2.2.3 Rotation test

The swivel shall be hydrostatically leak tested while being rotated at least $\pm 5^\circ$ at a period of the movements 10 s and at a pressure of 1 MPa or the specified operating pressure, whichever higher at ambient temperature.

No leakage shall 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 temperatures, filled with He or LH₂, and stabilize the swivel temperature profile lower than or equal to LH₂ temperature condition. Neither external loads nor internal pressure need be applied. Spray the swivel with water until a 10 mm layer of ice forms or is adequately wet and holds for one hour. Allow the swivel to return to ambient temperature.

Before filling LH₂, the swivel including all detecting ports shall be dried and internal air shall be replaced with He or H₂.

The swivel shall be rotated and oscillated during the test as specified in [9.2.2.2.3](#).

Drying He or H₂ pressure shall 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 to ensure that neither collection of water, formation of ice, nor damage to seals has occurred.

9.2.2.2.5 Load capacity test

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

$$P_{CT} = F_S \times P_{CA,swivel} + p$$

where

P_{CT}	test load: the maximum load resulting from the above calculation for each loading combination in Table A.6 ;
F_S	see Table 1 ;
$P_{CA,swivel}$	see 5.3.5 ;
p	pressure load: see 5.2.3.4 .

The test shall be carried out at ambient temperature and at a temperature lower than or equal to the LH₂ temperature condition at stage 1 and stage 2. Stage 3 shall be carried out at only an ambient temperature.

Safety factor at each stage is defined in [Table 5](#).

Table 5 — Safety factor at each stage

Stage	1	2	3
Safety factor	$F_{S.c}$	$F_{S.b}$	$F_{S.a}$

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

Apply internal design pressure using air and/or N2 or suitable liquid at ambient temperature and using He or LH2 at cryogenic temperature, but only stage 1 and stage 2, and then apply external loads.

Before filling LH2, the swivel including all detecting ports shall be dried and internal air shall be replaced with He or H2.

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 to or less than 8 % of the ball or roller diameter. Measurement of the ball or roller indentation shall be performed using suitable metrology equipment.

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

Acceptance criteria are as follows:

- at ambient temperature, no leakage shall be allowed. Depending on the measuring method, some non-continuous bubbles, which can arise because of changes in temperature, are acceptable;
- at cryogenic temperature, the leakage rate shall not exceed $10 \text{ cm}^3/\text{min}/\text{cm}$ primary seal diameters at the detection port between the primary and secondary seals;
- liquefied oxygen shall not be produced on the surface of the swivel, i.e. the temperature of the swivel surface shall be higher than $-183 \text{ }^\circ\text{C}$.

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) is applied even if p is not required in loading combination in [Table A.6](#). In this case, other external load, equivalent to p can be reduced from $F_S \times P_{CA,swivel}$.

NOTE 2 At stage 3, SF being over the leakage design criteria, internal pressure is not applied even if p is required in loading combination in [Table A.6](#). In this case, other external load, equivalent to p is added to $F_S \times P_{CA,swivel}$.

9.2.3 ERS

9.2.3.1 Hydrostatic pressure test

The hydrostatic pressure test of the 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. It shall be maintained for at least 30 min. Permanent deformation, which should preferably be checked after depressurisation, shall not be allowed.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.2.3.2 Pneumatic pressure test

Internal pressure of 0,6 MPa shall be applied using air, N2, and/or a mixture of N2 and He or H2 to check that there is 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.:

$$L_{CT} = F_{S,b} \times L_{CA} + p$$

where

L_{CT}	test load: the maximum load resulting from the above calculation for each loading combination in Table A.6 ;
$F_{S,b}$	see Table 2 ;
L_{CA}	see 6.4.2 ;
p	pressure load: see 5.2.3.4 .

The test shall be carried out at ambient temperature and at a temperature lower than or equal to the LH2 temperature condition with $F_{S,b}$.

In addition, it shall be proven by calculation that the ERS shall not allow structural failure with $F_{S,a}$ (see [Table 4](#)).

The holding time shall be at least 10 min.

Apply internal pressure using a suitable liquid or, when the owner specifies, air and/or N2 at ambient temperature and using He or LH2 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 p is not required in loading combination in [Table A.6](#). In this case, other external load, equivalent to p can be reduced from $F_{S,b} \times L_{CA}$.

9.2.3.4 Valve operating test

The ERS, when applicable, shall be tested for valve operating under the following simultaneous conditions:

- at a temperature lower than or equal to the LH2 temperature condition;
- L_{CA} ;
- design pressure.

Following the initial cooldown and once the temperature and pressure have stabilized, the valves, when applicable, shall be cycled (opened and closed 10 times under design pressure, and opened 10 times with a relief pressure of a valve sealing mechanism). Due to the self-pressure release design of valves sealing mechanism, the differential pressure with the trapped volume between valves shall not be higher than 0,5 MPa.

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

9.2.3.5 Release performance test

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

- at a temperature lower than or equal to the LH2 temperature condition;
- L_{CA} ;
- ice build-up by applying a fine water spray for at least 20 min if possible.

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

The hydraulic pressure shall be set to the minimum available.

Except for an ERS based on fail-safe-to-close check valves, the release test shall be performed three times. In all tests, the valves shall close and then the PERC shall release. For the first and second tests, confirm PERC releasing, but actual separation of two valves is not required to avoid icing of valve sealing surface using an appropriate device such as reassembling bolting system. The last of these tests shall confirm complete disconnection.

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

For an ERS based on fail-safe-to-close check valves, valves shall immediately close following PERC activation.

9.2.3.6 Cryogenic seat leak test

The test shall be conducted on an ERS upper valve complete, when applicable, 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 LHe or LH2 and conditions allowed to stabilize at a temperature lower than or equal to the LH2 temperature condition.

Before filling with LH2, the swivel including all detecting ports shall be dried and internal air shall be replaced with He or H2.

The pressure retaining valve seat shall remain immersed in LHe or LH2 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 $\times$ 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; if applicable;
- b) valve seat: 1 cm³/min of collected He or H2 per mm of the valve's nominal diameter.

9.2.4 Insulation flange

9.2.4.1 Hydrostatic pressure test

The hydrostatic pressure test of the insulation flange assembly shall be carried out at ambient temperature and not less than 1,5 times the design pressure maintained for at least 30 min. Permanent deformation, which should preferably be checked after depressurisation, shall not be allowed.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.2.4.2 Pneumatic pressure test

An internal pressure of 0,6 MPa shall be pneumatically applied using air, N2, and/or a mixture of N2 and He or H2 to check for 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 p as a minimum; loaded such that the test load combination L_{CT} is equal to the worst calculated load combination, i.e:

$$L_{CT} = F_{S,b} \times L_{CA} + p$$

where L_{CT} is test load, being the maximum load resulting from the calculation $F_{S,b}$ (see [Table 4](#)) $\times L_{CA}$ (see [7.2](#)) for each loading combination in [Table A.6](#) where p (see [5.2.3.4](#)) is also present.

The test shall be carried out at ambient temperature and at a temperature lower than or equal to the LH2 temperature condition with $F_{S,b}$.

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 N2 at ambient temperature and using LHe or LH2 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 p is not required in loading combination in [Table A.6](#). In this case, other external load, equivalent to p can be reduced from $F_{S,b} \times L_{CA}$.

9.2.5 QCDC

9.2.5.1 Hydrostatic test

The 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, which should preferably be checked after depressurisation, shall not be allowed.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.2.5.2 Pneumatic pressure test

An internal pressure of 0,6 MPa shall be pneumatically applied using air, N2, and/or a mixture of N2 and He or H2 to check for no leakage. The duration of the test shall be 30 min.

9.2.5.3 Strength test

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

$$L_{CT} = F_{S,b} \times L_{CA} + p$$

where L_{CT} is test load, being the maximum load resulting from the calculation $F_{S,b}$ (see [Table 2](#)) $\times L_{CA}$ (see [7.2](#)) for each loading combination in [Table A.6](#) where p (see [5.2.3.4](#)) is also present.

The test shall be carried out at ambient temperature and at a temperature lower than the LH2 temperature condition with $F_{S,b}$.

In addition, it shall be proven by calculation that the QCDC shall not allow structural failure with $F_{S,a}$ (see [Table 2](#)).

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

Apply internal pressure using a suitable liquid or, when the owner specifies, air and/or N₂ at ambient temperature and using He or LH₂ 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 (to be discussed) nor permanent deformation.

NOTE Internal pressure (design pressure) is applied even if p is not required in loading combination in [Table A.6](#). In this case, another external load, equivalent to p can be reduced from $F_{S,b} \times L_{CA}$.

9.2.5.4 Emergency leakage test

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

- a) with at least one of the 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, He and/or H₂ at a temperature lower than or equal to the LH₂ temperature condition.

No leakage shall be allowed.

9.2.5.5 Release performance 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 or equal to LH₂ temperature condition) under the following conditions (three times for each temperature condition).

For safety reasons, the QCDC shall not be pressurized.

At ambient temperature, the maximum QCDC 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 including related loads such as friction, reaction force of driven system, etc. on the manifold flange.

At low temperature (lower than or equal to LH₂ temperature condition):

- a) ice build-up of 25 mm (or thicker if specified by the owner) if applicable;
- b) the maximum QCDC 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 including related loads such as friction, reaction force of driven system, etc. on the manifold flange.

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

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, inspection certificate. Local or national standards and regulations can also apply.

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. Local or national standards and regulations can also apply.

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 with the exception of fillet welds and branch connections. Local or national standards and regulations can also apply.

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. Local or national standards and regulations can also apply.

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. Local or national standards and regulations can also apply.

9.3.5 Dimensional inspection

The base riser, inboard arm, outboard arm, ERS and QCDC shall have a dimensional inspection carried out to confirm the specifications.

9.3.6 Pressure test

A 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 the 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 the working condition.

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, if applied as the medium of hydrostatic test, shall 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 the pressure test, components shall be thoroughly dried. The direct application of heat is prohibited.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.3.7 ERS

9.3.7.1 Hydrostatic pressure test

The hydrostatic pressure test of the 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. The test medium for the 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 working condition.

Acceptance criteria shall be neither leakage nor permanent deformation.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.3.7.2 Release performance test

Except for ERS based on fail-safe-to-close check valves, the 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 $\pm 10\%$ tolerance and the PERC activation times are within 2 s and to confirm to operate below minimum available hydraulic pressure.

For ERS based on fail-safe-to-close check valves, the release performance test shall be carried out at ambient temperature to confirm that valves closed immediately following PERC activation.

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 N₂ at ambient temperature.

Any leakage is not allowed at a minimum test pressure of 0,3 MPa with no less than 5 min duration.

Depending on the measuring method, some non-continuous bubbles which can arise because of the temperature change, are acceptable.

9.3.8 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 shall 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 is required before hydrostatic test, resistance shall be not less than 10 000 Ω .

9.3.9 QCDC

9.3.9.1 Hydrostatic pressure test

The hydrostatic pressure test of the 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.

In order to verify the deformation, a test shall be carried out at a time when deformation can be checked visually. If a bellows is equipped, the extension of the bellows due to the effect of thrust force under internal pressure shall be considered.

9.3.9.2 Release performance test

The 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.

9.3.10 Hydraulic circuit test

All the hydraulic circuit components assembled in the workshop shall be tested by the 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 the empty condition at ambient temperature prior to transport to the 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.

At 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 shall be performed.
- 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 mass 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.

If an existing qualification for similar arms is not available or not acceptable to the owner, the owner may request functional tests at a temperature lower than or equal to LH2 temperature condition.

All the ERS factory acceptance tests shall 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 shall 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 N₂. 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 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

The 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 the horizontal position and the arm shall be to the stowed attitude finally.

A reconnection operation shall be carried out.

NOTE The owner can consider actual disconnection test of ERS at ambient temperature on one of the first LH2C that calls at LH2 terminal.

9.5.2.7 Electrical resistance test

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

Testing shall 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 the 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 the design pressure. Acceptance criteria shall be no leakage.

10 Quality assurance and control

10.1 General

The transfer arm manufacturer shall demonstrate that it has implemented and maintains a quality system to the requirements of appropriate quality control standards.

10.2 Quality plan

Prior to commencing the work (including design activities) the transfer arm manufacturer shall submit to the owner a project quality assurance plan which shall detail, for example, 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 shall incorporate the detailed quality control plans for design, manufacturing and testing.

The detailed quality control plan shall cover as a minimum:

- awareness of statutory and specified requirements;
- materials of all components;
- welding procedures and qualifications;
- heat treatment procedures;
- non-destructive examination;
- proposed repair procedures;
- tests within scope of supply;
- dimensional checks;
- cleanliness of hydraulic system;
- painting and corrosion prevention;
- insulation application;
- 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

Examples of documentation requirements are given in [Annex C](#).

The users of the forms given in [Table C.1](#) are allowed to copy these forms with the tender and after contact award respectively in order to define the owner's documentation requirement.

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Annex A (informative)

Design data sheets

A.1 General

This annex provides the data tables for transfer arm design.

NOTE The users of the data tables (owner and transfer arm manufacturer) given in this annex are allowed to copy these data tables.

The data tables in this annex (Tables A.1 to A.6) shall primarily be filled out by the owner.

For arm design details, product information and operational conditions, environmental data, ship and manifold details, ship motions, jetty design, and berth electrical supply and safety, users shall use the sheets A1, A2, A3, A4, A5, A6 and A7 of the OCIMF Specifications Tables for Marine Loading Arms, from the appendix of Reference [12], accessible from <https://www.ocimf.org/publications/books/design-and-construction-specification-for-marine-loading-arms>.

A.2 Additional data tables

Table A.1 — Example of a form of specific requirements

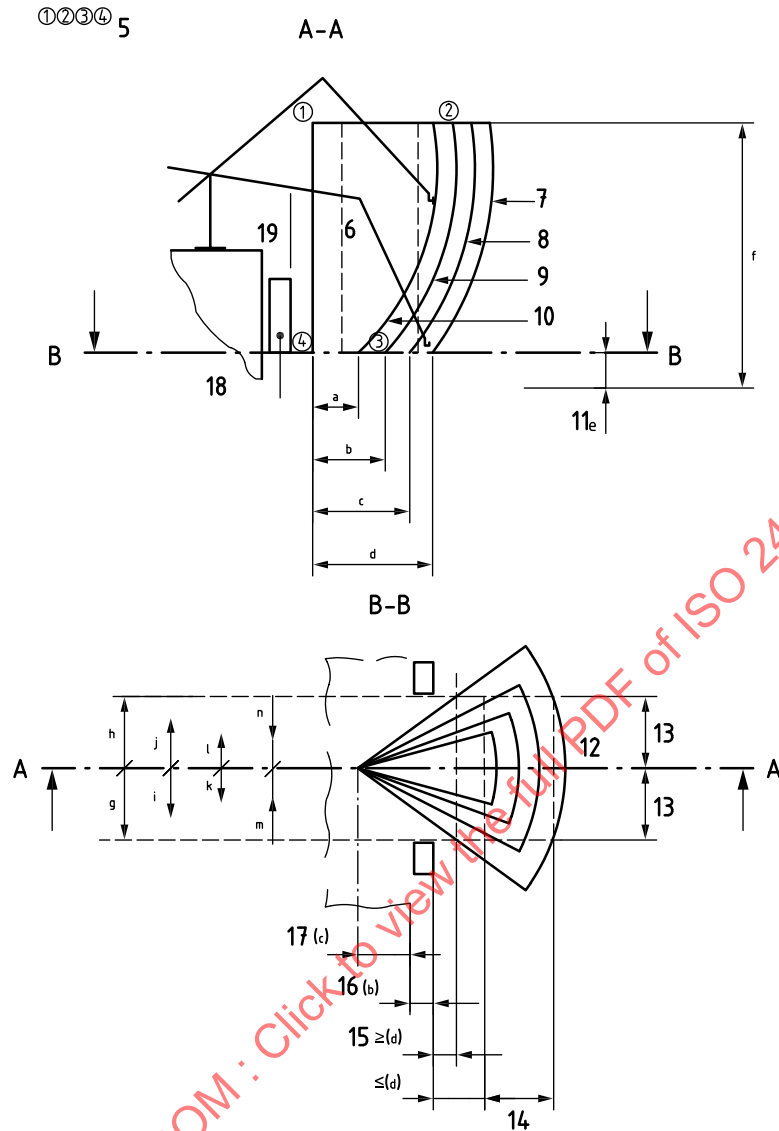
Berth no./arm no.		
ERS manufacturer and type		
ERS product valve closing time		First stage shutdown/second stage release
ERS product valve closure time	(s)	
PERC opening time	(s)	Within 2
ERS product valves — type — diameter — bore	(mm)	Full/reduced
Mechanical interlock		Yes/no
Hydraulic interlock		Yes/no
Quick connect disconnect coupler (QCDC)		Yes/no
QCDC operation		Hydraulic/manual
Clamp operating time minimum/maximum (hydraulic only)	(s)	10–15
Piggyback 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.3) — remote control (see Table A.4)		Yes/no Yes/no
Outboard arm locking device		Mechanical/hydraulic
Foundation — specified by transfer supplied by transfer arm manufacturer — supplied by transfer arm manufacturer		Yes/no Yes/no

Table A.1 (continued)

Berth no./arm 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
Consideration for thermal insulation		
— inboard arm		Yes/no
— outboard arm		Yes/no
— riser		Yes/no
Jack		Yes/no
Lubrication		
— grease specification		Yes/no
— cartridge		Yes/no
— local		Yes/no
— central		Yes/no
— other		Yes/no
Maintenance dummy manifold		Yes/no
Hydraulic accumulators		Yes/no
Ice fall protection		Yes/no
Design life	(years)	
Location of nitrogen injectors 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 the apex.		

Table A.2 — Envelope details (transfer arms with ERS)

Arm no.		Yes/no
	Pre-alarm required	
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 OCIMF website, Table A5 [12])	
h	Maximum slew left (surge) (see OCIMF website, Table A5 [12])	
i	2nd stage alarm slew right (m)	
j	2nd stage alarm slew left (m)	
k	1st stage alarm slew right (m)	
l	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 (sway direction) when reaching arm mechanical limit ^a (m/s)	
NOTE See Figure A.1		
^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.		



Key

5	safe working area ①②③④	13	surge (see OCIMF website, Table A5 [12])
6	flange connecting space	14	sway (see OCIMF website, Table A5 [12])
7	maximum reach	15	d
8	2nd stage alarm		$\geq d = d_{min}$
9	1st stage alarm		$\leq d = d_{max}$
10	pre-alarm (if specified)	16	b
11	chart datum	17	c fenders
12	spotting line	18	fenders
		19	berthing line

NOTE a, b, c, d, e, f, g, h, i, j, k, l, m, n are shown in Table A.2.

Figure A.1 — Transfer arms design and alarms setting, ESD/ERS detection and activation

Table A.3 — Jetty control console requirements

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 .	

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